Montenegrin Journal of Economics

INDEXING

ISSN 1800-5845

9 771800 584007

C O N T E N T S

Montenegrin Journal of Economics

ELIT
Economic Laboratory Transition
Research Podgorica

Integral Index of Structural Complexity of Regional Economies*

MIKHAIL Y. AFANASIEV[1] and ALEKSEI A. GUSEV[2]

[1]Professor. Central Economics and Mathematics Institute, RAS, (CEMI RAS) Moscow, Russian Federation,
email: mi.afan@yandex.ru https://orcid.org/0000-0001-6928-8821 Corresponding author
[2]Junior research assistant. Central Economics and Mathematics Institute, RAS (CEMI RAS), Moscow, Russian Federation
email: gusevalexeyal@yandex.ru ORCID: https://orcid.org/0000-0002-0551-6001

ARTICLE INFO

ABSTRACT

Current scientific discussions are focused on identifying professions and types of economic activity that will become most in demand in the future and determine priority areas for diversification of regional economies. Analysis of such trends is important for forecasting the dynamics of GRP. The purpose of this work is to construct an integral index of structural complexity on the basis of four basic indices of economic complexity of regional economies, calculated by the authors on the basis of data on the structure of employment, the structure of the distribution of enterprises and the structure of GRP. Two integral indices of structural complexity of regional economies have been constructed. Their advantages and disadvantages are analyzed. It is shown that the structural complexity of the regional economy has an impact on GRP. Moreover, one of the integral indices is significant in the production function of the GRP of 85 regions according to the data of 2019 and 2022

INTRODUCTION

The development of regional economies and the strengthening of the economic security of the regions presuppose an increase in the complexity of production structures and economic systems. Recommendations for the diversification of national and regional economies can be based on approaches focused on increasing economic complexity (Hausmann and Hwang; Rodrik, 2006; Hausmann and Klinger, 2006; Hidalgo and Hausmann, 2009; Hartmann, 2017; Sciarra et al., 2020). At present, the possibilities of assessing the economic complexity of regional economies have been studied based on data on the volume of exports and production volumes, on the number of people employed in various sectors of the economy (Lyubimov et al. 2017; Afanasiev and Kudrov, 2021; Afanasiev, 2023; Afanasiev et al., 2023; Afanasiev and Gusev, 2022; 2023; 2024). For example, in (Afanasiev and Ilyin, 2022) propose an approach to the selection of diversification areas based on recommendations for the development of sectors, aimed at increasing the economic complexity of the regional economy. structural complexity index. The construction of such an index and the analysis of the possibilities of its use is the purpose of this work. To construct an

integral index, the authors formed various structures of the regional economy: the structure of GRP according to data on production volumes by types of economic activities (TEA); the structure of employment of regions by professional groups; the structure of employment of regions by TEA; the structure of the distribution of enterprises by TEA. Based on the concept of economic complexity, the complexity of each structure is estimated and a corresponding basic index of economic complexity is constructed. The four basic indices are the basis for constructing an integral index of structural complexity. In this paper, two integral indices are proposed, built on a common information basis.

Four basic indices that form the information basis for the construction of integral indices are presented in the authors' previously published works. The approach to assessing the complexity of regional employment structures is described in the paper (Afanasiev et al., 2023). To construct the *ZPRF index* – the complexity of regional employment structures by trade union groups, Rosstat data on the number of employees of organizations on the payroll for 11 professional groups in the constituent entities of the Russian Federation for the period from 2019 to 2022 were used: «On the number and need of organizations for employees by professional groups»[1].

To construct the *ZV index of the* complexity of regional employment structures for 14 TEAs, Rosstat data «distribution of the average annual number of employed by type of economic activity (as a percentage of the total number of employees)[2]» for the period from 2019 to 2022 were used.

The scheme for calculating and analyzing the *VRPV index* of the complexity of GRP structures based on TEA production data are described in the paper (Gusev, 2024). To assess the economic complexity of 85 regions, the indicators of the GRP structure in 2016 prices for 19 TEA for the period from 2019 to 2022 from the UIISS were used: «Gross regional product (in constant 2016 prices; thousand rubles)[3]».

The *PRV index* of complexity of enterprise distribution structures in the regions by TEA was calculated in accordance with the methodology for assessing economic complexity based on the Rosstat indicator «distribution of the number of enterprises and organizations by type of economic activity (at the end of the year)[4]» for 19 TEA for the period from 2019 to 2022.

On the basis of basic indices of economic complexity, integral indices of structural complexity of regional economies are constructed and their comparative analysis is carried out. Production functions are constructed, including an integral index of structural complexity. It is shown that the structural complexity of the regional economy has an impact on the GRP of the region. Estimates of GRP elasticity based on the integral index of structural complexity are obtained.

1. INTEGRAL INDICES OF THE STRUCTURAL COMPLEXITY OF THE ECONOMY.

1.1 Preliminary stages of calculating integral indices

Various approaches can be used to construct integral indices of the complexity of the structures of regional economies using basic indices. Next, two approaches will be considered and a comparative analysis of the integral indices obtained on their basis will be carried out. Each approach involves the next two preliminary stages of calculations.

Stage 1. Calculation of basic complexity indices. The following four basic complexity indices are used in this study:

$VRPV$ – the index of complexity of GRP structures based on data on production volumes by TEA;
$ZPRF$ – index of complexity of employment structures of regions by trade union groups;
ZV – index of complexity of employment structures of regions by TEA;

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[1] On the Number and Needs of Organizations in Workers by Professional Groups / Rosstat. Moscow, 2022 (in Russian).

[2] EMISS: Average annual number of people employed in the economy (calculations based on data integration) since 2017 URL: https://www.fedstat.ru/indicator/58994 (accessed 15.03.2024)

[3] EMISS: Gross Regional Product in Basic Prices (OCTEA 2). URL: https://www.fedstat.ru/indicator/61497 (accessed 20.03.2024)

[4] Regions of Russia. Socio-economic indicators. 2022: Stat. Coll. / Rosstat. Moscow, 2022 (in Russian)

PRV – an index of the complexity of the distribution structures of enterprises in the regions by TEA.

The set of basic indices calculated at this stage can be expanded.

Stage 2. Normalization of the base indices calculated in step 1.

Let IND – one of the basic complexity indices calculated in stage 1 with components (IND_1, …, IND_k, …,IND_N). In here N – number of regions, k - region number, IND_k – index component corresponding to the region k. Let $\max IND$ – maximum index component value, $\min IND$ – minimum value of index components. Components $nIND_k$ normalized index $nIND$ are calculated according to the formula:

$$nIND_k = \frac{IND_k - minIND}{maxIND - minIND}.$$

Components of each normalized base complexity index $nVRPV, nZPRF, nZV, nPRV$ take values in the range [0; 1].

1.2 Approaches to the construction of integral indices and results based on 2022 data

Integral index $INT1$.

Integral index $INT1$ It is calculated using the principal component method using basic indices. The eigenvalues of the correlation matrix of the basic indices are 2.23; 1,04; 0,38; 0.36. The first main component explains 55.68% of the total variance of the four underlying indices. This is enough to consider the first main component as an integral index (Ayvazyan, 2012, p. 98). Index $INT1$ can be represented as a linear function of normalized basic indices (1) with the coefficient values given in Table 1.

$$INT1 = a * nVRPV + b * nZPRF + c * nZV + d * nPRV + const \qquad (1)$$

Table 1 also presents the coefficients of function (1) for the normalized (with component values in the interval [0; 1]) integral index $nINT1$. Index correlation coefficients $nINT1$ and $INT1$ with the basic indices are shown in Table 2. Note that the index normalization we use is a linear transformation. Therefore, the value of the correlation coefficient of the integral index and the basic index does not depend on whether these indices are normalized or not.

Table 1. Weighting coefficients of integral indices.

	a	*b*	*c*	*d*	*const*
INT1	2.7651	2.4972	2.2116	3.2487	-4.0314
nINT1	0.3228	0.2914	0.2581	0.3792	-0.2330
nINT2	0.2497***	0.2766***	0.2910***	0.3959***	-0.1961***

***The significance of the assessment at the 1% level
Source: own

Table 2. Correlation coefficients of integral and basic indices.

	$nVRPV$	$nZPRF$	nZV	$nPRV$
nINT1	0.6138	0.8317	0.7071	0.8116
nINT2	0.5524	0.8060	0.7486	0.8318

Source: own

Integral index INT2.

The idea of constructing the index is presented in the monograph (Ayvazyan, 2012, p. 103) and is based on measuring the distance from a point with coordinates $(nVRPV_k, nZPRF_k, nZV_k, nPRV_k)$, corresponding to each region k in the space of normalized basic indices, to the point – the "standard" with the coordinates (1; 1; 1; 1).

This distance is equal to:

$$D_k = ((1 - nVRPV_k)^2 + (1 - nZPRF_k)^2 + (1 - nZV_k)^2 + (1 - nPRV_k)^2)^{1/2}$$

Normalize the distances calculated for all regions using the formula:

$$nD_k = \frac{D_k - minD_k}{maxD_k - minD_k}$$

Calculating the value of the index component $INT2$ according to the formula: $INT2_k = 1 - nD_k$. The smaller the distance from the point $(nVRPV_k, nZPRF_k, nZV_k, nPRV_k)$, characterizing the region k in the space of the underlying indices, before the benchmark, the higher the value of the index component $INT2$. At the same time, the components of the index $INT2$ take values in the interval [0; 1]. That is, the index is already normalized and $INT2 = nINT2$.

The Pearson correlation coefficient of the *nINT1* and *nINT2* indices is above 0.9940. Spearman's rank correlation coefficient is 0.9871. The *nINT1* integral index constructed by the principal component method is the best way to differentiate regions by complexity estimates, explaining the maximum fraction of the aggregate variance of the underlying indices. The integral index *nINT2*, constructed as a result of calculating the "distances to the standard", differs little from the *nINT1* index. The *nINT2* index does not require special software for calculation and has a simple interpretation – proximity to the standard in the space of normalized basic indices.

Based on the approaches presented above, integral indices based on 2019 data were also calculated.

1.3 Integral indices for 2019

Integral index $nINT1$.

Integral index $nINT1$ calculated using the principal component method. The eigenvalues of the correlation matrix are 2.322; 0.813; 0.554; 0.308. The first main component explains 58.07 % of the total variance of the underlying indices. Weights for index calculation $nINT1$ according to formula (1) are given in Table 3. Correlation coefficients with basic indices are shown in Table 4.

Table 3. Weights of integral indices according to 2019 data

	a	b	c	d	const
nINT1	0.4097	0.2278	0.2453	0.3211	-0.1331
nINT2	0.3006***	0.2616***	0.2499***	0.3811***	-0.1103***

***The significance of the assessment at the 1% level
Source: own

Table 4. Correlation coefficients of integral and basic indices for 2019

	nVRPV	nZPRF	nZV	nPRV
nINT1	0.8679	0.7067	0.714	0.7334
nINT2	0.8252	0.7121	0.7052	0.763

Source: own

Integral index $nINT2$.

Correlation coefficients of the integral index $nINT2$ and basic indices are shown in Table 4. The last line of Table 3 shows estimates of the linear regression coefficients of the index $nINT2$ on normalized base indices. All scores are significant at the 1% level. Coefficient of determination $R^2 = 0.9908$.

As shown in Table 5, the largest change over a period of 3 years is observed in the employment structure by TEA. Perhaps it is this structure that has been most affected by the impact of the COVID-19 pandemic. At the same time, the structure of professional employment remains highly stable. The structure of the distribution of enterprises by TEA is the most stable, which indirectly indicates the correctness of the estimates obtained. All integral indices are stable over time. The correlation coefficients of integral indices for 2019 and 2022 exceed 0.9. Their stability is higher than most underlying indices.

Table 5. Correlation coefficients of the basic and integral indices of 2019 and 2022

$nVRPV$	$nZPRF$	nZV	$nPRV$	$nINT1$	$nINT2$
0.8397	0.8856	0.6172	0.9570	0.9472	0.9375

Source: own

2. ASSESSMENT OF THE IMPACT OF STRUCTURAL COMPLEXITY ON GRP

A number of foreign publications show that the complexity of the economy has an impact on GDP, the level of income of the population and the socio-economic development of national economies. In this section, we will assess the impact of the structural complexity of the economy on the GRP of Russian regions. At the same time, we proceed from the fact that structural complexity is not only a factor of GRP, but also has a direct impact on it.

Let us consider one-factor regressions (2) of the GRP logarithm for each normalized integral index of structural complexity according to 2022 data:

$$\ln(VRP_k) = s * nINT_k + const + eps_k \qquad (2)$$

In here VRP_k – GRP region k for 2022 year in continuous evaluations 2016 year; $nINT_k$ – value of the components of the normalized integral index of structural complexity for the region k $(at\ k = 1, …, n)$; $const$ – constant; eps_k – regression error.

The parameter score for each integral index is significant at the 1% level. But to use these estimates to predict the impact of changes in the value of the integral index on GRP with the explanatory ability R^2 at 0.1275 - 0.1658 is not appropriate. Let us include the integral index in the power production function

$$\ln(VRP_k) = \alpha * \ln(L_k) + \beta * \ln(K_k) + s * nINT_k + const + eps_k, \qquad (3)$$

where is L_k – number of employees, K_k – cost of fixed assets in the region k. Coefficient of Determination R^2 regression (3) with each integral indices exceeds 0.959. However, the estimates of the coefficients for integral indices for the population of 85 regions are insignificant.

Most regions have an exponential relationship (2). At the same time, as shown in Fig.1, for some regions with small values of the integral index $nINT2$ this dependence is disrupted due to the discrepancy between the relatively high volume of GRP and the relatively low value of the integral index. For these regions, it is possible to indicate the factors that affect GRP and structural complexity in different directions. For example, natural rent[5]. A number of studies provide estimates of the natural rent of some regions specializing in the field of oil and natural gas production. For example, estimates of the share of natural resource rent in GRP obtained in (Ayvazyan et al., 2018; Afanasiev, Kudrov, 2020) exceed 20% of GRP, and for some regions they reach 40%. This is the reason for the disproportion between the integral estimates of the structural complexity of economies and GRP. The regions specializing in oil and natural gas production (Afanasiev and Gusev, 2024) and making the largest contribution to the total GRP of Russian

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[5] In accordance with the generally accepted approach, the additional GRP received in excess of the inputs of production factors is considered as natural rent.

regions include: the Khanty-Mansi Autonomous Area, the Yamalo-Nenets Autonomous Area, the Nenets Autonomous Area, the Krasnoyarsk Territory, the Republic of Tatarstan, the Republic of Sakha (Yakutia), the Orenburg Region, and the Irkutsk Region.
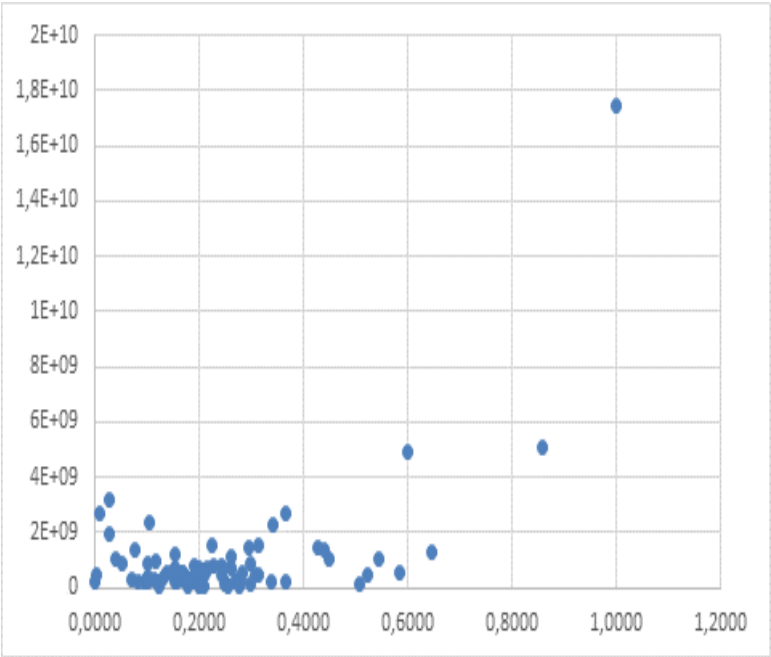
Figure 1. Dependence of GRP (y-axis) on the index $nINT2$ (x-axis)
Source: own
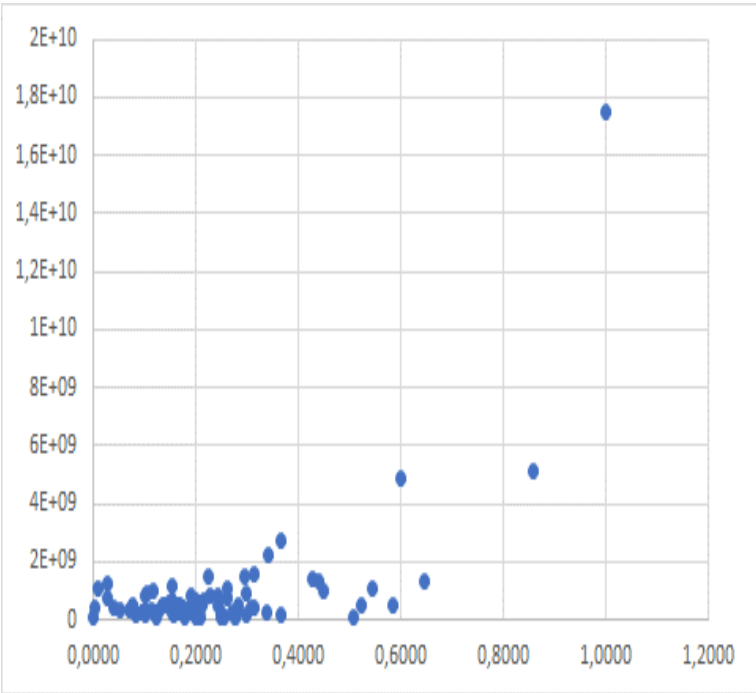
Figure 2. Dependence of GRP with excluded natural rent (y-axis) on the index $nINT2$ (x-axis)
Source: own

Due to the specialization of the economies and geographical features, these eight regions have relatively high GRP with relatively low integral estimates of structural complexity. Excluding eight regions from

consideration leads to an increase in the elasticity of the GRP for labor and a decrease in the elasticity of GRP for capital in the production function estimated without taking into account the integral index. This corresponds to the results of the assessment of elasticity coefficients in the work (Ayvazyan et al., 2016; Afanasiev, Kudrov, 2020) for extractive and evenly developed regions. Estimates of coefficients for integral indices $nINT1$ and $nINT2$ (columns (2), (3) of Table 6) in the production function (3) are significant at the 5% level.

Elasticity of the GRP of the region k on the integral index at the value of INT_k equals $sINT_k$. In our case, each index is normalized and takes values in the interval [0; 1]. Thus, the elasticity of the GRP of Russian regions according to the integral index of structural complexity takes values in the interval [0; s]. When the value of the integral index is changed to $x\%$, the change in the GRP of a region that does not specialize in oil and natural gas production is estimated at $sINT_k x\%$. It should be emphasized that the GRP growth estimated here is relative, that is, additional to the GRP growth due to the influence of other factors (time, scientific and technological progress, etc.). For a region specializing in neti and gas production, the growth of the structural complexity of the economy may be caused by the emergence of new strong TEAs due to the development of the extractive sector. In this case, the share of natural resource rent in GRP may be preserved, and the elasticity of GRP in terms of the integral index of structural complexity will be the same as that of a non-extractive region. However, for the eight regions specializing in oil and natural gas production, the increase in the structural complexity of the economy is not necessarily accompanied by an increase in the volume of production that generates natural rents. It may be a consequence of the emergence of new strong TEAs in the region that are not related to mining and do not bring natural rent. In this case, the assessment of the elasticity of GRP on the integral index will be $\exp(-r_k)snINT_k$, where is

$$r_k = \ln(VRP_k) - (\alpha\ln(L_k) + \beta\ln(K_k) + snINT_k + const)$$

– valuation of natural resource rent, $\exp(-r_k)$ – share of the region's GRP excluding natural resource rent, and $1 - \exp(-r_k)$ − Share of natural resource rent in GRP. Therefore, for the region, receiving natural rent from oil and natural gas production, the value of $snINT_k$ should be considered as a top-down estimate of the elasticity of GRP in terms of structural complexity. And the value $\exp(-r_k)snINT_k$ – as a bottom-up score. However, the assessment of natural rent in the form of r_k takes into account the impact on GRP of many factors that do not reflect the specialization of regional economies. At the same time, the main circumstance uniting these regions in our case is their specialization in oil and natural gas production. In this study, we do not consider the task of estimating the natural rent of each region. affects the elasticity of GRP by the value of the integral index. And, also to substantiate on this basis the choice of the parameter *s* for the purposes of forecasting and a priori assessment of the impact of the complexity of employment structures on GRP. Therefore, we will consider an alternative approach to assessing the impact of the complexity of employment structures on GRP, which takes into account the presence of natural rent, which is the general result of the specialization of a group of regions. Let's consider the modification of the production function (3):

$$\ln(VRP_k) = \alpha * \ln(L_k) + \beta * \ln(K_k) + s * nINT_k + r * d_k + const + eps_k, \quad (4)$$

in which d_k - boolean variable that takes values of 1 for a group of regions with general specialization, based on the aggregate of which natural rent is estimated. r – assessment of natural rent. A similar approach to the assessment of natural rent of extractive regions was used in (Ayvazyan et al., 2018; Afanasiev, Kudrov, 2020). Having evaluated the parameters of this function, we can estimate the elasticity of GRP by the value of the index $nINT$ structural complexity for the entire set of regions under consideration. At the same time, the share of GRP of each of the eight regions, excluding natural rent, is $exp(-r)$, and the share of natural resource rent in GRP is $1 - exp(-r)$.

The assessment of the parameter s with the integral index *nINT2* is significant at the 5% level and is equal to 0.298 (see column (5) of Table 6). The assessment of the parameter s with the integral index *nINT1* is significant at the 10% level (column (4) of Table 6). With this value, the score $1 - exp(-r)$ natural resource rent for eight regions is equal to 0.258 and does not exceed the share of natural rent of the extractive regions estimated in the works (Ayvazyan et al., 2018; Afanasyev, Kudrov, 2020). Estimated

share $exp(-r)$ GRP after excluding natural rent is 0.742. Dependence of the GRP of 85 regions with excluded natural rent of eight regions on the index $nINT2$ shown in Fig. 2.

Let us now consider the power production function (5) with time-dependent parameters to estimate the cumulative effect of integral indices of structural complexity constructed from data for 2019 and 2022 on GRP.

$$\ln(VRP_{kt}) = (\alpha + \alpha_1 * t) * \ln(L_{kt}) + (\beta + \beta_1 * t) * \ln(K_{kt}) + (s + s_1 * t) * nINT_{kt} +$$
$$+ (r + r_1 * t) * d_k + c * t + const + eps_{kt} \qquad (5)$$

For 2019 $t = 0$, for 2022 year $t = 3$. Estimates of the parameters of function (5) are presented in columns (6) and (7) in Table 6. Parameter estimates $\alpha_1, \beta_1, s_1, r_1$ are insignificant for each integral index and are not given in Table 6.

Table 6. Assessment of the parameters of production functions

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Parameters	nINT1	nINT2	nINT1	nINT2	nINT1	nINT2
α	0.319***	0.325***	0.208***	0.210***	0.211***	0.212***
t-stats	(5.28)	(5.44)	(4.73)	(4.82)	(6.27)	(6.32)
p-value	0.000	0.000	0.000	0.000	0.000	0.000
β	0.651***	0.641***	0.759***	0.753***	0.762***	0.759***
t-stats	(12.45)	(12.24)	(19.01)	(18.78)	(25.32)	(25.18)
p-value	0.000	0.000	0.000	0.000	0.000	0.000
s	0.378**	0.416**	0.252*	0.298**	0.216*	0.249**
t-stats	(2.28)	(2.53)	(1.70)	(2.02)	(1.82)	(2.12)
p-value	0.025	0.014	0.094	0.047	0.070	0.036
r			0.279***	0.284***	0.269***	0.273***
t-stats			(3.21)	(3.32)	(4.10)	(4.22)
p-value			0.002	0.001	0.000	0.000
c					-0.035***	-0.034***
t-stats					(-3.27)	(-3.21)
p-value					0.001	0.002
const	6.080***	6.138***	6.080***	6.057***	6.041***	6.057***
t-stats	(16.19)	(16.30)	(16.19)	(18.83)	(25.14)	(18.83)
p-value	0.000	0.000	0.000	0.000	0.000	0.000
N	77	77	85	85	170	170
R^2	0.9613	0.9618	0.9699	0.9702	0.9650	0.9652

***Significance of the assessment at the 1% level
**Significance of the assessment at the 5% level
* Significance of the assessment at the 10% level
Source: own

Index $nINT2$ shows the best statistical characteristics when evaluating the production function (5) according to the data of 2019 and 2022, as well as when evaluating the production function (4) according to the data of 2022. Therefore, we will consider it as the main integral index of the structural complexity of regional economies. At the 5% level, the assessment of the parameter is significant only with the integral index $nINT2$. It is equal to 0.249 and slightly lower than the one obtained when assessing the production function (4). However, the estimate of 0.249 is based on the use of two years of data and appears to be more reliable. We will consider it when estimating the elasticity of GRP by the integral index $nINT2$. Namely, as an assessment of the elasticity of the impact of structural complexity on the GRP of a region that does not specialize in oil and natural gas production, we will consider the value of 0.249 $nINT2$. For example, for the Vologda Oblast with a value in 2022 $nINT2 = 0.279$ a relative increase in the integral assessment of complexity by 10% to a value of 0.3 leads to an estimate of the relative growth of GRP by about 0.7%. And for the Moscow region, with the value of $nINT2 = 0.598$ a relative increase in the integral estimate of complexity by 10% to 0.648 leads to a relative increase in GRP by about 1.5%.

Value $1 - exp(-r)$ of the share of natural resource rent for eight regions is 0.238. Estimated share $exp(-r) exp(-r)$ GRP after excluding natural rent remains 0.761. For regions that receive natural rent

from neti and natural gas production, we will use the elasticity estimate from above $0.249 * nINT2$ and estimation of elasticity from below $0.761 * 0.249 * nINT2$. For example, for the Orenburg region, when the value $nINT2 = 0.065$ a relative increase in the integral estimate of complexity by 70% to the value of 0.111 leads to an estimate of the relative growth of GRP in the range [0.8%; 1.1%].

CONCLUSION

According to Rosstat data for 2019 and 2022, four basic complexity indices were formed for 85 regions: the index of complexity of GRP structures based on data on production volumes by TEA; the index of complexity of regional employment structures by occupational groups; the index of complexity of regional employment structures by TEA; the index of complexity of enterprise distribution structures in the regions by TEA. The leading positions in the four corresponding ratings are occupied by Moscow, St. Petersburg, the Novosibirsk Region, and the Moscow Region.

On the basis of basic indices of economic complexity, integral indices of structural complexity of regional economies are constructed and their comparative analysis is carried out. Despite the different methods of construction, integral indices are statistically strongly interrelated. At the same time, in specific problems of forecasting and mathematical modeling, their features are manifested. Therefore, noting the significant advantages of the integral index, which assesses the distance from the point characterizing the region in the space of basic indices to the standard, the authors consider it premature to exclude alternative index, as it allows for its potential usefulness.

An approach to assessing the impact of the structural complexity of regional economies on GRP is proposed. Production functions are constructed, including an integral index of structural complexity. It is shown that the structural complexity of the regional economy has an impact on the GRP of the region. Estimates of GRP elasticity based on the integral index of structural complexity are obtained.

The integral index of structural complexity of regional economies makes it possible to comprehensively assess the economic potential of territories, identify the most promising industries and industries, as well as identify areas of diversification that fit into the existing regional specialization. This creates the basis for the formation of sound spatial development strategies aimed at increasing the economic complexity and sustainability of regional economies.

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Corporate Image, Stakeholder Pressure, and Philanthropic CSR: Mediated by Cultural Influences and Moderated by Internal Oversight

DIRVI SURYA ABBAS[1], MUNAWAR MUCHLISH[2] and IMAM HIDAYAT[3]

[1]Lecturer at Department of Accounting, Universitas Muhammadiyah Tangerang, Indonesia, email: abbas.dirvi@gmail.com.
   ORCID ID: https://orcid.org/0000-0002-7819-2837
[2]Lecturer at Department of Accounting, Universitas Sultan Ageng Tirtayasa, Indonesia, email: muchlish_ak@untirta.ac.id,
   ORCID ID: https://orcid.org/0000-0002-1089-5552
[3]Lecturer at Department of Accounting, Universitas Muhammadiyah Tangerang, Indonesia,
   email: imam_accounting@yahoo.com, ORCID ID: https://orcid.org/0000-0003-4543-8658

ARTICLE INFO

ABSTRACT

This study explores the dynamic interactions between corporate image, stakeholder pressure, cultural influence, and philanthropic CSR, with the moderating role of internal oversight grounded in stakeholder theory. The respondents in this study were 480 managers and supervisors working at state-owned banks in Indonesia. The data was analyzed using AMOS. The results revealed that corporate image positively affected cultural influence. Additionally, the findings indicated that cultural influence significantly mediates the correlation between corporate image and philanthropic CSR through cultural influence. Internal bank oversight moderated the correlation between cultural influence and philanthropic CSR. This study provides new insights into philanthropic CSR in developing countries. It is expected to contribute to the philanthropic CSR literature while being beneficial for managing state-owned banks in Indonesia.

INTRODUCTION

The implementation of CSR in Indonesia is primarily focused on the concept of sustainable development. However, there are no standardized regulations on the ideal model of sustainable development for the banking sector in Indonesia. In practice, these activities fall short of meeting 50% of their humanitarian implementation targets. Humanitarian-based sustainable development activities are known as philanthropic CSR. On the other hand, philanthropic CSR activities are also used as advertising campaigns in social and mass media to enhance the company's positive image (Vollero, 2020).

Additionally, the philanthropic CSR activities conducted by state-owned banks are perceived as a means for the government to address gaps in social needs. It occurs due to the uncertainty surrounding the ideal philanthropic CSR model in Indonesia and other developing countries. The implementation of

philanthropic CSR in developing countries often relies on the cultural context of each nation to establish (Orpen, 1987; Vavpotic & Skerlavaj, 2023; Y. Wang & Pala, 2020). The absence of a regulatory framework for philanthropic CSR has resulted in various cultural influences shaping its practice across developing nations (Vavpotic & Skerlavaj, 2023). Thus, the role of cultural influences in each developing country can lead to varied concerns in implementing philanthropic CSR. Indonesia, as a developing country, sees significant public support for philanthropic CSR activities, as evidenced by the substantial funds raised. However, the large amount of funds collected from customers of state-owned banks presents a potential risk of fraud, both during collection, management, and distribution (Ohalehi, 2019). This is further exacerbated by the lack of transparency in reporting philanthropic activities in financial reports (Haß, 2019). Therefore, better internal oversight by the banks is needed.

Empirically, several problems can be identified and require further field verification. First, philanthropic CSR in Indonesia is often reactive, providing services such as healthcare and education only in disaster-affected areas. Second, philanthropic CSR in Indonesia is used by the government to address social resource gaps. Third, reactive cultural influences still dominate how managers formulate philanthropic CSR policies. Fourth, the reactive behavior of Indonesian society is demonstrated by the lack of community involvement in long-term philanthropic CSR activities. Fifth, the reactive behavior of Indonesian society is often exploited by the government, as philanthropic CSR activities are used for social media and mass media campaigns to enhance the government's positive image. Sixth, the weak internal oversight of philanthropic CSR fund distribution by banks creates a risk of financial fraud, considering the large amounts of philanthropic CSR funds being disbursed by banks.

Management science approaches can be used to address these issues and the objectives of this research (Sekaran & Bougie, 2016). A management science approach employs qualitative descriptive research to empirically and comparatively describe the situation (Sekaran & Bougie, 2016). This study aims to understand the perspectives of managers in state-owned banks in assessing and identifying information regarding philanthropic CSR in Indonesia. The empirical research is based on primary data sources.

The state of the art of this research complements most previous studies, which primarily focused on social factors within non-financial companies listed on the IDX, with a broad scope. However, none of these studies have examined the distribution of philanthropic CSR funds. This study focuses on banking institutions because financial institutions conduct more philanthropic CSR programs than non-financial companies. Research on philanthropy remains limited, mainly focusing on fund-raising from individuals, organizations, and formal or informal institutions, excluding government grants and corporate CSR funds (Tarigan et al., 2022). However, there has been no research in Indonesia that examines the oversight of philanthropic CSR fund distribution by state-owned banks. Ohalehi (2019) discusses types of fraud in charity fund-raising and distribution. Setiawan (2023) emphasizes the urgency of anti-fraud programs to allow institutions and philanthropic activities to grow and support poverty alleviation in Indonesia, highlighting the need for internal oversight as a moderating variable. Additionally, this study introduces cultural influence as a mediating variable. According to Samuel & Sakhile (2016), individuals from different cultural backgrounds adhere to varying norms and values; their behavior and perceptions differ, which affects how they cooperate to achieve shared goals or targets.

1. LITERATURE REVIEW

The theoretical approach of this study is based on three main theories relevant to understanding the philanthropic CSR activities of state-owned banks (BUMN) in Indonesia. These include Carroll's CSR Pyramid theory (Carroll, 2016; Lu, 2020), the Triple Bottom Line Theory (Carroll, 2017; Pan, 2021), and the Stakeholder Theory (Visser, 2012). The core idea of Carroll's CSR Pyramid is that companies contribute to society and the environment through their philanthropic responsibilities. Meanwhile, the Triple Bottom Line Theory categorizes CSR into three performance dimensions: economic, social, and environmental. The Stakeholder Theory explains how corporate management responds to stakeholder interests, aligning the company's goals with its stakeholders. In particular, Stakeholder Theory emphasizes the social-based approach to managing the correlation between the company and its constituencies. Concretely, companies must show that their management is responsive to societal interests, and, subsequently, they must devise

strategies to align their goals with those of diverse stakeholders. This research is guided by the Stakeholder Theory, built upon the foundations of Carroll's CSR Pyramid and the Triple Bottom Line Theory.

Profitable and successful companies that allocate substantial funds to CSR activities and comply with regulations tend to enhance their corporate reputation (Brammer & Millington, 2005; Sundarakani, 2018), as opposed to companies that merely adopt profit-driven strategies (Arjoon, 2000; Marshall, 2005). In developing countries, corporate image is often enhanced by aligning CSR activities with societal norms and values (Amaeshi et al., 2016). Hence, the hypothesis derived is:

H1: Corporate image has a positive correlation with cultural influence.

The profits generated by businesses should be shared with external stakeholders who have the most pressing claims, such as the general public (Adewuyi & Olowookere, 2010). Supporting all stakeholders can create the perception that businesses are adhering to standards set by regulatory frameworks (Lanis & Richardson, 2013; Suchman, 2014). However, there is the risk of reducing shareholder wealth maximization and potential conflict with society, where governments delegate social welfare responsibilities to companies, contributing little themselves (Brunton, Eweje, & Taskin, 2017; Carroll, 2015; Lu et al., 2020). Thus, the hypothesis derived is:

H2: Stakeholder pressure has a positive correlation with cultural influence.

Cultural influence is key in how managers formulate CSR policies (Duarte, 2010). It is why CSR policies in developing countries are often driven by religious, cultural, and socio-economic priorities (Abbas et al., 2021; Asemah et al., 2013). In contrast, developed countries tend to be more individualistic and impose excessive regulations (L. Wang, 2011). Thus, the hypotheses derived are:

H3: Cultural influence has a positive correlation with the philanthropic dimension of CSR.

H4: Cultural influence mediates the correlation between corporate image and philanthropic CSR.

H5: Cultural influence mediates the correlation between stakeholder pressure and philanthropic CSR.

Fraud opportunities frequently arise due to weak internal control systems within an institution. It opens the door for individuals who initially had no intention to commit fraud to do so when presented with the opportunity and weak oversight. Moreover, the lack of financial reporting and transparency exacerbates this issue. Therefore, the hypothesis derived is:

H6: Internal oversight moderates the correlation between cultural influence and philanthropic CSR.
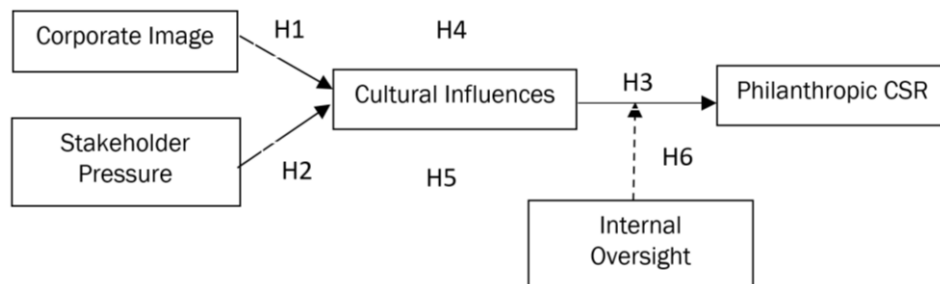
Figure 1: Conceptual Framework
Source: own

2. RESEARCH METHODOLOGY

This study fell under the category of explanatory research, aimed at assessing causal correlations between variables (Sekaran & Bougie, 2016). Specifically, the research examined the antecedents of client satisfaction and its effect on environmental performance. The unit of analysis was companies represented by bank managers, and the research used a cross-sectional time horizon. The primary data used in this research were collected from client perceptions through a field study approach.

2.1 Measurement

2.1.1 Population and Sample

This research was conducted in Indonesia, focusing on bank managers from state-owned banks (SOEs). The sample comprises 480 managers and supervisors from PT Bank Negara Indonesia, PT Bank Rakyat Indonesia, PT Bank Tabungan Negara, and PT Bank Mandiri. A quantitative descriptive method was employed, with data collected using a questionnaire. The sampling technique used was Convenience Sampling, a method in which elements were selected based on availability and ease of access (Sekaran & Bougie, 2016)

2.1.2 Data Collection Method

Data is collected through a survey using a combination of open-ended and closed-ended questionnaires. The open-ended questions seek information about the company's identity, while the closed-ended questions consist of a series of statements to gather data, adapted from Moraes et al. (2019).

2.1.3 Data Analysis Technique

The responses gathered aligned with the predetermined variable values were analyzed using the SEM AMOS (Analysis of Moment Structure) program. SEM AMOS evaluated the measurement model, the impact of predictor variables on mediators and dependent variables, and the reliability of the data. This investigation sought to demonstrate the correlations between Corporate Image, Stakeholder Pressure, and Philanthropic CSR, with the mediating role of Cultural Influences and the moderating effect of Internal Oversight. This approach could assess data from specific sectors or domains, such as Indonesian state-owned banks, when the correlation between variables or the sample size was minimal. Researchers benefited from the simultaneous measurement and estimation of latent components and the structural model using SEM AMOS. The method of data analysis employed was SEM. SEM AMOS allowed the modeling of latent variables with several important indicator variables and examined the reliability of each indicator. Unlike path analysis and multiple regression, which only reached the outer parts of a research model, SEM AMOS was more reliable for breaking down and analyzing every section developed by an equation model. SEM could handle complex data, such as time series data with autocorrelation errors, non-normally distributed data, and incomplete data.

The stages of this study first involved Data Sample Synthesis, aimed at explaining the gender composition of managers and supervisors working at Indonesian state-owned banks. Next, Measurement Model Testing was conducted, which included Fit Indices, Reliability, and Validity tests, covering CFA loadings, Cronbach's alpha, CR, and AVE, as well as Correlations, Divergent Validity, and Descriptive Statistics. Finally, Hypothesis Testing was conducted, which included tests for Direct Relation Effect, Mediating Effect, and Moderating Effect. For Mediating Effect testing, an analysis was developed to determine whether the mediation model was classified as complementary mediation, competitive mediation, indirect-only mediation, direct-only nonmediation, or no-effect nonmediation, according to Zhao et al. (2010), Baron & Kenny (1986). Similarly, for Moderating Effect testing, an analysis was performed to determine whether the moderation model was classified as Pure Moderator, Quasi Moderator, Predictor Moderator, or Homologizer Moderator (Baron & Kenny, 1986).

2.1.4 Operational Definitions and Variable Measurement

Operational definitions of variables were definitions of the variables used in this study. They indicated how data for each variable was measured: The first independent variable in this study was Corporate Image (Orpen, 1987), which consisted of 4 items of question instruments, including increasing trust and support from the community were signs that the corporate image was good, Aligning ethical behavior and local cultural traditions could enhance the corporate image. The institution's priority was to build a good image for tahe company's business, and an excellent corporate image would result in greater involvement in philanthropic CSR activities. The assessment indicators in the instrument used a Likert scale: 1. strongly disagree, 2. disagree, 3. neutral, 4. agree, 5. strongly agree.

The second independent variable in this study was Stakeholder Pressure (Orpen, 1987), which consists of 3 items of question instruments including Pressure from stakeholders leads to more CSR, Pressure from the government and shareholders influences managers' priorities more than other forms of stakeholder pressure, The Pressure from local community opinions regarding social gaps is the main reason for philanthropic CSR activities. The assessment indicators in the instrument use a Likert scale: 1. strongly disagree, 2. disagree, 3. neutral, 4. agree, 5. strongly agree. The dependent variable in this study was Philanthropic CSR (Y. Wang & Pala, 2020), which consisted of 4 items of question instruments including: Managers must set aside some profits for involvement in philanthropic CSR activities, Managers were expected to solve social gap issues such as poverty, health, and education, Managers must fully support charities and community groups like MSME partners, and managers should promote activities related to culture and spiritual development to the community. The assessment indicators in the instrument used a Likert scale: 1. strongly disagree, 2. disagree, 3. neutral, 4. agree, 5. strongly agree.

The moderating variable in this study was Internal Oversight (Zulfikar, 2021) which consists of 4 items of question instruments including: Every transaction and activity of CSR fund distribution to the community at my workplace had been supported by authorization from internal audit, Routine internal audits were conducted on the receipt and expenditure of CSR funds, Hiring employees with family correlation, and Evaluating internal control deficiencies in the internal audit party. The assessment indicators in the instrument used a Likert scale: 1. strongly disagree, 2. disagree, 3. neutral, 4. agree, 5. strongly agree.

The mediating variable in this study was Cultural Influence (Noorderhaven & Tidjani, 2001) which consists of 5 items of question instruments including: Managers must feel responsible for their concern in building community organizations, Managers from different tribal cultural backgrounds must be able to cooperate for the benefit of the local community and the company environment, Managers must appreciate and understand the philosophy of sharing with the community when involved in CSR activities, Managers must align cultural values with organizational goals, and Managers must understand the organization's communal wealth and ensure it is shared fairly. The assessment indicators in the instrument used a Likert scale: 1. strongly disagree, 2. disagree, 3. neutral, 4. agree, 5. strongly agree.4. Data Analysis

3. DATA ANALYSIS

3.1 Measurement Model: Fit Indices, Reliability, and Validity

This study involves collecting data through the distribution of questionnaires to respondents working in four state-owned banks (SOEs) in Indonesia. The selected respondents are managers spread across various departments and positions, thus providing a diverse representation in describing the conditions and dynamics in the banking environment.

No	Bank	Total	Male	Women	Male %	Women%
1	PT Bank Negara Indonesia Tbk	120	49	71	41%	59%
2	PT Bank Rakyat Indonesia Tbk	120	41	79	34%	66%
3	PT Bank Tabungan Negara Tbk	120	55	65	46%	54%
4	PT Bank Mandiri Tbk	120	64	56	53%	47%

Table 1. Respondent Demographics
Source: own

Based on the table, the researcher shows in the pie chart as follows:
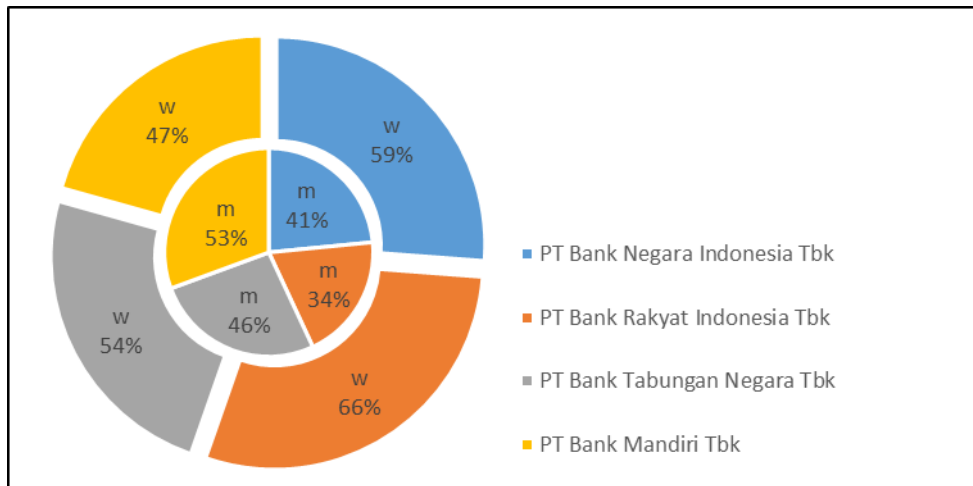
Figure 2. Respondent Demographics
Source: own

The demographic characteristics of the sample population consisted of 480 individuals. Gender distribution for PT Bank Negara Indonesia showed that 41% (49 individuals) were identified as male, while 59% (71 individuals) were identified as female. For PT Bank Rakyat Indonesia, 34% (41 individuals) were male, and 66% (79 individuals) were female. The gender distribution for PT Bank Tabungan Negara indicated that 46% (55 individuals) were male, and 54% (65 individuals) were female. PT Bank Mandiri indicated 53% (64 individuals) were male, and 47% (56 individuals) were female.

One of the goals of the study was to find possible different influences based on gender. Results by gender revealed that corporate image depicted by harmonizing ethical behavior and local cultural traditions can solve the problem of social disparities such as poverty, health and education felt in the views of male and female respondents. The next results in gender based on the perspective of male and female respondents revealed that the pressure from local community opinions related to social disparities is the main reason for CSR philanthropic activities, this can make it easier for companies to align cultural values with the achievement of their organizational goals. In addition, gender results revealed that philanthropic CSR, which is described by promoting activities related to culture and spiritual development to the community, can instill a sense of mutual respect and understand the philosophy of the meaning of sharing with the community when involved in CSR activities, which was agreed upon by both male and female respondents. The results of the gender analysis are reported in Table 2.

Table 2. Respondent Based on Gender

Path			Male			Female		
			B	P	Result	B	P	Result
Philantrophic CSR	<--	Corporate Image	.350	***	Supported	.305	***	Supported
Philantrophic CSR	<--	Stakeholder Pressure	.039	.838	Not Supported	-.144	.269	Not Supported
Culture Influence	<--	Corporate Image	.035	.455	Not Supported	.074	.056	Not Supported
Culture Influence	<--	Stakeholder Pressure	.809	***	Supported	.708	***	Supported
Culture Influence	<--	Philantrophic CSR	.096	.008	Supported	.158	.009	Supported

Source: own / Note: (N = 480), ***p<0.05

Based on the results of the test table 3, it shows that the average respondent aged 31 - 35, with a bachelor's degree education level and having an average of 6-8 years of experience, has the behavior of prioritizing the institution where they work in building a good image for the company's business in order to be able to solve the problem of social disparities such as poverty, health and education in the community, so they always try to harmonize values culture in Indonesia with the achievement of institutional priorities in building a good image for the company's business.

Table 3. Respondent Based on Experience, Age, Majority qualification

Path			Majority Age			Majority Qualifications			Experience		
			B	P	Result	B	P	Result	B	P	Result
Philantrophic CSR	<--	Corporate Image	.377	***	Supported	.290	***	Supported	.251	***	Supported
Philantrophic CSR	<--	Stakeholder Pressure	-.243	.060	Not Supported	-.058	.525	Not Supported	.094	.525	Not Supported
Culture Influence	<--	Corporate Image	.105	.282	Not Supported	.073	.046	Supported	.084	.046	Supported
Culture Influence	<--	Stakeholder Pressure	.550	***	Supported	.404	***	Supported	.457	***	Supported
Culture Influence	<--	Philantrophic CSR	.564	.049	Supported	.337	.029	Supported	.372	.029	Supported

Source: own / Note: (N = 480), ***p<0.05

A measurement model encompassed five latent constructs that incorporated observed variables. Confirmatory factor analysis was used to examine the model's validity, reliability, and fit to the data (Henseler et al., 2009). The measurement model demonstrated a good fit with the following indices: CMIN/DF 1.117, GFI 0.876, AGFI 0.842, NFI 0.835, and RMSEA 0.071. The observed variables presented strong convergence with their respective latent constructs, with loadings exceeding 0.70 (Bagozzi & Yi, 1988; Hair et al., 1998).

Table 4. CFA model fit Indices

Criteria	Chi-square	χ2 sig prob	CMIN/DF	GFI	AGFI	RMSEA	TLI	NFI	PGFI	PNFI
SEM Model	457.113	0.076	1.117	0.876	0.842	0.071	0.848	0.835	0.750	0.721
Cut of Value	≤ χ2-table (480; 5%) (553.127)	≥ 0.05	≤ 2.00	≥ 0.85	≥ 0.85	≤ 0.08	≥ 0.90	≥ 0.80	≥ 0.90	≥ 0.50
Evaluation	Good fit	Good Fit	Good Fit	Good fit	Good fit	Good fit	Moderat	Good fit	Moderat	Good fit

Source: AMOS, v. 21

To confirm the convergent validity of each latent construct, the Average Variance Extracted (AVE) was measured by calculating the squared average loading of each observed variable concerning each latent construct. The AVE values for each latent construct were discovered to be well above the recommended threshold of 0.50 (Hair et al., 2012). The reliability of the constructs was assessed using Cronbach's alpha (α) and Composite Reliability (CR). The suggested threshold for both measures was 0.70 or higher (Bagozzi & Yi, 1988; Hair et al., 1998), and all latent constructs exhibited Cronbach's alpha (α) and Composite Reliability (CR) statistics significantly above the recommended cutoff of 0.70. Based on these results, it could be drawn that all variables demonstrated a high level of reliability, as detailed in Table 5.

Table 5. CFA loadings, Cronbach's alpha, CR, and AVE

Variable	No of Item	Avg CFA Loading	Alpha	CR	AVE
Corporate Image	4	0.724	0.724	0.815	0.525
Stakeholder Pressure	3	0.754	0.754	0.798	0.569
Cultural Influences	5	0.731	0.731	0.852	0.530
Philanthropic CSR	4	0.711	0.711	0.805	0.512
Internal Oversight	4	0.782	0.782	0.864	0.615

Source: AMOS, v. 21

To confirm sufficient divergence of the latent constructs, the correlations among the constructs were compared with the square root of their AVE, which was the average loading of a construct. For divergent

validity to be confirmed, the square root of the AVE of a construct must be greater than its correlation with other constructs. Table 6 presented the correlations among constructs along with the square root of the AVE displayed on the diagonal in bold and in parentheses, confirming that the square root of the AVE for each construct was more significant than its correlations with other constructs, thus affirming divergent validity. The results of this testing indicated that the square root of the AVE, shown in bold on the diagonal, was more significant than the values outside the diagonal, indicating that the data possessed good divergent validity. Furthermore, the correlations in this study met the significant criterion at the 0.01 level. Based on these results, it could be drawn that all variables exhibited a high level of reliability, as summarized in Table 6.

Table 6. Correlations, divergent validity, and descriptive statistics

Variable Name	1	2	3	4	5
Corporate Image	**(0.876)**				
Stakeholder Pressure	-0.017	**(0.856)**			
Philanthropic CSR	0.311**	-0.030	**(0.874)**		
Cultural Influences	0.061	0.499**	0.023	**(0.876)**	
Internal Oversight	0.268**	0.016	.443**	0.001	**(0.899)**
Mean	3.793	3.285	4.940	4.099	3.445
Standart Deviation	0.914	0.486	1.041	0.874	0.532
Swekness	-0.152	0.552	-0.551	-0.475	-0.029

Source: AMOS v.21
Note: Squared root of AVE has been shown in bold on diagonals and it should be greater than off-diagonal values for divergent validity. **Correlations are significant at 0.01 level

3.2 Hypotheses Testing

3.2.1 Direct Relation Effect

The hypothesis testing was based on the Estimate, CR, and P values in the regression weights. A CR value >1.96 and a P value <0.05 were required for significance. The results revealed a positive correlation between corporate image and culture affected (Est = 0.316, P = 0.000, C.R = 6.148), supporting Hypothesis 1. However, Hypothesis 2 was rejected, as no significant correlation was found between stakeholder pressure and cultural influence (Est = -0.062, P = 0.569, C.R = -0.570). The hypothesis testing in this study examined the values of Estimate, CR, and P on the regression weights, where the CR value represented the critical ratio obtained by dividing the estimated value by its standard error (S.E.). A higher CR value indicated greater significance. The indicated CR and P values were> 1.96 for CR and < 0.05 for P. If the output results showed values that met these criteria, then the research hypothesis could be accepted.

Table 7. Direct Relations

	Corporate Image → Culture Influence	Stakeholder Pressure → Culture Influence
Estimate / P	.316 (.000)**	-.062 (.569)
S.E	.051	.110
C.R	6.148	-.570
Decision	*Accepted*	*Rejected*

Source: own
Note: (N = 480), **p<0.05

Based on the testing results, it is evident that there was a positive correlation between corporate image and cultural influence. Additionally, the analysis revealed that the predictive strength was considerably significant for corporate image concerning cultural influence (Est = .316, P = .000, C.R = 6.148). It indicated that the testing results for hypothesis 1 could be accepted. Furthermore, the results of the second hypothesis test indicated no positive correlation between stakeholder pressure and cultural influence. The analysis showed no significant negative correlation, indicating that stakeholder pressure does not

influence cultural influence. It was evidenced by the values (Est = -.062, P = .569, C.R = -.570). It indicated that the testing results for hypothesis 2 could be rejected.
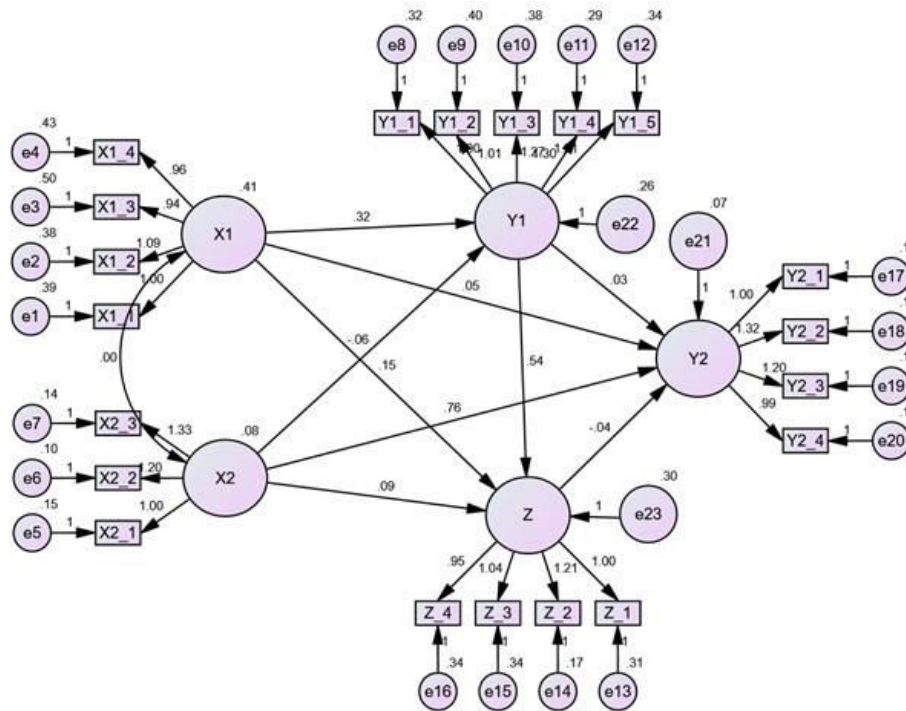
Figure 3. Model Direct Relations
Source: AMOS v.21

3.2.2 Mediating Effect

The mediating effect, also known as the indirect impact, occurs when a mediator or intervening variable influences or mediates the correlation between the independent variable and the dependent variable. In other words, the mediating variable helped explain how or why the independent variable affected the dependent variable (Hair Jr et al., 2021). Table 5 indicated that corporate image contributed a positive and significant effect on cultural influence (Est = .316, P = .000, C.R = 6.148). Furthermore, cultural influence, as a mediating variable, significantly impacted Philanthropic CSR (Est = .727, P = .001, C.R = 4.705). Meanwhile, the Sobel test results between corporate image and Philanthropic CSR, with cultural influence as a mediator, demonstrated that cultural influence could serve as a mediating variable with a Z-statistic value of 5.894643 > Z 1.98. Additionally, Table 5 indicated that cultural influence, as a mediating variable, could not mediate the correlation between stakeholder pressure and Philanthropic CSR, with a Z-statistic value of -0.563392 < Z 1.98. The research findings suggested that cultural influence could mediate the correlation between corporate image and Philanthropic CSR; however, cultural influence did not mediate the correlation between stakeholder pressure and Philanthropic CSR.

Table 8. Mediation Relations & Moderation model

	Corporate Image → Culture Influence	Stakeholder Pressure → Culture Influence	Cultural influence → Philanthropic CSR
Est/P	.316 (.000**)	-.062 (.569)	.727 (.001**)
S.E	. .051	.110	.038
C.R.	6.148	-.570	4.705
Decision Result	Accepted	Rejected	Accepted
Ab	0.229732		
b^2*SEa^2	0.001375		
a^2*SEb^2	0.000144		
√(b^2*SEa^2)+(a^2*SEb^2)	0.038973		

	Corporate Image → Culture Influence	Stakeholder Pressure → Culture Influence	Cultural influence → Philanthropic CSR
Model 1 (CoI→CI→PCSR)	5.894643**		Complementary mediation
Ab		-0.045074	
b^2*SEa^2		0.006395	
a^2*SEb^2		0.000006	
√(b^2*SEa^2)+(a^2*SEb^2)		0.080005	
Model 2 (SP→CI→PCSR)		-0.563392	Direct-only nonmediation

Source: AMOS v.21

Note:

*X! → Y1 . a: 0.316, a^2: 0.099856, SEa : 0.051, SEa^2 : 0.002601, b : 0.727, b^2 : 0.528529, Seb : 0.038, SEb^2 : 0.001444.

* X2 → Y1. a: -0.062, a^2: 0.003844, SEa : 0.11, SEa^2 : 0.0121, b : 0.727, b^2 : 0.528529, Seb : 0.038, SEb^2 : 0.001444.

** (N = 480), **p<0.05

Based on the Sobel test results, it could be drawn that model 1, where cultural influence served as the mediating variable, represented a type of complementary mediation. It implied that cultural influence, when acting as the dependent variable, could be affected by corporate image. When cultural influence acted as the independent variable, it could influence Philanthropic CSR, with both outcomes indicating a positive and significant direction. Furthermore, the Sobel test indicated that model 2, where cultural influence served as the mediating variable, represented a type of no-effect nonmediation. It meant that cultural influence, as the dependent variable, was not significantly influenced by stakeholder pressure. When cultural influence acted as the independent variable, it could influence Philanthropic CSR, with both outcomes indicating opposite directions.

3.2.3 Moderating Effect

A moderating variable altered the correlation between the independent and dependent variables, known as the moderating effect or interaction effect. In other words, the degree or presence of the moderating variable determined the direction of the correlation between the independent and dependent variables. Table 4 revealed that the internal oversight moderating role between cultural influence and Philanthropic CSR yielded a highly significant value (Est = .004, P = .000, C.R = -3.631). Therefore, H6 was accepted.

Table 9. Moderations Relations & Moderation model

	Cultural influence → Philanthropic CSR	Internal Oversight → Philanthropic CSR	Cultural influence * Internal Oversight → Philanthropic CSR	Decision Result	Moderation Model
Est/P	.028(.445)	-.038(.008)**	-.004(.000)**	Accepted	Pure Moderator
S.E	.037	.031	.001		
C.R.	.764	-2.832	-3.631		

Source: AMOS v.21

Note: (N = 480), **p<0.05

Based on the test results, it could be explained that internal oversight served as a pure moderator, acting as a variable that could moderate the correlation between cultural influence and Philanthropic CSR without becoming an independent variable. A pure moderator occurred when cultural influence on Philanthropic CSR did not have a significant effect, while internal oversight on Philanthropic CSR had a significant effect.
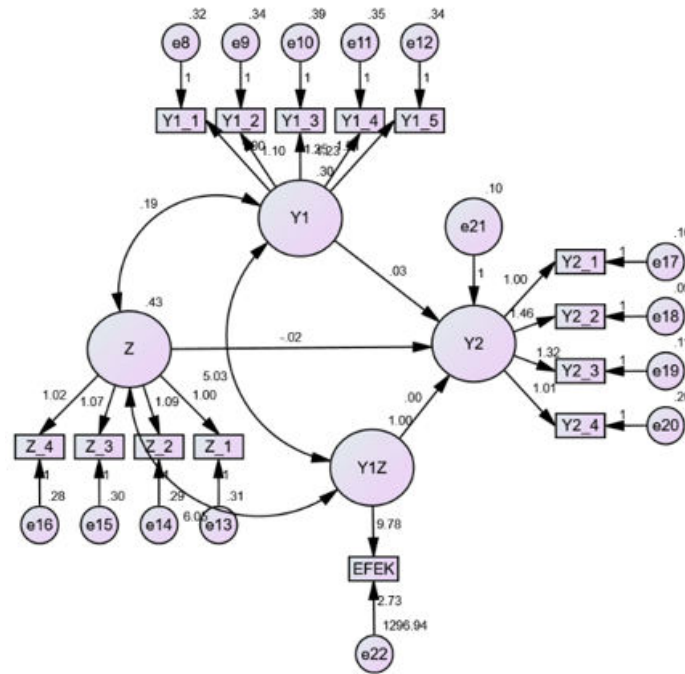
Figure 4. Model Moderations Relations
Source: AMOS v.21

3.3 Discussion

Based on the testing results, H1 demonstrated a significant positive correlation between the influence of corporate image and cultural influence. It implied that the corporate image of state-owned banks in Indonesia consistently provided benefits to the community. State-owned banks in Indonesia have always strived to enhance their image by contributing to society by developing educational facilities, healthcare infrastructure, places of worship, partnerships with micro, small, and medium enterprises, and active participation in humanitarian activities. Humanitarian activities were among the most needed by the Indonesian community. Thus, the promotional strategies employed by state-owned banks in Indonesia increased and fostered public trust to become loyal consumers of the products or services offered by these banks. Although humanitarian activities may have resulted in short-term losses for banks, such actions were worthwhile due to the long-term benefits of enhanced corporate reputation within society.

The results of H2 indicated no significant correlation between stakeholder pressure and cultural influence. It meant that the humanitarian activities conducted by state-owned banks in Indonesia were carried out without the necessity of stakeholder pressure. This research simultaneously asserted that the humanitarian efforts made by state-owned banks in Indonesia were not merely a government attempt to mask its weak performance, corruption, or inefficiency, or to fulfill the resource needs of the Indonesian community by utilizing the humanitarian activities conducted by state-owned enterprises, to present the government as participating in resolving social inequalities in society. Fundamentally, the humanitarian activities carried out by the management of state-owned banks in Indonesia were motivated by a genuine love for others to address social, and humanitarian issues and advance the public interest.

The results of H3 revealed a significant correlation between cultural influence and Philanthropic CSR. It implied that the spirit of cooperation among the general public regarding humanitarian efforts was also supported by the increasing humanitarian activities conducted by banks in Indonesia. The fact that the values of cooperation in Indonesia aligned with the discourse of humanitarian activities undertaken by managers of state-owned banks in Indonesia indicated that these banks adopted values intrinsic to Indonesian culture, such as cooperation. It facilitated the banks in gaining loyalty, legitimacy, and overall achievement of societal objectives.

The results of H4 indicated that cultural influence could serve as a link between corporate image and Philanthropic CSR. It meant that the corporate image of state-owned banks in Indonesia consistently

provided benefits to society. These banks always endeavored to enhance their image by contributing to society by developing educational facilities, healthcare infrastructure, places of worship, partnerships with micro, small, and medium enterprises, and active participation in humanitarian activities. Humanitarian activities were among the most needed by the Indonesian community. By leveraging the culture of cooperation, an inherent Indonesian cultural value based on community solidarity in humanitarian efforts, banks could ease their promotional strategies to enhance their image. Consequently, the plans of banks to increase and foster public trust as loyal consumers of their products or services could be effectively communicated.

The results of H5 indicated that cultural influence could not serve as a link between stakeholder pressure and Philanthropic CSR. It meant that the allocation of funds for humanitarian activities conducted by state-owned banks in Indonesia was carried out without the necessity of stakeholder pressure, such as specific regulatory pressures imposed by the government regarding humanitarian activities or Philanthropic CSR. It underscored that the Philanthropic CSR activities undertaken by these banks were fundamentally driven by a reactive urge of compassion toward others to address social and humanitarian issues and advance the public interest.

The results of H6 indicated that internal oversight could reduce the influence of culture on Philanthropic CSR. It meant that the existence of oversight systems over the uncertainties surrounding the implementation of Philanthropic CSR models in Indonesia, due to the absence of consistent regulatory concepts governing Philanthropic CSR practices, as well as the adoption of cultural values from various regions in Indonesia, could diminish opportunities for frequent occurrences resulting from the weak internal oversight systems in state-owned banks in Indonesia. It mitigated the potential for fraud in the misappropriation of humanitarian funds. Preventive actions taken by banks included measures such as supervision and authorization from internal audits for every transaction and activity related to the distribution of humanitarian funds to the community, as well as routine internal audits of the receipt and expenditure of humanitarian funds.

4. IMPLICATIONS OF THE STUDY

This research underscores the importance of corporate image and stakeholder pressure through cultural influence in enhancing humanitarian activities with internal oversight in banks. The study recommends that state-owned banks consistently participate in Philanthropic activities such as regional development, community development, and partnership programs, thereby aligning all CSR activities with the shared cultural norms of society to improve bank performance. By leveraging the culture of cooperation, an inherent Indonesian cultural value grounded in community solidarity concerning humanitarian efforts, banks could facilitate their marketing strategies to enhance their image. Thus, the plans of banks to increase and foster public trust as loyal consumers of their products or services can be effectively communicated. Fundamentally, the humanitarian activities undertaken by the management of state-owned banks in Indonesia are driven by a genuine love for others to address social and humanitarian issues and advance the public interest. The goodwill behind the humanitarian activities conducted by banks ideally received support from the government to ensure that the humanitarian initiatives undertaken by state-owned banks in Indonesia can continue. This finding recommends that state-owned banks in Indonesia maintain consistency in executing humanitarian activities by establishing subsidiaries focused on humanitarian efforts, allowing for better oversight of government funds and donations from community benefactors through the bank's oversight system. Moreover, this finding can also assist policymakers in formulating specific policies to enable state-owned banks in Indonesia to become institutions that can effectively allocate humanitarian funds to the community.

This research examined Corporate Image, Stakeholder Pressure, and Philanthropic CSR, mediated by Cultural Influences and moderated by internal oversight within Indonesian state-owned banks to support stakeholder theory. The study supported stakeholder theory by demonstrating that corporate image was a promotional strategy that aligned corporate objectives with various strategic stakeholders affecting organizational performance. Although humanitarian activities may have incurred short-term losses for banks, such actions were justified by the long-term benefits derived from enhanced corporate reputation within society. The study revealed that humanitarian activities undertaken by state-owned banks with a positive

image contributed to society by developing educational facilities, healthcare infrastructure, places of worship, partnerships with micro, small, and medium enterprises, and active participation in humanitarian efforts. The study also explored cultural influence as a mediating factor between corporate image and Philanthropic CSR, aiming to expand stakeholder theory. According to Carroll's pyramid theory, companies were obligated to contribute to the philanthropic responsibilities required by society and the environment, as reflected in the humanitarian activities conducted by banks in Indonesia, which adopted values intrinsic to Indonesian culture, such as cooperation. It facilitated banks in gaining loyalty, legitimacy and achieving overall objectives within society. This finding provided new insights that social activities in developing countries may differ in their delivery methods, as leveraging the country's inherent culture could facilitate the acceptance of humanitarian assistance by society and the government. Consequently, bank performance would be positively impacted by positive community correlations based on the cooperation values of Indonesian society and government.

4.1 Limitations of the Study

This study faced several limitations. The respondents were exclusively drawn from state-owned banks in Indonesia. Therefore, future research should consider distributing questionnaires to state-owned banks outside of Indonesia to obtain a broader perspective and enhance understanding of the cultural contexts of other countries. Future studies could also incorporate Islamic state-owned banks to examine humanitarian distributions based on Sharia principles. Literature on Sharia-based philanthropy remains limited.

Moreover, this research was constrained by the completeness of its scope. The reliance on quantitative data may have impeded comprehensive understanding, particularly concerning corporate image, stakeholder pressure, philanthropic, corporate social responsibility (CSR), cultural influences, and internal bank governance. It is advisable for subsequent research to not only utilize quantitative data from respondents but also to augment this with qualitative approaches, such as interviews and focus groups, to improve survey results and provide clearer insights into the topic, thereby assisting other researchers in gaining a more profound understanding of the subject matter.

It is also plausible that the data obtained from respondents, based on their questionnaire responses, may not always be valid. Respondents might have filled out the questionnaires unfocused or in haste, leading to inaccurate answers. The cross-sectional research design limits causal inferences, as data were collected at a single point in time. Longitudinal or experimental methodologies could clarify the complex correlations among corporate image, stakeholder pressure, and philanthropic CSR.

Future research could also consider incorporating analyses of financial reports from the studied companies, utilizing dynamic panel data analysis techniques, particularly the Arellano-Bond estimator. This approach could facilitate the examination of the temporal dynamics of the interaction between corporate image and stakeholder pressure on philanthropic CSR while mitigating endogeneity. Consequently, employing this panel data regression method could yield more reliable evidence of causal dynamics and interrelations. Scholars may explore sophisticated moderation and mediation models involving multiple mediators and moderators. The involvement of Corporate Sustainable Performance, or Green Profitability, affects Corporate Image, Stakeholder Pressure, Cultural Influence, and Philanthropic CSR.

CONCLUSION

This study explains the interaction between state-owned enterprise banks in distributing humanitarian funds. The research reveals that a strong corporate image can influence local culture and philanthropic CSR, highlighting the need for internal monitoring systems and processes to distribute philanthropic CSR funds. Furthermore, the study develops a moderated mediation model, making it unique in demonstrating how corporate image and stakeholder pressure contribute to the success of state-owned enterprise bank performance. The study also presents that corporate image can influence local culture and humanitarian fund distribution by adopting the stakeholder theory philosophy.

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The Effect of Economic Policy Uncertainty on the Capital Adequacy Ratio Adjustment of the Asian Banks

HO THANH TUNG[1] and PHAM THI TRAM ANH[2]

[1]Lecturer of Faculty of Finance and Banking, Ton Duc Thang University, 19 Nguyen Huu Tho Street, Tan Phong Ward, Dist 7, Ho Chi Minh City, Vietnam, email: hothanhtung@tdtu.edu.vn; ORCID: 0000-0003-1730-2139
[2]Faculty of Business Administration, University of Finance - Marketing, Vietnam, email: anhpham@ufm.edu.vn

ARTICLE INFO

ABSTRACT

Due to many factors, the CAR is frequently and continuously adjusted in the business. This research examines the factors that affect the CAR target and its adjustment speed. We apply the partial adjustment model to analyze the data of 9 Asia countries' banks from 2010 to 2019. Our key finding is that credit growth shows less influence and is statistically significant on the CAR target than the new variable created by the interaction between credit growth and the economic policy instability index. The adjustment has occurred through this new factor rather than adjustments to the risk sensitivity of the banks' assets or the growth of undivided profit. In addition, the Asian banks improved their CAR by increasing the main components of their core capital.

INTRODUCTION

Recently, uncertainty is a matter for economic decision-making that has been emphasized; economic policy uncertainty (EPU) helps predict recessions at the macro-level (Karnizova & Li, 2014) and in the presence of now-standard financial variables (Scott et al., 2015). The government has widespread effects on the country's overall economy (Ellen & Edward, 2005). When government policies are smooth and predictable, the economic sectors might be more informed about their business enlargement decisions. On the contrary, uncertainty about government policies has severe implications as firms tend to decrease investment and cut jobs (Scott et al., 2016; Huseyin & Mihai, 2016). Banks are sensitive and averse to EPU (Gissler et al., 2016); in reaction to EPU, banks may reduce credit growth to lower risk exposure (Bordo et al., 2016).

Recent studies focus on a bank lending channel through which economic policy uncertainty (EPU) slows US credit growth and eventually harms the economy (Bordo et al., 2016; Zelong and Jijun, 2018; Berger et al., 2018). Hu and Gong (2019) analyzed bank-level data in 19 major economies, adding

evidence that EPU significantly hinders bank credit growth. These authors also confirmed empirically that prudential regulation reduced the impact of EPU on bank lending. Hence, sound prudential policies help reduce bank credit risk when uncertainty rises.

After the financial crisis of 2008, bank regulations and supervision are being tightened to consolidate in the industry worldwide. The Basel Committee has identified the capital adequacy ratio (CAR) as one of the most important criteria financial institutions must follow to maintain their soundness. This requirement is carried out through the implementation of the high-quality capital concept. The public and private sectors have been urging banks to build more capital. Cohen and Scatigna (2016) analyzed 101 large banks from advanced and emerging economies; the results indicated that the adjustment was through the accumulation of retained earnings and shifting to the assets with other risk weights rather than through sharp adjustment in lending or asset growth channels. The authors also supposed that the developments in lending standards and lending spreads have been very weak relative to the other factors influencing bank lending supply. However, Asia countries, which are almost emerging economies, might have another way to comply with the CAR regulations. How did the Asian banks compliance the CAR? Especially with the impact of The World Uncertainty Index (WUI), a new upgrade index from the EPU. That is a gap that this study aims to fill.

1. LITERATURE REVIEW

The World Uncertainty Index (WUI) was developed by Hites Ahir (International Monetary Fund), Nicholas Bloom (Stanford University) and Davide Furceri (International Monetary Fund). The authors construct quarterly indices of economic uncertainty for 143 countries from 1996 onwards using frequency counts of "uncertainty" (and its variants) in the quarterly Economist Intelligence Unit country reports (Hites et al., 2022). The index is associated with greater economic policy uncertainty (EPU), stock market volatility, risk, and lower GDP growth (https://www.policyuncertainty.com/wui_quarterly.html). Uncertainty related to economic policy may affect the real economy. Firms tend to decrease investment and cut jobs amid high uncertainty, while households reduce consumption (Scott et al., 2016; Huseyin & Mihai, 2016).

Bordo et al. (2016) examined the impact of economic policy uncertainty on aggregate bank credit growth. The authors find that policy uncertainty significantly negatively affects bank credit growth. The effects are attributable to loan demand or loan supply if the impact varies with bank-level financial constraints. Findings are consistent with the possibility that high economic policy uncertainty may have slowed the United States' economic recovery from the Great Recession by restraining overall credit growth through the bank lending channel.

In the same line as Bordo et al. (2016), Hu and Gong (2019) analyzed bank-level data in 19 major economies and consolidated that the EPU has a significant negative effect on the growth of bank credit. In addition, the authors showed empirical evidence that the EPU significantly hinders bank credit growth, but the effect varies across banks. In particular, the negative effect of EPU on loan growth is greater for larger and riskier banks while weaker for more liquid and diversified banks. And the impact of EPU on bank lending depends critically on national prudential regulations. In addition, Badar and Yinjie (2019) analyzed bank data from 17 countries and concluded that the impact of EPU on banks' loan pricing remains persistent after controlling for banks' own idiosyncratic default risk and the political risk variables. These authors also found a significant positive association between loan spreads and the EPU index. Together, these results suggest that government economic policy uncertainty is an economically important risk factor for banks' loan pricing.

Recently, Badar and Yinjie (2919) concluded that government economic policy uncertainty has a significant positive association with interest rates on bank gross loans. Specifically, a one standard deviation increase in EPU leads to a 21.84 basis points increase in average interest rates on bank gross loans. CAR is suggested by the Basel committee as a benchmark for bank soundness and applied in the industry worldwide. Cohen and Scatigna (2016) analyzed data from 101 large banks from advanced and emerging economies to investigate the adjustment channel for the CAR implementation of these banks. The approach is based on the capital requirements regulatory. The authors indicated that retained earnings, issuing new equity, changing the asset side of the bank's balance sheet and shifting the risk-weighted asset (RWA) are the adjustment channels that the bank can employ. The evidence showed that the adjustment

channel was the accumulation of retained earnings, while reductions in risk weights were not the priority, and banks continued to expand their lending.

In addition (Shimizu, 2015) gave another approach to analyze the behavior of adjusting denominators of capital ratios upon the introduction of Basel II regulations of the Japanese banks. In this study, the first analysis investigates the adjustments to the size and composition of portfolios to achieve the target risk-weighted asset. Then, the second analysis investigates how quickly banks adjust the numerator and denominator of their capital ratio. The findings of Shimizu (2015) evidenced that banks adjusted the composition of their assets faster than their asset size to achieve the RWA targets. Besides, banks adjusted their level of regulatory capital faster than their RWA to achieve the capital ratio targets.

In this study, the author follows and combines the methods of both Shimizu (2015) and Cohen and Scatigna (2016) and also adds the economic policy uncertainty index (WUI) as a new factor into the analysis to find out whether this is a factor that might affect on the CAR adjustment speed of the banks in 9 Asia countries or the affect might cause the CAR through the interactive between the WUI and the loan growth.

2. METHODOLOGY AND DATA

The partial adjustment models are used to estimate the adjustment speed of the capital ratios and the contribution of the factors in the adjustment channels that build the CAR. The CAR is defined as the regulatory capital divided by the RWA. Defined by the formula below:

We begin with the simple definition of the RWA

$$CAR_{i,t} = \frac{(\text{Tier1}+\text{Tier2})_{i,t}}{\text{RWA}_{i,t}} \qquad (1)$$

where RWA_{it} is the total risk-weighted assets of bank I at year t. Under the current regulations, the RWA is specified as the average risk weight on risky total asset:

$$RWA_{i,t} = \Omega(\text{Risky total asset})_{i,t} \quad (2)$$

where Ω is denoted as the average risk weight.

In formula (2), almost all risky total assets are in the total financial asset securities, gross loan and advance to customer, and other assets of each bank I at year t. The gross loan and advance, which is the largest proportion in the bank asset portfolio, is proxy by its growth to investigate whether this growth is connected with the adjustment of the CAR. Additionally, in the formula (1), the undivided profit is a component of tier 1, a very important channel that adds to the bank's capital to improve the numerator of the CAR. Therefore, the author separates tier 1 from the total equity and the capital generation to make it easier to recognize the contribution of each part in tier 1 to the CAR adjustment.

Dividing the numerator and denominator of the left-hand side of formula (1) to the total assets. In which the Ω is divided into total assets, the risk-weighted asset intensity. Assuming that the other factors are stable, changing each part in the numerator might cause a positive associate relationship with the CAR, while the parts of the denominator might cause an invert.

This research expects to find some evidence of the effect of the WUI index, which is the standard deviation of the government economic policy uncertainty and its interaction with the loan growth on the CAR. The standard deviation of the government economic policy uncertainty is a negative effect on loan growth (Badar & Yinjie (2019), Hu & Gong (2018), Bordo et al., (2016)), while loan growth represents the change in gross loans, which is a part of the denominator of CAR. These two new indicators are added to the estimation model to analyze how the WUI affects the CAR compliance of Asian banks.

Table 1. The summary of the variables

Variable	Definition	Calculated	Expectation
CAR	Capital Adequacy Ratio	$CAR_{i,t} = \dfrac{(Tier1 + Tier2)_{i,t}}{RWA_{i,t}}$	+
Size	The logarithm of total asset	The logarithm of total assets of bank i,t	-
LoanG	Loan growth ratio	(Gross loan$_{i,t}$ - Gross loan$_{i,t-1}$)/Gross loan$_{i,t-1}$	-
WUI	WUI index by country	Standard deviation WUI index by country year t	+/-
LoanG*WUI	The interaction of WUI with the loan growth	Multiply the Loan growth ratio by the WUI index	+/-
FS_TA	The ratio of total financial asset securities to total assets of a bank	Total financial securities$_{i,t}$/total assets$_{i,t}$	-
OA_TA	The ratio of other assets to total asset	Other assets$_{i,t}$/Total Asset$_{i,t}$	-
RWA_I	The ratio of total risk-weighted asset to total asset	Total Risk-Weighted Assets$_{i,t}$/Total Asset$_{i,t}$	-
TE_TA	Equity ratio	Total equity$_{i,t}$/Total asset$_{i,t}$	+
T2	Tier 2	Tier 2 capital$_{i,t}$	+
CET1	Growth of Capital generation ratio	(Net income$_{i,t}$ – dividend$_{i,t}$) /Total equity$_{i,t}$	+

Source: Summary by the authors

3. THE MODEL

To estimate the adjustment speed of the banks, in the long run, the CAR is a function of the factors that affect itself;

$$Y^{*}_{i,t+1} = \sum_{j=1}^{j} \beta_j X_{j,i,t} + \theta_n C_{n,i,t}, n = 1 \quad (3)$$

Y* is the CAR target, the partial adjustment model of the CAR and its target:

$$Y_{i,t} - Y_{i,t-1} = \lambda(Y^{*}_{i,t} - Y_{i,t-1}) + \varepsilon_{i,t} \quad (4)$$

where Y is respectively the capital on total assets ratio and the capital on risk-weighted assets ratio of bank i, the X_j is the vector of factors jth that affect the adjustment of the CAR, and the C_n is the control variable, t is the year from 2010 to 2019; λ is the gap or speed of adjustment during a point time, ($0 \leq \lambda \leq 1$). Substituting equation (3) into equation (4), then a model that the speed of adjustment (λ) is estimated as follows:

$$Y_{i,t} = (1-\lambda)Y_{i,t-1} + (\lambda\theta_n)C_{n,i,t} + \sum_{j=1}^{j}(\lambda\beta_j)X_{j,i,t} + \varepsilon_{i,t} \quad (5)$$

Then, the author includes bank fixed effects (Bank$_i$), year fixed effects (Year$_t$), country fixed effect (Country$_I$) and bank type effects (Bank_type$_k$) to absorb any unobserved, time-invariant bank and bank type heterogeneity and business cycle effects, respectively. In addition, the logarithm of the total asset (Size) is a control variable added into the equation, the same as almost all of the analyses in this area. The model could be rewritten as the function below:

$$CAR_{i,t} = (1 - \lambda)CAR_{i,t-1} + (\lambda\theta)Size_{i,t} + (\lambda\beta_1)LoanG_{i,t} + (\lambda\beta_2)WUI_t$$
$$+ (\lambda\beta_3)WUI_t * LoanG_{i,t} + (\lambda\beta_4)FS\_TA_{i,t} + (\lambda\beta_5)OA\_TA_{i,t}$$
$$+ (\lambda\beta_6)RWA\_I_{i,t} + (\lambda\beta_7)TE\_TA_{i,t} + (\lambda\beta_8)T2\_TA_{i,t}$$
$$+ (\lambda\beta_9)CET1\_G_{i,t} + \varepsilon_{i,t} \quad (6)$$

3.1 Data

The sample was constructed by collecting the economic policy uncertainty index data from the website https://www.policyuncertainty.com/wui_quarterly.html. This website hosts the economic policy uncertainty index data developed by Hites et al. (2022). These authors have constructed a new index, the World Trade Uncertainty Index, that measures uncertainty related to trade for 143 individual countries every quarter from 1996 onwards, using the Economist Intelligence Unit (EIU) country reports. The approach to constructing the WTU index is to count the number of times uncertainty is mentioned within proximity to a word related to trade in the EIU country reports. In this research, we downloaded the index data for 9 Asian countries and merged them with bank-level financial statements yearly data of banks operating in these countries from the Bankscope database from 2010–2019.

4. RESULTS AND DISCUSSIONS

The collected data is an unbalanced panel data. The loan growth and capital generation ratio information is less than the other 12 observations and 01 observation, respectively.

Table 2. Summary statistics of the data

	N	Mean	Sd	min	max	Se
CAR	5040	0.123	0.317	0.001	4.882	0.004
Size	5040	7.779	1.265	1.643	11.489	0.018
LoanG	5028	0.118	0.441	-1.000	8.455	0.006
WUI	5040	0.096	0.053	0.000	0.376	0.001
FS_TA	5040	0.213	0.147	0.000	0.879	0.002
OA_TA	5040	0.250	0.177	0.000	0.727	0.002
RWA_I	5040	0.293	0.347	0.001	6.080	0.005
TE_TA	5040	0.126	0.129	-0.811	0.756	0.002
T2_TA	5040	0.006	0.010	0.000	0.202	0.000
CET1	5039	0.035	0.207	-7.826	7.843	0.003

Source: Calculated by the authors

Table 2a. Summary statistics by year – Mean

Year	CAR	Size	LoanG	WUI	FS_TA	OA_TA	RWA_I	TE_TA	T2_TA	CET1
2010	0.019	7.401	0.019	0.045	0.238	0.087	0.081	0.054	0.009	0.000
2011	0.017	7.438	0.038	0.146	0.241	0.099	0.061	0.110	0.008	0.000
2012	0.018	7.483	0.041	0.138	0.240	0.171	0.108	0.096	0.007	0.000
2013	0.041	7.500	0.072	0.132	0.242	0.136	0.065	0.115	0.004	0.001
2014	0.103	7.992	0.130	0.133	0.216	0.151	0.236	0.110	0.009	0.022
2015	0.098	7.956	0.166	0.110	0.217	0.166	0.275	0.116	0.006	0.032
2016	0.142	7.796	0.163	0.066	0.218	0.184	0.375	0.122	0.006	0.073
2017	0.143	7.813	0.142	0.092	0.227	0.181	0.341	0.125	0.006	0.039
2018	0.154	7.850	0.184	0.110	0.228	0.180	0.343	0.130	0.006	0.063
2019	0.151	7.798	0.141	0.084	0.218	0.189	0.330	0.152	0.006	0.043

Source: Calculated by the authors

Table 2b. Summary statistics by country – Mean

	CAR	Size	LoanG	WUI	FS_TA	OA_TA	RWA_I	TE_TA	T2_TA	CET1
China	0.153	7.378	0.195	0.069	0.290	0.288	0.546	0.106	0.007	0.123
India	0.124	6.990	0.131	0.124	0.243	0.153	0.411	0.115	0.009	0.061
Indonesia	0.227	9.169	0.204	0.104	0.108	0.236	0.647	0.162	0.011	0.057
Japan	0.111	7.709	0.051	0.106	0.251	0.164	0.078	0.074	0.004	0.007
Korea	0.135	10.826	0.082	0.094	0.157	0.106	0.536	0.075	0.015	0.069
Malaysia	0.288	6.643	0.113	0.112	0.224	0.339	0.497	0.194	0.011	0.075
Philippine	0.045	7.273	0.184	0.128	0.140	0.379	0.169	0.236	0.004	-0.005
Singapore	0.070	8.822	0.259	0.063	0.410	0.254	0.125	0.196	0.002	0.007
Vietnam	0.038	8.725	0.212	0.066	0.115	0.285	0.645	0.172	0.001	0.001

Source: Calculated by the authors

Table 2c. Summary statistics by bank type – Mean

	CAR	Size	LoanG	WUI	FS_TA	OA_TA	RWA_I	TE_TA	T2_TA	CET1
Commercial	0.108	7.883	0.138	0.096	0.217	0.211	0.334	0.105	0.007	0.050
Cooperative	0.133	6.369	0.102	0.091	0.243	0.204	0.538	0.101	0.011	0.030
Investment	0.395	7.860	0.225	0.092	0.332	0.423	0.081	0.271	0.002	0.014
Real estate	0.118	6.941	0.178	0.119	0.056	0.142	0.222	0.110	0.001	0.004
Saving	0.016	7.311	0.106	0.126	0.129	0.415	0.059	0.287	0.002	0.003

Source: Calculated by the authors

The figures in Table 2a show that in the three years from 2010 to 2012, the CAR was under 2%. The risk sensitivity was low during that time, and the banks almost did not increase their capital generation levels. Meanwhile, the equity to total assets ratio increased twice between 2010 and 2011, and the tier 2 capital ratio fluctuated slightly. After 2013, almost all the Asian banks in the data improved their CAR; the equity ratio and the capital generation were higher than the previous; meanwhile, the asset sensitivity also increased. The figures in Table 2b and 2c supplement the information that from 2010 to 2019, the CAR of the banks in China, India, Japan and Korea were around the middle range, while in Singapore, Philippines and Vietnam, the CAR was respective. The CAR in Malaysia and Indonesia were the highest and the second highest, respectively. In the industry, saving banks had the lowest CAR, 1.6%, while investment banks showed the highest at 39.5%.

Table 3. Correlation matrix between the independent variables

	CAR_{t-1}	Size	LoanG	WUI	FS_TA	OA_TA	RWA_I	TE_TA	T2_TA	CET1
CAR_{t-1}	1	0.1	0.07	-0.01	0.02	0.17	0.15	0.05	0.02	0.02
Size		1	0.06	-0.06	-0.02	-0.04	0.08	-0.04	0.05	0.01
LoanG			1	0	-0.04	0.07	0.01	0.04	-0.03	0.04
WUI				1	-0.05	-0.03	-0.08	0.01	0.06	-0.04
FS_TA					1	-0.18	-0.03	-0.03	0.02	0.06
OA_TA						1	0.03	0.34	-0.12	0.01
RWA_I							1	-0.04	0.44	0.19
TE_TA								1	-0.08	-0.01
T2_TA									1	0.07
CET1										1

Source: Calculated by the authors

In Table 3, the correlations matrix between variables shows that most of the variables do not have very high correlation coefficients between each other, suggesting that the chances of multicollinearity in multivariate analysis are low.

The estimated results of models (6) in Table 4 show the significance statistically for the CAR adjustment speed calculation, in which the year fixed effects (6a) provide a low adjustment speed at only 0.094 while the estimations added bank and country fixed effects (6b), bank and bank type fixed effects (6c) give almost the same CAR adjustment speed at 0.82. The control variable loses its significant statistical effect on CAR in both models (6a) and (6b) and shows a statistically significant from the estimation of the model (6b) at 95%. The results also provide that the loan growth variable has a statistically significant effect on CAR in models (6b) and (6c), but in model (6a), this factor does not have enough evidence of this effect. Additionally, the WUI alone does not give any evidence of its effect on the CAR. Meanwhile, the interaction of WUI and loan growth showed strong evidence that this interaction has a positive statistically significant effect on the CAR and has the highest impact compared with the other variables in the models. Results of the interactive variable might be understood that the impact of WUI on CAR might be calculated by the WUI multiple the coefficient of loan growth and the coefficient of the interactive variable, a magnitude of the loan growth and the WUI together impact on CAR and stronger than the impact of loan growth alone on the CAR. The findings are associated with and contribute to the findings of Bordo et al. (2016) and Hu & Gong (2018). The relationship between loan growth and economic policy uncertainty also provides evidence of its effect on the CAR adjustment of Asian banks from 2010 to 2019.

Table 4. Panel regression of Capital Adequacy Ratio: partial adjustment model

Dependent variable:		CAR	
Model	(6a)	(6b)	(6c)
Constant	-0.028	0.136	0.500
	(-1.386)	(1.363)	(1.521)
CAR1	0.906**	0.181***	0.180***
	(11.233)	(3.741)	(11.306)
	$\lambda = 0.094$	$\lambda = 0.819$	$\lambda = 0.82$
Size	0.003	-0.015	-0.054**
	(1.274)	(-0.667)	(-1.998)
LoanG	-0.022	-0.016**	-0.015***
	(-0.991)	(-2.421)	(-3.106)
WUI	-0.027	-0.041	-0.037
	(-0.519)	(-0.764)	(-0.359)
LoanGxWUI	0.096	0.137***	0.139***
	(0.766)	(3.411)	(3.412)
FS_TA	-0.001	-0.041	-0.036
	(-0.106)	(-0.473)	(-0.223)
OA_TA	0.046	0.130	0.146
	(1.618)	(0.991)	(1.232)
RWA_I	0.019	0.054	0.049
	(1.095)	(1.569)	(1.434)
TE_TA	0.030	0.753*	0.716
	(1.029)	(1.891)	(1.584)
T2_TA	0.286*	0.746**	0.804
	(1.788)	(2.075)	(0.510)
CET1	0.009	0.004	0.005
	(0.542)	(0.416)	(0.974)
Adj R^2:	0.775	0.879	0.879

Model 6a: Year fixed effects (Year$_t$)

| Model 6b: bank fixed effects (Bank$_i$), year fixed effects (Year$_t$); and country (Country$_l$) |
| Model 6c: bank fixed effects (Bank$_i$), year fixed effects (Year$_t$) and bank type effects (Bank_type$_j$) |

The results also show evidence that the banks neither adjust their assets nor shift the risk weight to achieve their CAR target. On the other hand, some evidence indicates that in the period, the Asian banks improved their core capital, and these improvements had a positive, statistically significant effect on the CAR target. The core capital improvements of the Asian banks in the sample data were similar to the calculations of Cohen and Scatigna (2016) on the advanced economic banks and Tung et al., (2018) on Vietnamese commercial banks. Besides, even though the summary statistic shows a similar trend in the change of risk-weighted assets as the findings of Cohen & Scatigna (2016) on emerging-economy banks, the authors do not have evidence that the Asian banks shift risk-weight assets to adjust the CAR.

If we stand on the approach of Shimizu (2015), the results indicate that the CAR gets the impact from more factors of the numerator than the denominator. Additionally, the strength of the effect from the components of the numerator is also higher than that from the denominator. Only the estimation with the fixed effect of the bank type proves that the bank's asset size is associated with CAR. This result suggests that the different bank types might have other ways to achieve their CAR target. The difference might be within the characteristics of the assets held by each bank type.

Finally, the partial adjustment models provide the adjustment speeds, in which model 6a shows a very slow adjustment speed while models 6b and 6c indicate the speed at the CAR adjusts 82% toward its target within a year.

CONCLUSION

The results could indicate that to implicate the CAR regulation. Asian banks improved their core capital rather than adjusted their asset portfolio. This research finds that the loan growth is evident in the impact on the CAR adjustment; WUI has to interact with the loan growth and then show evidence of a magnified effect of the loan growth on the CAR adjustment. Applying fixed effects by the bank, country fixed effects, and bank type effects to absorb any unobserved, time-invariant bank type and country heterogeneity and business cycle effects give strong evidence of this than only the year used. During this period, Asian banks might not regularly use the shift of risk-weight assets to achieve their target CAR.

Our findings give the bank monitoring and manager a point to analyze when the economic policy uncertainty rises. Early on, this situation could not be found to be a factor that directly affected CAR improvement. However, there is evidence that the increase in economic policy uncertainty would cause a decrease in banks' lending in a year lag (Bordo et al., 2016; Hu & Gong, (2018)). Accordingly, the growth of loans is going to be decreased. Thus, through the interaction calculation between loan growth and WUI, the manager could estimate a CAR trend for managing this indicator.

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The Influence of Agricultural Price on Stock Markets in Short and Long Run. Evidence from ASEAN

DO PHUC QUYEN BUI[1] and THI MY THUY NGO[2]

[1]PhD, Lecturer, University of Labour and Social Affairs II, Vietnam, email: quyenbdp1003@gmail.com
[2]PhD, Lecturer, University of Finance – Marketing, Vietnam, email: ntm.thuy@ufm.edu.vn

ARTICLE INFO

ABSTRACT

Commodity price volatility affects the stability of countries' exports, input costs for industrial production, the allocation of world capital flows, national economic growth rates and stock markets. This study examines the impact of the agricultural price on the stock market of six Southeast Asian countries, including Malaysia, Indonesia, Thailand, Singapore, Philippines, and Vietnam, during the period from 2007 to 2023. The paper not only uses the dependent variable of agricultural prices, but also uses the control variables of domestic macroeconomic factors including inflation, exchange rate, and interest rate to explain the fluctuations of Southeast Asian stock markets. The Pooled Mean Group (PMG) method to estimate the dynamic heterogeneous panel data model and to verify the correlation between the agricultural price index and the stock market index. According to empirical results, the agricultural price and stock market index have a long-run co-integration relationship. In the short term, the stock market is not affected by agricultural price. In addition, other macroeconomics such as interest rates, exchange rates, inflation rates are also effective on the stock market.

INTRODUCTION

An efficient capital market is essential for economic development. The stock market is a part of the capital market, which plays a pivotal role in the growth of a country and is important in directing idle resources to productive sectors. If the capital market can create instantaneous changes in the flow of money, the stock market is considered the heartbeat of the national economy. Therefore, the movement and development of the economy cannot be without the companionship of the stock market (Mohammed et al., 2009).

The impact of commodity prices on stock markets has been a topic of open macroeconomics research for a long time. Studies by Creti et al. (2013), Drechsel and Tenreyro (2018), Kang et al. (2020) also show that commodity price shocks and stock market volatility are interrelated and affect real economic activity.

Southeast Asian countries are mostly small open economies with high trade deficits, so they are easily affected by fluctuations in global commodity prices. Indeed, the IMF (2015) reported that fluctuations in energy prices, including oil, during the period 2008-2014 had a large impact on stock prices and output

for oil-importing countries in emerging markets, including Southeast Asia. The increased volatility in global commodity prices in 2018-2019 has put inflationary pressures on emerging market economies including Southeast Asian economies and has also had a certain impact on the stock market (IMF, 2020). Fluctuations in global commodity prices also cause global inflation to increase from 4.7 percent in 2021 to 8.8 percent in 2022 but decline to 6.5 percent in 2023 and is forecast to decline to 4.1 percent in 2024 (IMF, 2024). The potential global imbalance in the supply and demand of agricultural products could cause a serious increase in the prices of agricultural products. In this regard, the international prices of agricultural products, which are known as strategic products of the future, are likely to have a significant impact on the economies and financial markets of countries including Southeast Asia. The impact of agricultural commodities on the stock market can be realized through two channels, direct and indirect. Accordingly, the increase or decrease in agricultural commodity prices can cause an increase or decrease in the income of enterprises engaged in agricultural production or marketing listed on the stock exchange, which can directly affect the stock market performance of related enterprises. Furthermore, increases or decreases in agricultural commodity prices affect countries' economic indicators, such as exports, imports, employment, and inflation. Positive or negative developments in macroeconomic indicators arising from these commodities can indirectly cause increases or decreases in stock market indices.

With the increasing integration of economies and the interdependence of commodity markets, agricultural commodity prices have been volatile, becoming more sensitive to innovations in financial markets and tending to have a greater impact on stock prices. Analyzing the spillover of agricultural prices to stock markets can provide useful information about possible alternative investment strategies between stocks and commodities, thus positively affecting asset allocation (Choi and Hammoudeh 2010).

There is empirical evidence that in addition to the influence of domestic macroeconomic factors, Southeast Asian stock markets are also affected by world commodity prices such as gold prices (Ismail M. T., 2017; Ehsan H. et al., 2013), oil prices (Alam, 2013; Fatemeh R. et al. 2016; Sugeng W. et al., 2017; Robiyanto R., 2018), or both gold and oil prices (Hossenidoust, E. et al., 2013). However, these are individual commodities and so far there has been no research document linking world agricultural prices to Southeast Asian stock price indexes. Therefore, this study was conducted to clarify the impact of the world agricultural price index, along with domestic macroeconomic variables, on the stock markets of six selected Southeast Asian countries (including Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam).

1. LITERATURE REVIEW

Girardi D. (2015) studies the correlation of agricultural prices with stock markets. The author discusses the possible role of financial, macroeconomic, and monetary factors in driving this time-varying relationship, with the aim of understanding what has caused the positive correlation between agricultural commodities and stock markets in recent years. While previous studies on commodity correlations have focused on general commodity price indices, this study focuses on specific agricultural commodities (as well as differences between agricultural markets). Conduct a series of univariate Granger causality tests by estimating OLS regressions between the S&P500 index and the agricultural commodity price index along with control variables (interest rate, inflation, exchange rate) for the period from September 2008 to July 2013. The results show that there is a correlation between agricultural price changes and stock market returns. Moreover, the impact of financial instability on the correlation becomes stronger as the proportion of financial investors in the agricultural derivatives market increases.

Baldi L. et al. (2016) focus on commodity financialization and the gradual integration between commodity and financial markets, investigating the extent to which stock market reactions to agricultural commodity price movements and the existence of this phenomenon. To achieve this goal, we use an impulse response function from the perspective of the impact of agricultural commodity prices on the stock market over a symmetrical window before and after the two most significant crises since the new millennium, the dot.com bubble in 2000 and the financial crisis in 2008. We use monthly data from 1970 to 2015 for the S&P500 index with an agricultural price index, a grain price index, and a corn price index. The agricultural price index is a benchmark for evaluating the investment performance of the global agricultural commodity market and includes wheat, corn, soybeans, coffee, sugar, cocoa, and cotton. The grain price index is a

composite index of grain commodity prices, including soybeans, corn, and wheat, while the corn price index reflects the risk/return characteristics of corn, which is the most traded commodity on the market. The overall stock market is represented by the S&P 500 index. Results from the GARCH model show that spillover volatility increased significantly after the 2008 financial crisis, signaling an increasing connection between agricultural commodities and the stock market.

Hernandez J. A. et al. (2020) investigate the spillover of agricultural prices to global and regional stock markets. By applying a directional spillover index and a nonlinear portfolio optimization method. The deployed data sample includes daily frequency prices spanning from March 18, 2009 to February 12, 2019, corresponding to nine agricultural commodities (wheat, corn, soybeans, coffee, sugarcane, sugar beets, cocoa, cotton, lumber) and four global stock market indices, namely MSCI ACWI Index (All World World Stock Index), MSCI AC Americas Index (All Americas Stock Index), MSCI AC Europe Index (All Europe Stock Index), and MSCI Asia ex-Japan Index (All Asia excluding Japan Stock Index). The motivation for selecting the above nine agricultural commodities is that they are the major agricultural commodities traded worldwide, thus together they provide a good representation of the agricultural commodity market and, given the historical negative correlation that agricultural commodities have shown with the stock market, they have the potential to be used by investors to diversify and hedge their equity portfolios. Applying a generalized vector autoregression (GVAR) approach and incorporating a variance decomposition matrix, the results show that the global and regional stock market indices are considered to be largely influenced by cotton and cocoa. The American stock market index is mainly influenced by corn and soybeans. In addition, while the European stock market index is mainly influenced by cotton, the Asia Pacific stock market index is mainly influenced by wheat and coffee. Portfolio optimization shows that sugar, followed by wheat and corn, are the largest contributors to total portfolio risk, while cocoa, followed by timber and cotton, are the lowest contributors to total portfolio risk. Cocoa and timber are the most desirable investments.

İlarslan K. & Yıldız M. (2022) analyzed the impact of international prices of wheat, rice, sugar and beef on the Turkish and Polish stock markets using quantile regression and cointegration regression methods from December 2008 to November 2020. According to the analysis results, it cannot be said that agricultural commodities do not affect the stock market index. In addition, empirical evidence shows that the impact of agricultural commodities on the Turkish stock market is more significant than that on the Polish stock market. This may be due to the fact that the economic ecosystem of Poland is more industrialized than that of Türkiye. Moreover, these findings indicate that agricultural commodities have both similar and different impacts on the stock market indices of these two countries.

Karjbundit B. (2022) proposed to determine the price of agricultural commodities in the Thai stock market during the period 2000-2020. The correlation between assets under extreme market conditions (tail dependence) is important to classify financial assets as safe haven assets. The agricultural commodities considered in this study are the most active asset classes in the market (grains, oilseeds, other soft commodities, and mixed commodities). The results show that agricultural assets have a clearer correlation with the Thai stock market. Agricultural commodities, including wheat, oats, and canola, can play a strong safe haven role in the Thai stock market, according to the lowest percentile cross-sectional data (bearish market). According to the results of the overall percentile (normal situation), wheat, corn, canola, soybeans, and sugar can all be used as hedges. Therefore, including these specific agricultural commodities (Safe Havens or Hedges) in a Thai equity portfolio will help reduce risk and boost performance in both normal and extreme recessionary scenarios. This section illustrates how to present quotes in text, footnotes, equations, tables, and figures.

In summary, studies by Girardi D. (2015), Baldi L. et al. (2016), Hernandez J. A. et al. (2020), İlarslan K. & Yıldız M. (2022), Karjbundit B. (2022) through modeling the influence of agricultural commodity prices on stock markets have shown the same results. The next steps in this study are to examine the impact of agricultural prices on Southeast Asian stock markets in the short and long run.

2. DATA AND METHODOLOGY

2.1 Research data

This study uses mounthly data from ASEAN6 countries including Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam from 2007 to 2023. The stock market index data have been collected from the Stock Exchange of Thailand (SET) index (Thailand), the Kuala Lumpur Composite Index (KLSE) index (Malaysia), Financial Times Share Index (FTSI) (Singapore), Philippine Stock Exchange (PSE), and the Jakarta Composite Index (JKSE) (Indonesia), and the Ho Chi Minh Stock Exchange (HSX). The data of interest rate, inflation rate, exchange rate, gross domestis product is taken from International Financial Statistics published by International Monetary Fund.

2.2 Research methodology

The paper used the PMG method proposed by Pesaran et al. (1999) to consider a lower degree of heterogeneity, as it imposes homogeneity in the long-run coefficients while still allowing for heterogeneity in the short-run coefficients and error variances. Based on the research of Al-Mamun M. (2013), Mahmood S. et al. (2017), Megaravalli A. and Sampagnaro G. (2018), the mean group (MG) model of Pesaran and Smith (1995), the pooled mean group (PMG) model developed by Pesaran and Shin (1999) the dynamic heterogeneous panel regression can be integrated into the error correction model using the ARDL (p, q) technique of spontaneous distributed lags, where p is the lag of the dependent variable, q is the lag of the independent variables and is stated as follows:

$$\Delta SI_{i,t} = \sum_{j=1}^{p-1} \gamma_j^i \Delta SI_{i,t-j} + \sum_{j=0}^{q-1} \delta_j^i \Delta X_{i,t-j}^{API+\cdots} + \varphi^i \left[SI_{i,t-1} - \left\{ \beta_0^i + \beta_1^i \Delta X_{i,t-j}^{API+\cdots} \right\} \right] + \varepsilon_{i,t-1}$$

Where, SI is the stock market index, X is a set of independent variables including agricultural prices and domestic macro variables (exchange rate, inflation rate, country interest rate), γ and δ denote the short-run coefficients of the dependent and independent variables respectively, β are the long-run coefficients and φ is the coefficient of the speed of adjustment to long-run equilibrium. The subscripts i and t represent the country and time respectively. The terms in square brackets of the above equations contain the long-run growth regression, including the long-run coefficients of the vector X.

3. RESULTS OF RESEARCH

3.1 Descriptive statistics

The descriptive statistics results show that the dependent variable SI has the highest value of 1.2221, while the lowest value is -0.6763, the mean value is 0.0507, with a standard deviation of 0.2371. The data distribution of the independent variables is also presented. API representing agricultural prices has the highest value of 0.3662, the lowest is only -0.2694, the mean value is 0.0131, the standard deviation is 0.3255. For the macro variables used in the model, it is noteworthy that the interest rate (IR) has quite large fluctuations with a standard deviation of 0.1241, which is quite different from the remaining variables.

Table 1. Descriptive statistics of the variables

Variable name	Number of ob-servations	Mean value	Standard deviation	Maximum value	Minimum value
SI	1,152	0.0507	0.2371	-0.6763	1.0221
API	1,152	0.0131	0.1347	-0.2694	0.3662
ER	1,152	0.0144	0.0707	-0.2208	0.3589
CPI	1,152	0.0350	0.0400	-0.0443	0.2832
IR	1,152	-0.0195	0.1241	-0.5081	0.8113

Source: Authors' caculation

3.2 Panel unit root test and panel cointegration test

3.2.1 Panel unit root test

There are four different types of unit root tests performed, namely Breitung (2000); Im, Pesaran and Shin (2003), also known as IPS; ADF-Fisher and Philips Perron-PP (1999). Specifically, Breitung tests the common unit root assumption for all countries, i.e. ρi= ρ; Im, Pesaran and Shin (2003), ADF-Fisher, Philips Perron (PP) presented by Maddala and Wu (1999) allows for different unit root tests for each country. The unit root test results are presented both in the original order and in the first difference order.

The test results show that each variable is non-stationary at the same level of integration (Table 2). When performing unit root tests at the root level, the agricultural price index is only stationary at the root level at the 5% significance level in the IPS test and 10% in the Fisher-ADF test.

Table 2. Results of stationarity test

Level	Breitung	IPS	Fisher-ADF	Fisher-PP
SI	-0.5054	-4.0431	7.3974	-8.4647
	0.2061	0.2578	0.2412	0.5043
API	3.4042	-6.4852**	-8.4701*	6.1847
	0.2291	0.0327	0.0508	0.2961
ER	-1.7543*	-2.8435*	4.8031**	3.6968
	0.0516	0.0713	0.0325	0.3426
CPI	3.1503	-3.9145	6.2581	5.9068***
	0.5102	0.2912	0.9634	0.0019
IR	-4.0096	-1.4271	3.2847***	3.8249***
	0.1478	0.1058	0.0032	0.0051
1st difference	Breitung	IPS	Fisher-ADF	Fisher-PP
SI	-13.6203***	-24.6112***	75.0156***	81.8391***
	0.0000	0.0000	0.0000	0.0000
API	-16.3588***	-21.7349***	68.2603***	81.3351***
	0.0000	0.0000	0.0000	0.0000
ER	-14.1288***	-26.2394***	78.0763***	86.3065***
	0.0000	0.0000	0.0000	0.0000
CPI	-15.8217***	-32.4368***	52.6707***	83.6819***
	0.0000	-0.0000	0.0000	0.0000
IR	-13.5903***	-25.3455***	74.0236***	55.6902***
	0.0000	0.0000	0.0000	0.0000

Note: those in ( ) are standard errors; *, **, and *** denote significance at 10%, 5%, and 1% levels.
Source: Authors' caculation

Applying the unit root test for the first-order differences of the variables, the results show that all variables are stationary at the 1% significance level. Thus, the unit root test results indicate that each variable has a different level of integration in the order of integration 0, i.e. I(0) and in the order of integration 1, i.e. I(1), or there are variables that are stationary at order 0, and there are variables that are stationary at order 1. Based on the mixed stationarity of I(0) and I(1) of the variables, the study continues to conduct the panel data cointegration test in the next section.

3.2.2 Panel cointegration test

The results of Westerlund's (2007) test for cointegration between the Southeast Asian stock market index (SI) with the agricultural price index (API) and other macroeconomic variables including, the exchange rate between domestic currency and the US dollar (ER), the consumer price index (CPI), and the lending

rate (IR). To select the optimal lag length, the study relies on the minimum value of Akaike's Information Criterion (AIC). Westerlund (2007) uses four statistics to test the existence of cointegration. For the group statistics G_t and G_α, the null hypothesis is "there is no cointegration for cross-sectional units" and the alternative hypothesis is "there is no cointegration in some units, but there is cointegration in some other units". Similarly, the statistical H_0 hypothesis for the Pt and Pα groups indicates that the information for all panels is "there is no cointegration for all cross-sectional units" and the alternative hypothesis H_1 is "there is cointegration for all cross-sectional units"

Table 3. Westerlund Panel Cointegration Test, *(Dependent variable: SI)*

Variables		Gt	Gα	Pt	Pα
API	Value	-4.087	-38.033	-11.791	-39.585
	P	0.0000	0.0000	0.0000	0.0000
ER	Value	-3.662	-34.373	-11.920	-45.522
	P	0.0000	0.0000	0.0000	0.0000
CPI	Value	-3.512	-33.442	-8.387	-33.519
	P	0.0000	0.0000	0.0000	0.0000
IR	Value	-3.625	-33.814	-11.745	-44.261
	P	0.0000	0.0000	0.0000	0.0000

Source: Authors' caculation

When the P-value of the statistics obtained are all < α (5%), the null hypothesis H_0 that there is no cointegration of all statistics was rejected. Accordingly, cointegration was achieved in all models for all countries (Table 3). Thus, at the 1% significance level, agricultural commodity prices and all other macroeconomic variables including MSCI global stock index, exchange rate, domestic consumer price index and lending interest rate are all cointegrated with the stock market index of the selected countries. Therefore, the model applied in the study suggests the possibility of long-term and short-term correlation between Southeast Asian stock markets and agricultural prices and other macroeconomic variables.

3.3 Panel ARDL approach

The results of the PMG model show that the agricultural price index has a positive long-term impact on the Southeast Asian stock market at the 1% significance level, but no impact in the short term. The results of the MG model determine that the agricultural price index variable has a negative impact on the stock market index in the long term and is insignificant in the short term.

The Hausman test (Yerdelen, 2013) is used to select the MG or PMG estimator, with the hypothesis H_0 that the PMG estimator is more effective than the MG estimator, then the p-value > α significance level (5%), so this hypothesis cannot be rejected. Thus, it can be concluded that PMG is a more effective estimator than MG to assess the impact of the agricultural price index on the Southeast Asian stock market index, so the following analysis will be based on the results of the PMG model.

Table 4. Results of the Panel ARDL model

Dependent variable: LSI	PMG		MG	
	Coefficients	Std. Error	Coefficients	Std. Error
Long Run				
API	0.137***	0.190	0.128**	0.120
ER	-1.256***	1.320	-1.093*	0.402
CPI	1.586**	1.638	1.396	1.068
IR	-0.352**	0.610	-0.292	0.501
Short Run				

Adjustment	-0.163***	0.026	-0.199***	0.103
ΔAPI	0.086	0.124	0.094	0.121
ΔER	1.017***	0.331	-0.897***	0.341
ΔCPI	-1.218*	0.678	-1.325**	0.664
ΔIR	-0.848*	0.514	-0.860	0.508
ΔSI(-1)	-0.206*	0.157	-0.179*	0.165
C (constant)	0.103**	0.108	0.100*	0.106
Observation	1,140		1,140	
Num. of countries	6		6	
Hausman Test	6.13			
Pvalue	0.4007			

Note: *, **, and *** denote significance at 10%, 5%, and 1% levels
Source: Authors' caculation

Agricultural prices have a slight positive impact on the stock price index in the long term but no impact in the short term. Accordingly, when the agricultural price index increases, it will adjust the Southeast Asian stock market index to increase in the long term. Southeast Asian countries are strong exporters of agricultural products such as rice, coffee, rubber, wood, cotton, etc. Therefore, the increase in prices of these goods in the world has more or less the effect of stimulating export growth, increasing revenue and profits for companies exporting the corresponding products, thereby also affecting the stock prices of these companies and creating positive impacts on the stock price index of Southeast Asian countries. In particular, Thailand and Vietnam are always in the group of three countries exporting the most rice in the world, accounting for 55% of the total world rice demand, so for these two countries, when the world rice price increases, it will have a positive impact on the stock prices of rice exporting companies. However, this impact is not significant for selected Southeast Asian countries because apart from Indonesia, where rice production has exceeded domestic demand since 2017 and is moving towards export, the rice supply of the Philippines and Singapore depends largely on imports, while Malaysia has gradually increased domestic rice cultivation to import only a portion of the world's rice. Some Southeast Asian countries have become major coffee exporters, such as Indonesia and Vietnam, the world's two leading coffee producers, contributing 18% and 6% respectively to global output, while Thailand continues to attract business and investment due to increasing demand for coffee, and the Philippines is also stepping up competition in the coffee export industry. Rubber trees are grown mainly in Southeast Asian countries, Africa and a small part in the Americas. According to the report of the Association of Natural Rubber Producing Countries, Thailand, Indonesia, Malaysia and Vietnam are the largest rubber producing countries with a total production output accounting for about 70% of the global rubber supply. Therefore, the increase in world rubber prices also has a positive impact on the stock prices of exporting companies in this field.

Members of the ASEAN Furniture Industry Council (AFIC) all share the view that ASEAN is a region with many outstanding advantages in terms of raw materials, production, distribution, and market size to develop the wood and furniture industry. As evidence for this view, Mr. Emmanuel Padiernos, Chairman of AFIC, said that the export figures for wooden furniture of the entire ASEAN bloc in 2021 reached 12.1 billion USD out of the total export value of 150 billion USD globally. By 2022, Indonesia, Malaysia, the Philippines, Thailand and Vietnam will be fast-growing Southeast Asian furniture suppliers with two-thirds of their production capacity prioritized for export. The region's wood furniture export ratio is about 66%, more than double the world average (about 30%). It is estimated that Southeast Asia's wood and furniture production capacity will meet 5% of total furniture consumption in the US and 2% in Western Europe. This shows that ASEAN is a major wood furniture production center in the world, so when global agricultural prices increase, it will bring better profitability to wood industry enterprises and improve the stock prices of companies in this industry. In addition, although global agricultural prices fluctuate over a long period of time, it will create difficulties for companies importing milk powder, cereals and oils to produce milk, animal feed, cooking oil, etc. because most of the input materials are imported. This leads to the challenge

of higher input costs for these producers, which may have some negative impacts on their operations. However, perhaps due to the successful hedging strategies of the companies, specifically those with raw material supply contracts, based on their business models. Furthermore, they pass on most of the raw material prices directly to their selling prices, thereby ensuring that their profit margins remain unchanged, this is still not enough to affect the stock market index. Therefore, in the short run, the stock markets of the Southeast Asian group of countries are not affected by agricultural prices, which is also consistent with the studies of Kang J. S. et al. (2013), Baldi L. et al. (2016). Thus, the possibility of price arbitrage is eliminated and the stock markets of the selected Southeast Asian countries can be considered informationally efficient for agricultural prices in the short run.

Other macroeconomic variables also have different implications for the stock markets of each Southeast Asian country.

CONCLUSION

The results show that agricultural prices affect Southeast Asian stock markets in the long run but are not significant in the short run. Therefore, any study that does not include commodity prices will miss an important variable in the regression analysis. Policy makers need to monitor agricultural prices to forecast their potential impact on Southeast Asian stock markets when any changes occur. In particular, agricultural prices do not affect the Southeast Asian stock market index in the short run, the policy implication of this finding is that changes in agricultural prices cannot predict Southeast Asian stock market prices, the possibility of arbitrage is eliminated and the stock markets of the countries can be considered informationally efficient with respect to agricultural prices. This also has important policy implications for domestic and foreign institutional investors and portfolio managers as the above finding can assist in structuring tightly traded portfolios. Thus, the movement of capital markets cannot be separated from the fluctuations in commodity prices. Understanding the importance of the relationship between agricultural prices and stock market developments in Southeast Asian countries is expected to be important information for investors in diversifying financial asset risks and taking intermediate steps to minimize losses due to fluctuations in world commodity prices. At the same time, the results show that the impact of agricultural prices on stock markets can provide useful information for investors and portfolio managers to identify markets that are most vulnerable to external shocks, thereby reallocating capital and adjusting their short- or long-term capital.

Domestic macroeconomic factors including exchange rates, inflation rates, and lending rates also have long-term impacts on the stock markets of Southeast Asian countries. The inflation rate also has a negative impact on the stock market in the short term and a positive impact in the long term. This result implies that although rising inflation represents economic instability, negatively affecting the stock market in the short term, in the long term, the market will allocate resources efficiently by adjusting to the general increase in prices. Stocks are a good hedge against inflation, but only in the long term. In the short term, inflation and stock prices can have an inverse relationship. Rising inflation can cause stock prices to fall, and vice versa. Indeed, there is evidence that stock markets have long protected investors from inflation risks.

In short, to maintain healthy domestic stock markets, the governments of each selected Southeast Asian country need to develop appropriate strategies in monitoring agricultural prices, global stock indexes, and controlling domestic macroeconomic factors. In fact, the authorities are doing their best to stabilize their economies and seek the highest possible growth, but still within the safest options. With accurate estimates of these relationships, ASEAN central banks can develop competitive and credible policies that can influence the health of their economies as well as convince more capital to flow into their countries' stock markets. Furthermore, increasing transparency and consistency of policies while providing prudence to deal with short-term volatility and long-term stability are essential, before the benefits of controlling macroeconomic variables can be realized.

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The Response of Monetary Policy to Adjustments in Macroeconomic Dynamics in the United Arab Emirates

SATO RYOJI[1], AWADH AHMED MOHAMMED GAMAL[2] (Corresponding author),
MOHD ASRI MOHD NOOR[3], GAN PEI THA[4], MOHD YAHYA MOHD HUSSIN[5]
and NORMALA ZULKIFLI [6]

[1] PhD candidate, Department of Economics, Faculty of Management and Economics, Sultan Idris Education University (UPSI), 35900 Tanjong Malim, Perak Darul Ridzuan, Malaysia, email: post@midori-system.com; ORCID: 0009-0008-7761-834X

[2] Senior lecturer, Department of Economics, Faculty of Management and Economics, Sultan Idris Education University (UPSI), 35900 Tanjong Malim, Perak Darul Ridzuan, Malaysia, email: awadh.gamal@fpe.upsi.edu.my; ORCID:0000-0002-8529-951X

[3] Associate Professor, Department of Economics, Faculty of Management and Economics, Sultan Idris Education University (UPSI), 35900 Tanjong Malim, Perak Darul Ridzuan, Malaysia, email: mohd.asri@fpe.upsi.edu.my, ORCiD: 0000-0001-5801-7719

[4] Associate Professor, Department of Economics, Faculty of Management and Economics, Sultan Idris Education University (UPSI),35900 Tanjong Malim, Perak Darul Ridzuan, Malaysia, email: gan.pt@fpe.upsi.edu.my; ORCiD: 0000-0003-0992-9951

[5] Associate Professor, Department Department of Economics, Faculty of Management and Economics, Sultan Idris Education University (UPSI),35900 Tanjong Malim, Perak Darul Ridzuan, Malaysia, email: yahya@fpe.upsi.edu.my, ORCiD: 0000-0002-2065-1199

[6] Senior lecturer, Department Department of Economics, Faculty of Management and Economics, Sultan Idris Education University (UPSI),35900 Tanjong Malim, Perak Darul Ridzuan, Malaysia, email: normala@fpe.upsi.edu.my, ORCiD: 0000-0002-5920-6033

ARTICLE INFO

ABSTRACT

This study explores the response of monetary policy to changes in selected macroeconomic variables in the United Arab Emirates (UAE) over the period from 1990 to 2022. To achieve this objective, the study utilizes the auto-regressive distributed lag (ARDL) approach alongside the Gregory-Hansen cointegration test. The results from the bounds-testing procedure provide evidence of a cointegrating relationship between monetary policy measured by the money market rate and, selected macroeconomic variables including the inflation rate, financial deepening, foreign direct investment, economic activity, and monetary uncertainty. In addition, the estimation results demonstrate that monetary policy responds positively to changes in economic activity, financial deepening, and FDI, and negatively to monetary uncertainty in the long run. Moreover, the short-term results show that the central bank follows an expansionary monetary policy in response to short-term changes in economic activity and financial deepening, and a lax monetary policy following short-term changes in FDI and inflation. Based on these findings, the UAE's monetary authority is encouraged to take advantage of the various monetary policy tools at its disposal to stimulate the economy, especially as the country attempts to diversify its economy away from oil.

INTRODUCTION

Monetary policy is a critical instrument for stabilising economies, influencing inflation, employment, and overall economic growth through the regulation of interest rates, money supply, and financial markets. Central banks across the world utilise monetary policy to manage the business cycle and mitigate external shocks, adjusting policy settings based on a range of macroeconomic indicators such as inflation, output, and investment (Mishkin, 2001). The effectiveness of monetary policy in achieving its objectives hinges largely on how responsive it is to changes in these macroeconomic variables (Cioran, 2014). At the core of this dynamic is the interaction between monetary policy and key economic indicators, which informs the optimal policy response in any given economic situation (Ahmad & Nasrin, 2017).

The relationship between monetary policy and macroeconomic variables has been extensively studied in both advanced and emerging economies. In advanced economies, the transmission of monetary policy typically involves a well-functioning financial system that efficiently channels policy adjustments into the broader economy, affecting consumption, investment, and inflation expectations (Taghizadeh-Hesary & Yoshino, 2016). In contrast, the transmission mechanism in emerging markets often differs due to less-developed financial systems, external vulnerabilities, and structural rigidities, which can lead to asymmetric responses to monetary policy shocks (Mishra et al., 2014). The degree to which monetary policy influences macroeconomic outcomes also depends on factors such as financial deepening, foreign direct investment (FDI), and the level of economic activity, all of which shape how quickly and effectively policy adjustments are felt throughout the economy (Islam & Lee, 2020).

Empirical research has demonstrated that monetary policy responds differently to various macroeconomic variables, depending on the structure and development of the financial system. For instance, monetary policy tends to be more responsive to inflation in economies with higher levels of financial development, where credit markets and banking sectors are more integrated into the real economy (Ma & Lin, 2016). Meanwhile, financial deepening, characterised by an expanding financial sector that provides greater access to credit and investment, enhances the effectiveness of monetary policy by amplifying its transmission channels (Seth & Kalyanaraman, 2017). Foreign direct investment also plays a significant role, as economies with substantial FDI inflows may experience stronger policy responses to global capital market shifts, necessitating adjustments in interest rates or liquidity management to stabilise domestic markets (Karahan & Bayır, 2022). These dynamics suggest that understanding how monetary policy responds to changes in macroeconomic variables is crucial for formulating effective economic policies, particularly in economies that are undergoing rapid structural changes.

While considerable research has focused on the effectiveness of monetary policy in advanced economies, less attention has been given to the interactions between monetary policy and macroeconomic variables in small, open economies, particularly those in the Gulf Cooperation Council (GCC) region (Polyzos, 2022). For GCC countries like the United Arab Emirates (UAE), monetary policy plays a significant role in managing external economic shocks, fluctuations in global oil prices, and evolving economic structures (Vandyck et al., 2018). Over the past few decades, the UAE's economy has undergone rapid transformation, shifting from an oil-dependent structure to a more diversified economy with notable investments in sectors such as tourism, financial services, and real estate (Shariq et al., 2015). This diversification necessitates a re-evaluation of the country's monetary policy framework, as the traditional approach of stabilizing oil revenue fluctuations may no longer be adequate to address the complexities of a diversified economy (Polyzos, 2022). Additionally, as the UAE deepens its financial sector and continues to attract substantial FDI, understanding the interaction between monetary policy and macroeconomic indicators—such as inflation, economic growth, and monetary uncertainty—becomes increasingly crucial for shaping the country's economic trajectory. The devastating impact of the 2008 global financial crisis highlighted the importance of effective monetary policy in managing such shocks (Elsayed et al., 2023). Thus, understanding how monetary policy responds to changes in key macroeconomic variables is essential for maintaining economic stability and ensuring sustainable long-term growth.

Against this backdrop, this study contributes to the literature by examining the response of monetary policy in the UAE to adjustments in key macroeconomic variables over the period from 1990 to 2022. Employing the autoregressive distributed lag (ARDL) method and the Gregory-Hansen cointegration test, this paper investigates the long-run and short-run relationships between monetary policy, as measured by

the money market rate, and selected macroeconomic variables, including inflation, financial deepening, FDI, economic activity, and monetary uncertainty. The findings provide valuable insights into the dynamics of monetary policy adjustments in the UAE, highlighting how the central bank strategically responds to both long-term economic shifts and short-term fluctuations in key economic indicators. Moreover, by exploring how the UAE's monetary policy responds to macroeconomic changes, this study contributes to a broader understanding of policy formulation in resource-rich economies pursuing economic diversification. The results also offer practical recommendations for the UAE's monetary authorities, particularly in utilising the various monetary policy tools available to stimulate non-oil sector growth and support the broader goals of economic diversification. As the UAE continues to transition toward a more complex and diversified economic structure, these insights are essential for ensuring that monetary policy remains an effective instrument for fostering sustainable economic growth and maintaining financial stability.

The remainder of this paper is organised as follows. Section two discusses the research method and data. Section three presents and discusses the empirical results. Section four concludes the paper.

1. DATA AND METHODOLOGY

1.1 Model specification

Following Elsayed et al. (2023), the following econometric model is specified to investigate the response of monetary policy to adjustments in selected macroeconomic variables:

$$mpr_t = a + \pi_1 y_t + \pi_2 p_t + \pi_3 fd_t + \pi_4 fdi_t + \pi_5 mu_t + \mu_t \tag{1}$$

where $t = 1,2, \dots, T$ denotes time. mpr is monetary policy regulation. y denote economic activities. p is inflation rate. fd is financial deepening. fdi represent foreign direct investment. mu is monetary uncertainty. a is the intercept. π_i is the vector of slope coefficients. μ_t is stochastic error term, with zero mean and constant variance.

To reduce skewness, the model in Equation (2) is rewritten by taking the logarithm of economic activities and monetary uncertainty:

$$mpr_t = a + \pi_1 l. y_t + \pi_2 p_t + \pi_3 fd_t + \pi_4 fdi_t + \pi_5 l. mu_t + \mu_t \tag{2}$$

where $l.$ represent log transformation.

1.2 Econometric Procedure

To explore the response of monetary policy to selected macroeconomic variables, both the Gregory-Hansen (GH) cointegration method and the ARDL bounds-testing approach are applied. The Gregory-Hansen cointegration method, developed by Gregory and Hansen (1996), is used to assess cointegration in the presence of a potential single structural break. This approach allows us to identify the exact point of structural change in the cointegrating relationship (Gamal et al., 2020).

To enhance robustness in determining the cointegrating relationship between monetary policy and macroeconomic variables, the ARDL bounds-testing approach (Pesaran et al., 2001) is used. The Gregory-Hansen method's structural time-break (Gamal et al., 2019a) is integrated into the ARDL model, ensuring accurate estimation of Equation (2) and a comprehensive understanding of the long-run dynamics of the relationship.

Typically, a bivariate ARDL model is given by:

$$y_t = \alpha + \sum_{i=1}^{p} \beta_i' y_{t-i} + \sum_{j=0}^{q} \omega_i' x_{t-i} + \chi_j' D_{t,j} + \mu_t \tag{3}$$

where i and j denote the lag indices, with $i = 1,2, \dots, p$, and $j = 0,1,2, \dots, q$. $t = 1,2 \dots, T$ represents time. y_t is the dependent variable, x_t is the independent variable, and $D_{t,j}$ denotes the structural break

dummy (identified by the Gregory-Hansen test). β_i, ω_i and χ_j are the coefficients for the lags of y_t, x_t, and $D_{t,j}$, respectively. α is the constant term. μ_t is the stochastic error term.

Re-parameterising equation (3) into an error correction representation yield:

$$\Delta y_t = \alpha + \rho' y_{t-1} + \gamma' x_{t-1} + \sum_{i=1}^{p-1} \lambda_i' \Delta y_{t-i} + \sum_{j=1}^{q-1} \delta_i' \Delta x_{t-i} + \eta_j' D_{t,j} + \varepsilon_t \tag{4}$$

where Δ represents the difference operator; λ_i, δ_i, η_i are the functions of the original parameters in Equation (2). $\rho = -\left(1 - \sum_{i=0}^{p} \beta_i\right)$, and $\gamma = \sum_{j=0}^{q} \omega_j$.

Pesaran et al. (2001) demonstrated that a cointegrating relationship between y_t and x_t can be established by testing the null hypothesis of no cointegration H_0: $\rho = \gamma = 0$ against the alternative hypothesis of cointegration H_1: $\rho \neq \gamma \neq 0$. To reach a valid conclusion, the null hypothesis must be rejected. This is done by comparing the F-statistic, computed from the Wald test, with the upper and lower critical bounds provided by Pesaran et al. (2001). The null hypothesis H_0 can be rejected if the F-statistic exceeds the upper critical bound. However, if the F-statistic falls between the lower and upper bounds, the inference remains inconclusive.

If cointegration is established, the long-run estimates are obtained by normalizing the coefficients of the lagged explanatory variables (γ) by the coefficient of lagged dependent variables (ρ), i.e., $-(\gamma/\rho)$. Additionally, the dynamic short-run estimates of the ARDL model are obtained by estimating a dynamic restricted error-correction ARDL-ECM model as follows:

$$\Delta y_t = \alpha + \sum_{i=1}^{p-1} \zeta_i' \Delta y_{t-i} + \sum_{j=1}^{q-1} \xi_i' \Delta x_{t-i} + \chi_j' D_{t,j} + \phi \mu_{t-1} + \varepsilon_t \tag{5}$$

where ϕ represents the coefficient of the lagged error term (μ_{t-1}), indicating the rate of adjustment back to the long-run equilibrium following a short-run deviation. The optimal lag length for both the restricted and unrestricted error correction models is determined using the Akaike Information Criterion (AIC).

1.3 The Data

The paper uses annual time-series data from 1990 to 2022. The variables are measured as follows: mpr is represented by the lending interest rate; y is proxied by GDP at current market prices; p is the annual percentage change in the Consumer Price Index (CPI); fd is the ratio of credit to the private sector relative to GDP; fdi is foreign direct investment inflow as a percentage of GDP; and mu is the uncertainty for aggregate money supply proxied by money supply fluctuations in millions of UAE Dirham. Data on the lending interest rate is obtained from the Central Bank of the UAE (CBUAE), while the remaining variables are sourced from the World Bank's World Development Indicators (WDI).

2. EMPIRICAL RESULTS

2.1 Unit Root test

To examine the stationarity properties of the series, the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Zivot-Andrews (ZA) unit root tests were conducted. The results, summarized in Table 1, indicate that both the ADF and Phillips-Perron tests reject the null hypothesis of non-stationarity for all six series at the 1 percent significance level after first differencing, suggesting that the series are integrated of order I(1). Since these tests do not account for structural breaks, the ZA and Perron (1997) tests were applied for robustness. Unlike the traditional tests, the ZA results show that financial deepening and FDI are stationary at level at the 1 percent significance level, while the monetary policy rate, inflation, aggregate economic activities, and monetary uncertainty are stationary after first differencing at the 5 percent significance level. This implies that, apart from financial deepening and FDI, the other variables are I(1). Despite

the differences among the tests regarding the order of integration, the series comprise a mix of I(0) and l(1), justifying the use of the ARDL bounds-testing technique.

Table 1. Results of Unit Root Tests

		mpr	$l.y$	p	fd	fdi	$l.mu$
ADF	Level	-1.968	-1.235	-2.494	-0.763	-2.434	-0.689
	1st Diff.	-4.647***	-4.927***	-5.114***	-4.102***	-3.609**	-2.676*
PP	Level	-1.579	-1.235	-2.494	-0.545	-2.001	-0.744
	1st Diff.	-3.333**	-4.927***	-5.388***	-5.099***	-5.072***	-2.672*
ZA	Level	-4.243	-2.504	-4.082	-5.989***	-6.015***	-3.441
	T_b	1998	2015	2009	2007	2003	2004
	1st Diff.	-5.064*	-6.237***	-6.036***	–	–	-5.248**
	T_b	2000	2009	2009	–	–	2009

Notes: l. represent log transformation. T_b is the structural break-date. ADF represents the Augmented Dickey-Fuller (1979) test, PP denotes Philips-Peron (1988) test, ZA is the Zivot and Andrews (1992) test with one break, and Perron represents Perron (1997) unit root test with one break. The ADF and PP unit root test tests the null hypothesis of unit root against the alternative hypothesis of a stationary process. ZA and Perron tests the null of unit root against the alternative hypothesis of a trend-stationary process with one-time structural break occurring at an unknown point in time. Both the ZA and Perron unit root tests are conducted based on Model A which represent structural change in the level shift or intercept. The optimal lag length selection in ADF, ZA, and Perron tests are based on the Schwarz Information Criteria (SIC) of Schwarz (1978), while the maximum lag-length is set to 8. For PP test, the bandwidth is automatically determined based on the Newey-West method using the Bartlett kernel spectra estimation method. MacKinnon's (1996) critical values (CV) for ADF and PP tests (intercept only) are given as: -3.679, -2.968, and -2.623, at 1%, 5% and 10% levels, respectively. ZA's CV for structural change in the level shift are: -5.34 (1%), -4.93 (5%) and -4.58 (10%). Perron (1997)'s CV for structural change in level are -5.92 (1%), -5.23 (5%), and -4.92 (10%). Asterisks (***), (**) and (*) indicate significance at 1%, 5% and 10% level, respectively.
Source: Estimation's output

2.2 Cointegration test

To assess the cointegrating relationship between the regressand and its variables in Equation (1), the Gregory-Hansen (GH) cointegration test and the ARDL bounds-testing approach by Pesaran et al. (2001) are applied. The results, presented in Tables 2 and 3, show that the GH test's ADF^* statistic (-6.653) exceeds the critical value of -4.72 (in absolute terms) at the 5 percent significance level in GH-2 (cointegration with level shift and trend), indicating evidence to reject the null hypothesis of no cointegration for model GH-2. However, there is insufficient evidence to reject the null hypothesis for models GH-1 and GH-3. The identified 2001 break point aligns with heightened monetary regulation in the UAE following the September 11, 2001 terrorist attacks, which led to increased scrutiny of the country's financial sector by international bodies (Alkrisheh & Jaffal, 2018). This came after investigations revealed that the attackers used UAE financial institutions to facilitate the plot (Malnick & Heighton, 2017).

Table 2. Results of Gregory-Hansen Cointegration Test

Model	ADF^*	T_b	t-critical	Decision
GH-1 (Level shift)	-4.584	1994	-4.61	Accept null hypothesis
GH-2 (Level shift with trend)	-6.653**	2001	-4.72	Reject null hypothesis
GH-3 (Region shift of full break)	-4.5832	2000	-4.68	Accept null hypothesis

Notes: T_b is time break. Asterisk (**) denote statistical significance at 5 percent level. Critical values are obtained from Gregory and Hansen (1996, Table 1 pp.109) for m=1.
Source: Estimation's output

The ARDL bounds-testing results (including a 2001 break dummy) indicate that the F-statistic (9.66) exceeds the upper critical bound value (4.15) at the 1 percent significance level. This provides strong evidence to reject the null hypothesis of no cointegration among the series. Therefore, it can be concluded that a significant long-run cointegrating relationship exists between the monetary policy rate and the selected macroeconomic variables.

Table 3. Results of ARDL Bounds Testing

Lag Length	F-statistic	k	n	Bounds	10%	5%	1%
				I(0)	2.08	2.39	3.06
2,2,1,2,3,1	9.660***	5	27	I(1)	3.00	3.38	4.15

Notes: k is the number of regressors. and n represent the sample size Asterisk (***) denotes significance at 1% level based on critical values provided by Pesaran et al. (2001). The optimal lag-length is suggested by AIC.
Source: Authors' estimation output

2.3 Estimation Results of the ARDL Model

Following the determination of the presence of cointegrating (long-run) relationship between the monetary policy and the selected macroeconomic variables, a long-run and short-run error correction model with an optimal lag-length of (2,2,1,2,3,1), as suggested by AIC, are estimated. The long-run and short-run estimates of the ARDL model, alongside the post-estimation diagnostics (for autocorrelation, heteroscedasticity, normality, and stability), are summarised in panel A, panel B, and panel C of Table 4, respectively.

The long-run (panel A) and short-run (panel B) estimation results reveal that the immediate and long-term response of monetary policy to changes in aggregate economic activities is positive, and the relationship is significant at 5 percent level of significance. The result indicates that a percent increase in the size of aggregate economic activities leads to about 0.04637 percent increase in monetary policy rate in the long-term and 0.05581 percent in the short-run. This demonstrate that monetary policy in the UAE responds positively to changes in aggregate economic activities which is in line with the Taylor rule as well as previous empirical studies (Elsayed et al., 2023). Moreover, the coefficient of inflation, it is reported to be negative both in the short-run and long-run estimation, but only significant in the short-term. The results reveal that the UAE's monetary authority response to inflationary pressure in the short-term by adjusting money market rates downward by 19.2 percent. The outcome simply explains that inflation is negative and significantly associated with the market rate in the short run. The evidence supports the findings of Elsayed et al. (2023), which demonstrate that monetary policy in the UAE responds negatively to changes in inflationary pressure in the short-term.

Table 4. Estimation Results of ARDL Model

Panel A: ARDL(2,2,1,2,3,1) Long-run coefficient estimates – Dependent variable: mpr

$Cons$	$l.y$	p	fd	fdi	$l.mu$
47.462	4.637 (1.853)*	-0.034 (-0.322)	0.093 (1.997)*	0.408 (2.419)**	-6.214 (-2.792)**

Panel B: ARDL(2,2,1,2,3,1) Short-run coefficient estimates – Dependent variable: Δmpr

Regressors	Lag order		
	0	1	2
Δmpr_{t-1}		0.578 (5.387)***	
$\Delta l.y$	5.581 (2.629)**	-10.902 (-4.309)***	
Δp	-0.192 (-3.669)***		
Δfd	0.096 (2.656)**	-0.185 (-5.081)***	
Δfdi	-0.268 (-4.311)***	-0.576 (-6.149)***	-0.280 (-3.982)***
$\Delta l.mu$	-2.213 (-1.253)		
d_2001	2.415 (3.681)***		

Panel C: Diagnostic test statistics

ECT_{t-1}	$\chi^2_{SC}(3)$	χ^2_{HET}	$\chi^2_{FF}(1)$	χ^2_{J-B}	$Adj.R^2$
-1.293 (-10.62)***	0.080 [0.777]	12.704 [0.756]	0.812 [0.394]	2.125 [0.346]	0.843

Notes: The model is estimated with a maximum lag of 4, while the optimal lag-length is suggested by AIC. Δ represents the first difference operator. Asterisk (***), (**) and (*) denote significance at 1%, 5%, and 10% level, respectively. In panels A and B, in parenthesis (.) are the t-ratio, and values in square parenthesis [.] in panel C are the probability values of the LM test statistics. χ^2_{SC}, χ^2_{HET}, χ^2_{J-B}, and χ^2_{FF} denote the Breusch-Godfrey serial correlation, Breusch-Pagan-Godfrey heteroscedasticity, Jarque-Bera normality, and Ramsey 's functional form test statistics, respectively.
Source: Authors' estimation output

Furthermore, the estimation results illustrate a significant positive long-term and short-term relationship between financial deepening and monetary policy at 5 percent level of significance. An increase in the level of depth and development of the financial sector by a percent lead to an upward adjustment in the UAE's monetary policy rate by 9.3 percent and 9.6 percent in the long- and short-run, respectively. As the conduit for transmitting monetary policy actions to the real economy, development in the financial system play a significant role in shaping the effectiveness or otherwise of monetary policy (Sena et al., 2021). Indeed, this finding supports the findings of several empirical studies (Takyi et al., 2023), and further reinforce the important role of the financial sector in the conduct of monetary policy. In addition, the estimation results reveal the significant positive response of money market rate to the adjustment in FDI in the short-term in the UAE, while the short-term evidence demonstrate that the UAE central bank follows contractionary monetary policy in the short-run in response to changes in FDI inflow into the country. An increase in FDI by a percent is associated with an increase in long-term money market interest rate by 40.8 percent, but it leads to a decrease in short-term money market interest rate by 26.8 percent. The results imply that the central bank will reduce the money market rate or contract money supply in response to short-term inflows in FDI to control inflationary pressures (especially when the inflow becomes rapid to deviates from its target), but increase the rate over the long-term to stimulate the economy.

Moreover, the shot-term estimation results show that the monetary uncertainty coefficient is negative but statistically insignificant. However, the long-term estimation results in panel A of Table 4 demonstrate that the central bank follows contractionary monetary policy in response to monetary uncertainty in the UAE. The negative and significant negative long-term monetary policy response to monetary uncertainty suggest that the central bank adjust the money market rate downward by 0.0621 percent following a unit change in monetary uncertainty. During periods of monetary uncertainty, central bank central banks are often more cautious about raising interest rates because they don't want to make unpredictable changes that could destabilise the economy. In such cases, they may lower or hold rates steady to avoid causing disruptions in borrowing, lending, and spending, while also reducing both risk aversion and uncertainty (Bekaert et al., 2013).

Finally, Table 4 shows that the coefficient of the error correction term lagged by one period (ECT_{t-1}), which represents the speed of adjustment to long-run equilibrium, is negative, statistically significant at 1 percent level of significance, and lies between -1 and -2. The size of the coefficient being between -1 and -2 suggests that the speed of adjustment of monetary policy to long-run equilibrium is very rapid, with a possibility of leading to overshooting (Narayan & Smyth, 2005). This implies that if the system is a unit away from equilibrium, it will move 1.293 units towards the equilibrium in the next period, potentially causing oscillations or instability as the system over-adjusts and then corrects again. In other words, "rather than converging monotonically directly to the equilibrium path, the process of error correction fluctuates around the long-run value in a dampened manner. However, the convergence to equilibrium path becomes rapid upon completion of the error correction process" (Abu et al., 2024).

2.4 Results of diagnostic and model stability tests

To assess the adequacy and stability of the estimated model, a series of diagnostic tests for serial correlation, heteroscedasticity, normality, and model specification bias were conducted. The results of the Breusch-Godfrey (BG) serial correlation test, Breusch-Pagan-Godfrey (BPG) heteroscedasticity tests, and Ramsey's test, summarised in panel C of Table 4, indicate that the estimated ARDL model is free from issues of serial correlation, heteroscedasticity, and specification bias. Additionally, the Jarque-Bera test statistic shows that the errors in the estimated model are normally distributed. Furthermore, the plots of the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ), shown in Figure 1(a) and Figure 1(b), respectively, demonstrate that the parameters of the estimated monetary policy model remain stable over time.
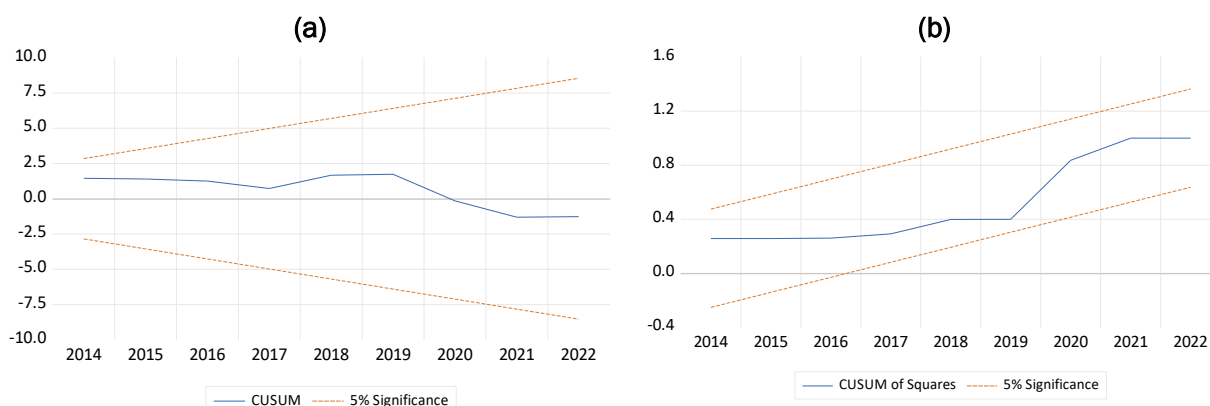
Figure 1. Plots of CUSUM (a) and CUSUMQ (b)
Source: Authors' estimation

CONCLUSION

This research examines the response of monetary policy to changes in selected macroeconomic variables in the UAE over the period from 1990 to 2022. Adopting the Gregory-Hansen cointegration test and the ARDL bounds-testing procedure provide evidence of a cointegrating (long-run) relationship between monetary policy (money market rate) and selected macroeconomic variables (inflation rate, financial deepening, foreign direct investment, economic activity, and monetary uncertainty). In addition, the estimation results based on the ARDL model reveal that monetary policy responds positively to changes in economic activity, financial deepening, and FDI, and negatively to monetary uncertainty in the long run. Moreover, the short-term results show that the central bank follows an expansionary monetary policy in response to short-term changes in economic activity and financial deepening, and a lax monetary policy following short-term changes in FDI and inflation. Given this outcome, the UAE's monetary authority is encouraged to take advantage of the various monetary policy tools at its disposal to stimulate the economy, especially as the country attempts to diversify its economy away from oil. This finding indicates that the monetary authority must adopt a judicious approach, particularly given the fixed exchange rate regime associated with the US Dirham policy. This situation requires a coherent strategy for monetary policy to effectively address external pressures and uphold currency stability.

Although this study offers novel insights into the response of monetary policy to changes in selected macroeconomic variables in the UAE, it is not without limitations. One key limitation is the use of only the money market interest rate, rather than a range of monetary policy tools, to gauge the response of monetary policy to macroeconomic adjustments. Additionally, the focus on just the UAE restricts the generalisability of the findings. Nevertheless, these limitations do not diminish the study's uniqueness or its relevance to policy. Future research could build on this work by using a more comprehensive dataset with alternative indicators of monetary policy, and by extending the analysis to other countries, regions, or economic blocs, such as the GCC, the Organization of the Petroleum Exporting Countries (OPEC), or BRICS, of which the UAE is a member, using alternative estimation strategies.

ACKNOWLEDGEMENT

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The Impact of Military Expenditures and Corruption on Economic Efficiency in G20 Countries

USAMA R. AL-QALAWI[1], AHMAD ALWAKED[2] and ANAS AL QUDAH[3]

[1]Associate Professor, Department of Economics, Business School, The Hashemite University, Zarqa 13133, Jordan. email: urmal-qalawi@hu.edu.jo; Department of finance, College of Business Administration, Prince Sultan University (PSU), Riyadh 11586, Saudi Arabia, e-mail: uqalawi@psu.edu.sa, ORCID #: 0000-0002-7612-9260
[2]Associate Professor, Department of Economics, Yarmouk University, Irbid, Jordan, email: ahmad.waked@yu.edu.jo, ORCID #: 0000-0002-2182-037X
[3]Associate Professor, Department of Banking and Finance, Yarmouk University, Irbid, Jordan, email: anas.qudah@yu.edu.jo, ORCID #: 0000-0002-3713-6740

ARTICLE INFO

ABSTRACT

The study examines the effects of military spending and corruption on G20 countries' production efficiency from 2006 to 2021. It seeks to understand the forces shaping these economies. It will recommend policies to improve efficiency. This research uses Stochastic Frontier Analysis (SFA) and analyzes data from the World Bank, SIPRI, and the Worldwide Governance Indicators. The study models production efficiency using military spending and corruption. It controls for GDP, labor, and capital inputs and thoroughly analyzes efficiency dynamics. The research shows that higher military spending can cut inefficiencies. For every extra billion spent, inefficiency decreases by 0.28%. A 1% improvement in corruption control leads to a 0.34% drop in inefficiency. These interactions suggest that military spending can boost the economy. However, it harms economic performance in the long run. Moreover, corruption exacerbates inefficiency by diverting resources from productive uses to military spending. This paper shows that military spending has two roles. It can boost the economy, but it can also distort it. The study's findings stress the need for good governance. They offer a complex view to help policymakers. It can guide them in using resources better and promoting sustainable growth.

INTRODUCTION

Military mechanisms act as a safeguard. They ensure a nation's market economy against external agitators (Aharoni, 2024). Military spending is a vital and impactful issue for all countries. Recent events have unfolded, leading to conflict in various forms and manifestations. The current favored guerrilla warfare tactics have made no country immune to risks. Even high-income, affluent nations know this. Some suggest they are more likely to start wars than other nations. It is wrong to assume that starting such conflicts affects success. No matter the odds, we face every conflict with a will to win. We know it may result in a significant loss for us. Military action has many far-reaching effects and a wide range of consequences. It is indisputable that large-scale warfare requires reallocating resources. We must use them to produce more military equipment. This diversion, in turn, disrupts the prevailing situation within the realms

of production. Neoclassical economic models have often ignored the effects of war. They are redirecting resources to the military limits nations' economic growth. So, military activities shield against external threats. They also guard against "belligerent outsiders." They cause market failures and inefficiencies.

In 2023, SIPRI reported world military spending at $2.443 trillion. That is about 2.3 percent of the global GDP (Fleurant & Quéau, 2020). That year, Correlates of War data showed that the USA, China, Russia, India, and Saudi Arabia accounted for over 61% of global military spending. The international trade in conventional weapons is about $30 billion a year. The US and Russia are the leading suppliers (Foxley, 2007). This is an extensive resource commitment. These figures suggest we must analyze how military spending affects the economy at the national level. Need to. Some claim that high military spending for long periods helps and harms the economy. Some say military Keynesianism can help escape a recession by boosting demand. This hypothesis suggests that military spending acts like public works spending. It is an expansionary fiscal policy. A recent example is the army buildup before World War II. Researchers believe it helped end the Great Depression (Demirtaş et al., 2023).

Also, corruption can lead decision-makers to misallocate resources to the military. The rewards from rent-seeking are higher than those from producing public goods. Engaging in rent-seeking has costs. These include promotion to higher military ranks and increased profits from government contracts. Both lead to more consumption of private goods (Leite & Weidmann, 1999). These activities shift the public sector's focus. They emphasize military production over other public goods (Dreher & Siemers, 2009). More military, compared to other public goods, means higher military spending as a share of GDP. This affects the trade-offs between military and other goods. The opportunity cost of resource allocation is the loss of an alternative good. Analyzing the impact of corruption on overall efficiency levels is often challenging. Corruption can misallocate resources to military spending through bribery (Al Qudah, 2024).

We recognize the importance of the tasks at hand. You can only understand a house by examining the foundations in their entirety. The same is true of production. One can only understand a country's economy and efficiency by examining the factors influencing it. Studies show that military spending and corruption lower a country's efficiency (Alqalawi et al., 2023). We concentrate on world leaders, particularly G20 countries. These 20 nations account for a large share of world trade. Their decisions will affect others due to global economic ties.

1. RESEARCH OBJECTIVES

The study's novel aim is to estimate the productive efficiency of the G20 countries. It will consider military spending and corruption as factors affecting it. This will be the first attempt to measure the impact of military spending and corruption on efficiency across countries. In particular, detailed estimates have yet to be provided for higher-income or most developed countries.

The study of military spending and corruption will link to a broader efficiency measure. This is the unexamined case in much of the dual economy literature. It treats military spending as a primitive accumulation activity. There is a belief that military spending and corruption cause inefficiency. This is true in a theoretical context and a social welfare framework. They are worse than other public and private spending.

The analysis uses data from the World Bank's GDP, labor, and capital databases. Data on military spending came from SIPRI Military Expenditure, an independent agency in Stockholm. The collected data cover information about G20 countries from 2006 until 2021. Researchers defined the corruption variable using "The Worldwide Governance Indicators (WGI)" by Kaufmann et al. (2010).

2. LITERATURE REVIEW

This section reviews the literature on corruption and military spending. It examines their effects on a country's productivity and efficiency. It explains how these two factors hurt a country's efficiency. This is instead of the perceived benefits they bring. It also analyzes the G-20 nations' past and present productivity and efficiency.

2.1 Military Expenditure and Efficiency

Many studies say military spending harms economic growth. It has even caused negative growth (Devarajan et al., 1996; Ram, 1988). Ram (1988) tested the impact of military spending on growth. He used multivariate cointegration and causality analysis. The study used a sample of 103 countries from 1965 to 1985. His findings support the "opportunity cost" hypothesis. It says military spending hurts economic growth in both developed and developing countries. Seiglie (1996) conducted tests on the "crowding out" hypothesis. It says that military spending crowds out productive investment at home and abroad. The author used data from 41 developing countries in 1975. It shows that military spending crowds out public investment and hurts capital efficiency. The "varieties of capitalism" theory bases itself on rational choice theory. It says that different capitalist systems use different institutions to meet similar goals (Hall & Soskice, 2001).

It has recently studied how capitalist economies secure their military and economic interests. Elsy (2009) builds on this. It analyzes the Swiss military and social security from the mid-19th century to the end of the Cold War. He concludes that security may be better for small neutral states than a free market. This finding is significant. European countries that are not in NATO want to build a military force. It would support European security and defense goals (Biscop & Drieskens, 2006). This new policy aims to create a standard foreign and security policy. It will boost the EU member states' security and economic ties. Studying the trade-offs in detail will be vital for future policy. This includes the balance between security and economic efficiency. It should also assess the military's economic effectiveness within and outside the EU.

2.2 Other Factors Influencing Production Efficiency

Political instability lowers efficiency and wastes time and resources. Bird et al. (2012) argue that political instability undermines policy and property rights. Cohen and DeLong (2016) argue that producing arms usually reduces a country's prior consumption of products. This reallocates resources from the private sector to the military. It lowers the current and future standard of living. Also, high military spending usually requires a large army and military bureaucracy. Mandel (2020) referred to this as the permanent war economy. An expansive military apparatus is a substitute resource for producing civilian goods. All this will reduce production efficiency.

Moving on to formal institutions, the regulatory burden hurts production efficiency. It uses an index of regulations on price and quantity controls and firm entry. Firms in regulated markets find them less profitable. They may need to adopt more efficient production methods. The firms may leave these markets. Alternatively, they may use corruption to bypass the regulations. They will drop social welfare in the future. Reinhardt (1999) argues that regulation raises compliance costs for firms. It is often higher for smaller firms than for new entrants to the regulated sectors. It is rational for small firms to steer clear of sectors with heavy regulation.

Corruption, a significant part of informal institutions, also hurts production efficiency. Estimate: (bribe price/catch probability) * (total money in corrupt activities) = annual bribe tax. This is a waste to society. Paying bribes shifts resources away from making products. The tax reduces the government's potential revenue from other sources. This cuts public services and infrastructure. Firms will seek to avoid regulation or get government contracts. This will lead to inefficient, corrupt rent-seeking. This will happen if the firm's gain exceeds the bribe cost and the chance of getting the contract. Rent-seeking causes a deadweight loss of social benefits. It wastes resources on non-productive activities, hurting more productive ones. This reduces national productivity and causes carbon leakage. Resources shift to rent-seeking and corrupt activities in some countries (Al Qudah, 2009).

Political instability, regulatory burden, and corruption harm production efficiency. These factors hinder economic growth, resource allocation, and the country's development. Governments must fix these issues and create a better environment for efficient economies (Al Qudah, 2024).

3. DATA AND METHODOLOGY

This research used data from the G20 countries: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, South Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the UK, the US, and the EU. However, it excluded the European Union to avoid having duplicate data. The analysis uses the World Bank's GDP, labor, and capital databases. SIPRI Military Expenditure provided data on military spending. The collected data covers information about G20 countries from 2006 to 2021. The corruption variable uses "The Worldwide Governance Indicators (WGI)" by Kaufmann et al. (2010).

The study aims to assess the efficiency of G20 countries using SFA. It will then predict their production efficiency and analyze how military spending and corruption affect it. Researchers estimate this method's parameters using the maximum likelihood method (Kumbhakar & Lovell, 2003). Knowing that Meeusen and van Den Broeck (1977) and Aigner et al. (1977) are the first to create and apply the SFA econometric technique. The difference between actual and ideal production measures a country's technical inefficiency. Yit denotes the actual production of the ith country at period t. Then Battese and Coelli (1995) can express production as

$$Y_{it} = x_{it}\beta + \epsilon_{it} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

where X is the vector of inputs, "i" stands for the countries, "t" for the period, and B is the parameter vector. The letters v and u compose the error, where vit stands for random error and uit for inefficiency. The system describes the error.

$$\varepsilon_{it} = v_{it} - u_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (2)$$

The random error, vit, is a normally distributed variable with a mean of zero and a variance. It is independently and identically distributed. Where ui is a normally distributed, non-negative, zero-truncated variable. It has mean δzit and variance. Zi stands for factors that affect efficiency. δ is an unknown coefficient to be estimated. The technical inefficiency can be illustrated.

$$u_{it} = \delta z_{it} + w_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

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$$TE_{it} = E[exp(u_{it})\backslash\varepsilon_{it}] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$
$$TE_{it} = \left\{\frac{\theta(r_i - \sigma_*)}{\theta(r_i)}\right\} exp\left\{-\mu_{*it} + \frac{1}{2}\sigma_*^2\right\} \dots\dots\dots\dots\dots\dots (5)$$

Where $\theta(\cdot)$ represent the standard normal cumulative distribution, and

$$r_i = \frac{\mu_{*it}}{\sigma_*}, \ \mu_{*it} = \frac{-\sigma_u^2\varepsilon_{it} + \delta z_{it}\sigma_v^2}{\sigma_u^2 + \sigma_v^2}, \ \sigma_*^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma_u^2 + \sigma_v^2} \dots\dots\dots\dots\dots(6)$$

The trans-log production function is most often used in this literature type. So, researchers can compare the estimates from this study to those from earlier investigations. Also, this study assumes that GDP is a function of capital, labor, government military spending, and time.

$$GDP_{it} = f(K_{it}, L_{it}, DS_{it}, T) \dots\dots\dots\dots\dots\dots.. (7)$$

Where; GDP_{it} is the Actual nominal Gross Domestic Product for the country i at time t. and is intended to measure the total output produced by a country measured in millions of dollars. Kit is the capital for country i at time t, in millions of dollars. is the number of workers in country i at time t, in millions. DSit is the money allocated in millions of dollars for military purposes in country i at time t. It includes military expenditures and equipment. Tit represents time and captures technical progress. Stochastic frontier analysis is used to estimate the previously described production function. The efficiency is then determined annually for each country. This efficiency calculates the best practice production and, thus, the production efficiency gap.

The Fund for Peace (FFP) designed the Fragile States Index (FSI). It is a set of tools and methods. They measure vulnerability and its impact on field efforts. The methodology uses open-source data. It employs qualitative and quantitative indicators and generates measurable results. Researchers use twelve conflict risk indicators to assess the state of a country at any one time. The indicators provide a moment to compare to others in a time series. This shows if things are getting better or worse. It shows their vulnerability to political, economic, and social instability. The FSI is an independent variable. It explains why efficiency differs across countries in the study period. To estimate production efficiency, first, we specify the production function. The most common functional form used in the literature is the translog function. The translog production frontier specification for this study is as follows:

$$\ln GDP_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 (T_{it}) + 0.5 \left[\beta_4 (\ln K_{it})^2 + \beta_5 (\ln L_{it})^2 + \beta_6 T_{it}^2 \right]$$
$$+ \beta_7 (\ln K_{it})(\ln L_{it}) + \beta_8 (T_{it})(\ln K_{it}) + \beta_9 (T_{it})(\ln L_{it}) + v_{it} - u_{it} \dots\dots\dots\dots\dots\dots. (8)$$
$$u_{it} = \delta_0 + \delta_1 Cor_{it} + \delta_2 Def_{it} + \omega_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$$

Where Cor_{it} is the corruption index for country i in time t and Def_{it} is military spending for country i in time t. Table 1 shows descriptive data for all study variables per country. It presents the statistics of GDP, capital, labor, corruption, and military spending. Each column also has stats for each country: the mean, max, min, and standard deviation.

4. RESULTS

We started by describing the data used, as shown in Table 1. The table shows that the U.S. has the highest GDP, capital, and military spending. It has the world's largest, most diverse economy. It is highly innovative and driven by technology. It has a robust environment for entrepreneurship, many resources, and a stable political system. It also has high levels of international trade. China has the most significant employed labor force, with over 1.4 billion people. It has the world's largest population. Canada has the highest corruption control. It has a strong legal system, stable politics, and strict anti-corruption laws. These prevent and punish corruption at home and abroad.

Table1. Descriptive statistics for G20 countries between 2006 and 2021

Country		GDP (M$)	Capital (M$)	Labor(M)	Military (M$)	Corruption
Argentina	Mean	245,184.11	45,774.57	14.30	2,721.44	43.05
	Maximum	361,558.04	70,766.94	16.56	3,801.95	53.81
	Minimum	97,724.00	10,606.87	12.34	1,114.17	33.81
	Std. Dev.	68,084.91	15,914.75	1.28	929.29	5.44
Australia	Mean	515,936.50	136,015.50	3.68	10,022.47	94.75
	Maximum	1,055,642.79	302,065.35	4.06	18,633.09	96.21
	Minimum	312,138.14	73,669.90	3.28	6,733.83	92.38
	Std. Dev.	215,535.57	65,404.34	0.21	3,850.52	1.19
Brazil	Mean	806,557.22	151,069.91	72.48	13,080.38	47.97
	Maximum	1,695,824.57	366,626.81	86.06	24,452.90	63.03
	Minimum	368,295.78	76,776.25	61.14	7,099.90	34.29
	Std. Dev.	347,948.32	75,148.80	8.23	4,507.92	9.95
Canada	Mean	877,256.64	188,959.61	15.29	10,785.36	94.86
	Maximum	1,552,989.69	373,843.49	17.52	19,342.06	96.65
	Minimum	577,170.76	106,980.08	13.18	7,748.61	91.90
	Std. Dev.	329,296.65	88,436.30	1.42	3,553.43	1.40
China	Mean	1,656,979.37	649,463.14	702.36	30,465.32	42.79
	Maximum	4,594,307.03	1,941,968.87	742.29	78,840.80	56.19
	Minimum	444,731.28	192,493.71	645.43	9,867.12	32.52
	Std. Dev.	1,142,198.95	488,607.81	32.72	19,867.14	6.76
France	Mean	1,793,123.40	391,718.11	25.08	38,717.58	89.13
	Maximum	2,930,303.78	707,078.93	27.58	55,365.97	91.75
	Minimum	1,322,815.61	258,523.28	23.14	27,951.57	83.81
	Std. Dev.	501,928.85	137,292.07	1.53	7,817.80	2.17
Germany	Mean	2,519,126.41	559,724.32	36.67	33,621.72	94.05
	Maximum	3,745,264.09	803,216.33	38.77	45,098.96	95.71

	Minimum	1,945,790.97	431,834.06	35.74	25,815.40	92.23
	Std. Dev.	527,711.15	97,932.03	0.84	5,168.44	1.03
India	Mean	601,105.28	200,029.71	377.75	16,410.38	42.17
	Maximum	1,216,735.44	510,430.23	429.82	33,002.38	47.62
	Minimum	279,296.02	63,446.03	318.31	8,253.54	35.55
	Std. Dev.	296,237.90	139,354.73	38.54	7,315.91	3.89
Indonesia	Mean	238,826.18	62,718.37	92.79	2,136.69	32.07
	Maximum	510,228.63	141,926.45	105.11	3,348.76	45.24
	Minimum	95,445.55	26,180.24	80.59	919.02	20.49
	Std. Dev.	111,229.69	30,509.51	6.94	830.09	7.72
Italy	Mean	1,488,800.20	310,152.83	21.48	23,910.48	63.12
	Maximum	2,408,655.35	524,569.35	23.15	36,839.99	71.22
	Minimum	1,064,958.08	203,113.92	20.26	17,185.85	56.73
	Std. Dev.	425,766.15	102,806.96	1.07	6,010.77	4.08
Japan	Mean	4,700,427.80	1,329,196.17	64.47	43,026.69	90.28
	Maximum	5,545,563.66	1,715,444.25	65.89	49,961.67	92.89
	Minimum	4,098,362.71	1,083,309.41	63.33	37,849.01	85.44
	Std. Dev.	369,294.62	171,614.72	0.78	3,069.39	1.80
Korea, Rep.	Mean	683,667.53	230,941.42	22.19	16,965.56	70.18
	Maximum	1,172,614.09	388,105.75	24.33	27,726.13	76.67
	Minimum	383,330.93	106,485.69	19.79	10,457.96	64.29
	Std. Dev.	245,851.96	80,455.95	1.43	5,379.60	3.82
Mexico	Mean	699,412.02	157,170.67	37.18	2,829.27	30.14
	Maximum	1,109,989.06	267,583.33	43.77	4,334.65	45.63
	Minimum	360,073.91	75,492.63	31.17	1,562.62	16.19
	Std. Dev.	225,720.57	53,239.25	4.13	751.82	12.13
Russian Federation	Mean	571,053.85	129,327.50	66.36	19,765.16	16.97
	Maximum	1,660,846.39	423,536.09	71.16	56,183.79	23.81
	Minimum	195,907.13	29,053.61	59.54	6,469.04	11.00
	Std. Dev.	411,504.58	105,189.52	3.33	14,033.85	3.36
Saudi Arabia	Mean	232,720.85	51,534.89	6.72	21,399.70	58.16
	Maximum	519,796.74	141,882.60	9.03	38,222.93	63.81
	Minimum	132,967.90	27,517.54	5.27	13,200.27	47.87
	Std. Dev.	116,280.46	33,179.76	1.11	7,346.54	4.62
South Africa	Mean	201,262.00	34,541.51	12.34	2,730.81	57.10
	Maximum	333,075.46	67,295.84	15.47	3,566.96	69.76
	Minimum	129,088.13	19,409.85	10.57	1,738.04	52.38
	Std. Dev.	71,706.45	16,139.53	1.41	722.59	4.87
Turkiye	Mean	333,684.40	85,712.50	20.31	9,836.58	53.14
	Maximum	770,462.16	221,000.00	21.54	16,809.58	61.61
	Minimum	130,690.17	27,900.00	17.90	5,293.17	39.52
	Std. Dev.	195,262.81	60,220.91	0.84	3,148.86	7.82
United Kingdom	Mean	1,920,942.52	348,969.69	27.96	48,959.08	87.70
	Maximum	3,092,821.13	573,137.25	30.13	73,448.03	91.75
	Minimum	1,061,388.72	196,861.53	25.80	38,113.21	81.90
	Std. Dev.	633,240.27	111,430.85	1.40	13,082.10	2.94
United States	Mean	10,541,544.38	2,353,992.38	138.39	399,540.16	93.30
	Maximum	14,769,857.91	3,265,035.00	148.85	656,756.00	95.24
	Minimum	6,858,559.00	1,398,709.00	123.51	287,960.67	91.87
	Std. Dev.	2,578,429.44	611,176.74	7.67	126,209.24	0.96
All	Mean	1,611,979.51	390,369.09	92.52	39,311.83	63.21
	Maximum	14,769,857.91	3,265,035.00	742.29	656,756.00	96.65
	Minimum	95,445.55	10,606.87	3.28	919.02	11.00
	Std. Dev.	2,464,418.19	583,955.62	166.30	90,913.26	25.49

Source: Author calculations

In contrast, South Africa had a lower GDP than other G20 countries. Its political history, high inequality, and unemployment caused this. Australia is a developed country. But it has a smaller population than many other G20 nations. This leads to a labor force with fewer employed people. Indonesia has the lowest military spending. It has few funds and no direct threats. So it follows a non-aligned policy. Russia has the lowest control of corruption. A weak political legacy caused this. It led to weak legal and judicial systems. The analysis gives some insights into the G20 economies. But, it does not imply a link between GDP, efficiency, corruption, and military spending. We need to test those relationships. So, we must analyze some indicators and contexts in more depth.

Table 2 shows the estimates of models 8 and 9. It also shows the coefficients of the level term, the square, and the product terms. The estimated parameter, γ, is the inefficiency component of the error term's variance. It is divided by the error variance. It is about 0.99 and very significant. It means that inefficiency explains most of the variation in total error. As a result, we conclude that utilizing the stochastic frontier model is suitable.

Table 2. Stochastic production frontier results for G20 country during the period 2006-2021

Variables	coefficient	standard-error	t-ratio
Intercept (β_0)	1.5211	1.7976	0.8462
Ln (K)	0.1646	0.2205	0.7465
Ln (L)	1.4364***	0.2678	5.3641
T	0.0463	0.0305	1.5180
0.5*T*T	0.0008	0.0006	1.3263
0.5*Ln (K)*Ln (K)	-0.0038	0.0177	-0.2155
0.5*Ln (L)* Ln (L)	-0.1454***	0.0118	-12.3102
Ln (K)* Ln (L)	0.0449***	0.0152	2.9598
T* Ln (K)	0.0011	0.0019	0.6135
T* Ln (L)	-0.0044**	0.0022	-2.0454
Intercept (δ_0)	0.5248***	0.0836	6.2807
Corruption	-0.0034***	0.0010	-3.3697
Military	-0.0028***	0.0002	-17.9078
sigma-squared	0.0384***	0.0052	7.3299
Gamma	0.9935***	0.0103	96.8427

Source: Author calculations using frontier 4.1 programs.

The results show that capital and time (technology) help production. But, their effect is small and not significant. Their only effect comes from their interaction with labor input. The results show that, with less labor, technology will boost production more. This is because businesses invest in technology when labor is scarce or costly. It increases efficiency and reduces reliance on physical labor to become more competitive. Also, the results show that capital will have a more significant effect with more labor. This supports the idea that labor can use more capital to increase productivity. It will raise productivity since both inputs complement each other. The labor input had a significant, nonlinear, concave effect on production. This suggests an optimal level of labor that maximizes its marginal product. Beyond this point, each extra worker is less productive. The production function shows diminishing returns.

Of factors that affect efficiency. The result shows that a 1% rise in corruption control reduces inefficiency by 0.34%. This result is in line with Del Mar Salinas-Jiménez and Salinas-Jiménez (2007). Also, the result shows that as military spending rises by one billion dollars, inefficiency falls by 0.28 percent. This result supports the finding of Dongming and Siqi (2014) and Wang et al. (2012). Table 3 shows the production elasticity of capital, labor, and technology for all G20 countries and each one. The results show that the elasticity of capital was positive and under one for all countries. This means that a rise in capital

used in production will cause a slight increase in output. China and India have the highest capital elasticity of production. Both countries have low capital intensity. They began shifting from labor-intensive to capital-intensive production methods. Australia and Saudi Arabia have the lowest capital elasticity of production. This may be due to resource-rich countries relying on low-capital primary industries. So, increasing capital may not increase output.

Table 3. The production elasticity of factor of production for each G20 country

Country	$\dfrac{\partial LY}{\partial LK}$	$\dfrac{\partial LY}{\partial LL}$	$\dfrac{\partial LY}{\partial T}$	Sum	Return to scale
Argentina	0.8206	0.1022	0.0075	0.9303	DRS
Australia	0.7556	0.3480	0.0147	1.1183	IRS
Brazil	0.8888	-0.0799	0.0017	0.8107	DRS
Canada	0.8182	0.1561	0.0088	0.9831	DRS
China	0.9860	-0.3513	-0.0068	0.6278	DRS
France	0.8376	0.1183	0.0075	0.9634	DRS
Germany	0.8532	0.0805	0.0062	0.9400	DRS
India	0.9624	-0.3124	-0.0054	0.6446	DRS
Indonesia	0.9035	-0.1563	-0.0004	0.7468	DRS
Italy	0.8316	0.1304	0.0079	0.9698	DRS
Japan	0.8753	0.0376	0.0047	0.9175	DRS
Korea, Rep.	0.8341	0.1121	0.0074	0.9536	DRS
Mexico	0.8586	0.0205	0.0047	0.8838	DRS
Russian F.	0.8863	-0.0817	0.0017	0.8063	DRS
Saudi Arabia	0.7861	0.2161	0.0110	1.0132	IRS
South Africa	0.8150	0.1113	0.0079	0.9341	DRS
Turkey	0.8345	0.0740	0.0065	0.9151	DRS
United Kingdom	0.8429	0.0974	0.0068	0.9472	DRS
United States	0.9074	-0.0488	0.0019	0.8605	DRS
All	0.8578	0.0302	0.0050	0.8929	DRS

Source: Author calculations
IRS: Increasing Return to Scale, DRS: Decreasing return to scale

The result in Table 3 shows that elasticity of labor has a negative sign for relatively large, populated countries such as China, India, Indonesia, Brazil, Russia, and the USA, and this may happen because of technological improvements that exchange labor for capital-intensive production. From the other direction, the country with the highest labor elasticity was Australia, followed by Saudi Arabia, and this is because their output is enormous compared to their population.

The production elasticity of technological progress is also shown in Table 3. Most countries have the expected positive sign that reflects that the percentage increase in technology will result in a higher percentage increase in production. This elasticity was the highest for Australia and Saudi Arabia. However, the results for China, India, and Indonesia could have been more evident since they had negative elasticity of production. The decreasing TFP may explain this during the study period, characterized by the global financial crisis and Corona. The inadequate infrastructure, intellectual property rights, R&D expenditure, significant informal sector, and governments' policies are among the factors responsible for these results.

The sum of all elasticity shows that G20 countries generally have decreasing returns to scale. This means that during the production process, as input increases, output increases but at a lower rate. This was more severe for China than India. However, this was different for Australia and Saudi Arabia, which have increased returns to scale since they have positive and relatively high capital, labor, and technological elasticity.

Table 4 shows descriptive statistics for the calculated efficiency for each G20 country. The result indicates that G20 countries were 76% efficient. The United States was the most efficient country, followed by the UK and Australia, with average efficiency equal to 96.7%, 96% and 87.8%, respectively. Conversely, Korea Rep., Indonesia, and Turkey have the lowest efficiency scores among the G20 countries.

Table 4. The efficiency for each G20 country

Country	Average	max	min	std	obs	rank
Argentina	0.7460	0.9575	0.6503	0.0804	16	10
Australia	0.8786	0.9688	0.8315	0.0462	16	3
Brazil	0.8414	0.9123	0.6867	0.0707	16	6
Canada	0.8148	0.9093	0.7288	0.0523	16	8
China	0.7215	0.8242	0.5703	0.0662	16	12
France	0.8461	0.9393	0.7630	0.0600	16	5
Germany	0.8323	0.9242	0.7511	0.0519	16	7
India	0.7248	0.8822	0.5725	0.0929	16	11
Indonesia	0.5656	0.6694	0.4698	0.0700	16	18
Italy	0.8642	0.9369	0.8086	0.0464	16	4
Japan	0.7202	0.7727	0.6497	0.0392	16	13
Korea, Rep.	0.5009	0.5572	0.4462	0.0348	16	19
Mexico	0.6865	0.7476	0.6266	0.0338	16	16
Russian Feder.	0.7006	0.8935	0.5649	0.0934	16	15
Saudi Arabia	0.7194	0.8103	0.6005	0.0632	16	14
South Africa	0.7754	0.8944	0.6244	0.0584	16	9
Turkiye	0.5810	0.7034	0.5220	0.0502	16	17
United Kingdom	0.9608	0.9898	0.8848	0.0289	16	2
United States	0.9677	0.9943	0.9291	0.0222	16	1
ALL	0.7604	0.9943	0.4462	0.1350	304	

Source: Author's calculations

Table 2 shows that corruption control and military spending explain the efficiency results. The US, the UK, and Australia have a strong history of controlling corruption. Their institutions are well-regarded for this. Also, they have high military spending. Their advanced, established industry boosts their GDP. Conversely, Korea, Rep., Indonesia, and Turkey have low military spending as a share of GDP. Their corruption control is also low compared to other G20 countries.

Table 5 shows the losses incurred by all G20 countries due to inefficiency. The results show that G20 countries lost 107,427 B$ during the study period due to inefficiency. Among the G20 countries, Japan, Korea, and China lost the most. Their total losses amount to 29,535.56 B$, 10,823.17 B$, and 10,176.15 B$. South Africa, the UK, and Australia have the lowest total losses, at 1040.84 B$, 1081.48 B$, and 1287.89 B$, respectively.

Table 5. The loss in GDP due to inefficiency for all and each G20 country

Country	Loss in GDP due inefficiency					
	mean	max	min	std	sum	Rank of mean
Argentina	90.27	169.52	4.34	42.49	1444.34	16
Australia	80.49	213.92	10.05	58.92	1287.89	17
Brazil	151.07	473.86	70.97	103.38	2417.07	14
Canada	225.79	577.90	57.57	162.29	3612.59	12
China	636.01	2021.92	258.38	492.29	10176.15	3
France	362.46	906.68	103.76	248.68	5799.42	6
Germany	496.07	651.62	233.49	141.51	7937.17	4
India	283.73	908.57	52.46	261.06	4539.62	8
Indonesia	183.33	381.47	84.25	81.09	2933.26	13
Italy	253.81	523.85	85.28	150.76	4060.93	10
Japan	1845.97	2508.14	1304.29	395.79	29535.56	1
Korea, Rep.	676.45	1072.48	304.63	217.53	10823.17	2
Mexico	318.02	590.36	167.04	110.04	5088.34	7
Russian F.	261.21	842.69	28.32	206.27	4179.35	9
Saudi Arabia	101.66	345.81	37.14	87.11	1626.57	15
South Africa	65.05	190.17	17.38	47.10	1040.84	19
Turkiye	251.35	633.70	85.07	173.14	4021.58	11
United Kingd.	67.59	148.49	19.93	34.52	1081.48	18
United States	363.85	889.67	61.59	280.67	5821.65	5
All	353.38	2508.14	4.34	442.93	107427.00	

Source: Author calculations

Table 6 shows the gain for each G20 country. The analysis is based on a 1% increase in corruption control. The result shows that G20 countries would gain $611.89B if they improved corruption control by 1%. This gain is the highest for Japan, the Korean Republic, and China and was the lowest for South Africa, the United and Australia.

Table 6. The gain in GDP from 1% increase in corruption control

Country	The Gain from 1% increase in corruption control					
	mean	max	min	sum	std	Rank
Argentina	1.56	2.64	0.36	25.03	0.56	18
Australia	2.34	5.17	1.13	37.44	1.16	16
Brazil	3.87	9.40	2.37	61.98	1.82	13
Canada	4.71	9.89	2.36	75.44	2.42	10
China	10.78	32.24	4.62	172.56	7.82	4
France	8.82	17.01	5.27	141.05	3.59	6
Germany	12.26	17.48	9.52	196.20	1.99	3
India	4.48	12.55	1.38	71.61	3.40	11
Indonesia	2.56	5.27	1.21	40.89	1.10	15
Italy	6.92	12.08	4.26	110.79	2.54	8
Japan	30.94	38.88	24.36	495.05	4.30	2
Korea, Rep.	9.17	14.52	4.17	146.77	2.93	5
Mexico	5.02	8.81	2.61	80.29	1.65	9
Russian F.	4.14	12.77	0.87	66.32	3.07	12
Saudi Arabia	1.64	4.87	0.81	26.28	1.17	17
South Africa	1.20	2.74	0.62	19.23	0.64	19
Turkiye	3.48	8.65	1.28	55.73	2.33	14
United Kingdom	6.98	11.19	4.29	111.66	2.08	7
United States	38.24	53.03	23.66	611.89	9.58	1
All	8.38	53.03	0.36	2546.21	10.22	

Source: Author calculations

Table 7 calculates the gain that would result from raising defense expenses by 1 billion. The total gain is equal to 504.22 B$. The rank of the gain is like that in Table 6.

Table 7. the gain in GDP from 1 billion increase in defense expense

Country	The gain from 1B$ increase in defense expense					
	mean	max	min	sum	std	Rank
Argentina	1.29	2.18	0.30	20.63	0.46	18.00
Australia	1.93	4.26	0.93	30.85	0.96	16.00
Brazil	3.19	7.74	1.95	51.08	1.50	13.00
Canada	3.89	8.16	1.95	62.17	2.00	10.00
China	8.89	26.57	3.81	142.22	6.45	4.00
France	7.27	14.02	4.34	116.25	2.96	6.00
Germany	10.11	14.41	7.85	161.69	1.64	3.00
India	3.69	10.34	1.14	59.03	2.80	11.00
Indonesia	2.11	4.34	1.00	33.71	0.91	15.00
Italy	5.71	9.95	3.51	91.30	2.09	8.00
Japan	25.50	32.05	20.08	408.03	3.55	2.00
Korea, Rep.	7.56	11.97	3.44	121.01	2.42	5.00
Mexico	4.14	7.26	2.15	66.18	1.36	9.00
Russian F.	3.42	10.52	0.72	54.66	2.53	12.00
Saudi Arabia	1.35	4.02	0.67	21.66	0.97	17.00
South Africa	0.99	2.26	0.51	15.85	0.53	19.00
Turkiye	2.87	7.13	1.06	45.95	1.92	14.00
United Kingdom	5.75	9.22	3.53	92.02	1.71	7.00
United States	31.51	43.70	19.50	504.22	7.89	1.00
All	6.90	43.70	0.30	2098.51	8.42	

Source: Author calculations

Graph 1. It shows the yearly average gain from a 1% rise in corruption and military spending. It is a percentage of the average GDP for each G20 country. The results show that Korea has the highest GDP gain. It is due to increased corruption control and military spending, which rose by 1.34% and 1.11%, respectively. Indonesia is next, with gains of 1.07% and 0.88%. The lowest rates were for the US and the UK. They were 0.362% and 0.299% for the US, and 0.363% and 0.299% for the UK.
Calculate the effect of a 1% yearly increase in corruption control on the average annual GDP. Also, find the impact of a $1B yearly increase in military spending on the average annual GDP.
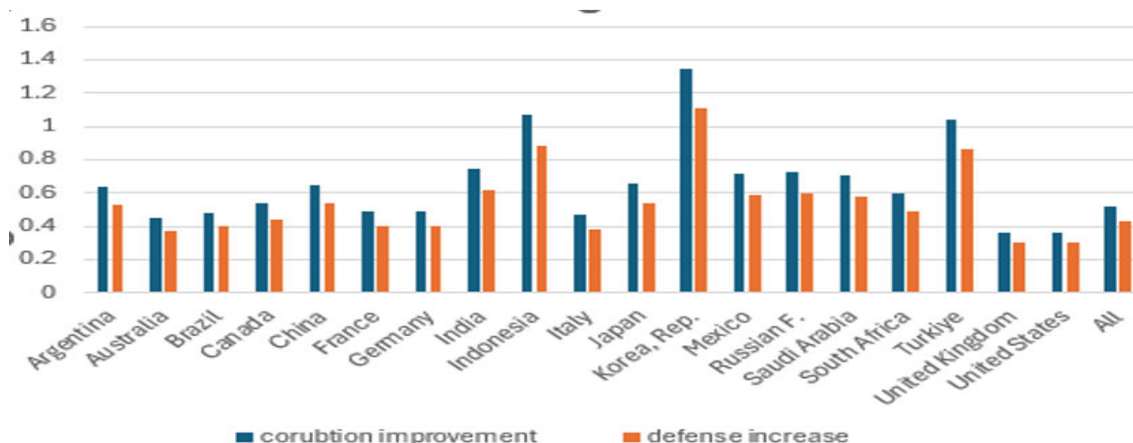
Figure 1. The effect of a 1 % average yearly increase in corruption control over the average annual GDP and the impact of 1 B$ yearly increase in Military expenditure over the yearly average GDP
Source: Authors calculations

Figure 2 presents the trend of yearly efficiency for each G20 country. The results show a decline in efficiency in Australia, Canada, France, India, Italy, and South Africa. In contrast, Germany, Indonesia, Japan, Korea, and the U.S. have a positive trend. The rest of the countries' trends could have been more straightforward.
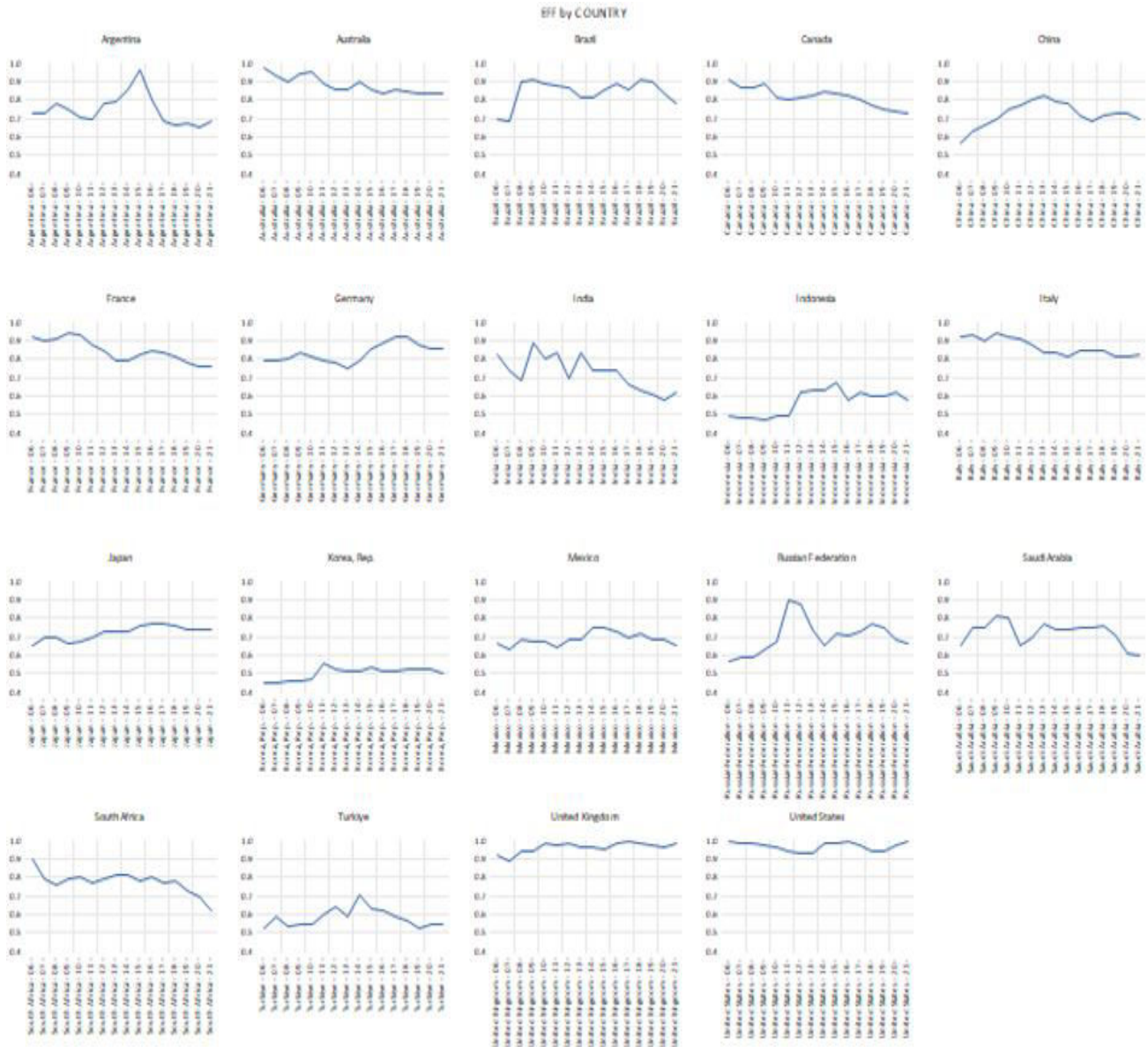
Figure 2. Efficiency trend for G20 countries during the period 2006-2021

Source: Authors calculations

CONCLUSIONS AND FUTURE RESEARCH

This analysis has shown, in detail, how military spending and corruption affected the production efficiency of G20 nations from 2006 to 2021. It used a strong method called Stochastic Frontier Analysis. The research shows a complex link between military spending and corruption. It affects production efficiency. Higher military spending is linked to fewer inefficiencies. So, it may boost economic efficiency, but only in certain cases. However, this relationship is complex. The effect depends on how much is spent and how it is managed. Also, corruption wastes money on the military. It hurts vital public and private investments, slowing economic growth.

The study highlights production efficiency's diversity across G20 nations. It also emphasizes that governance quality affects economic outcomes. It stresses the need for good governance. It can curb corruption and wasteful military spending.

The study highlights a wide range of production efficiency among the G20 nations. It emphasizes the role of differing institutional qualities and governance. Nations with strong, transparent institutions can cut the harms of military spending. Anti-corruption measures help. They use their resources more efficiently. It shows that good governance is key to economic success. We need to reform global institutions.

In light of these findings, the study has implications for policy formulation. G20 countries, and others, could improve their economies. They could also boost social outcomes. They should cut excessive military spending and reduce corruption.

These policies could include:

− Strengthening oversight.
− Enhancing budget process transparency.
− Investing in institutional capacity building.

We should standardize anti-corruption practices and promote global cooperation. Our economies are now interconnected.

Future research could build on this study's findings. It should explore several directions to understand the dynamics at play better.

− Forecasts could predict future trends in production efficiency under different policies. But, they need analysis beyond 2021.
− Including smaller or developing economies in future analyses could provide a better global view.
− Investigating the impact of military spending and corruption at the subnational level,
− Integrating psychology, sociology, and political science could improve economic analyses. It could add public trust, social cohesion, and political stability to efficiency models.
− Exploring how blockchain and AI can fight corruption and boost efficiency in public administration.

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Circularity Performance in Benelux Economies: A Comparative Analysis

JUSTAS STREIMIKIS[1]

[1]Senior Researcher, Lithuanian Centre for Social Sciences, Institute of Economics and Rural Development
[2]VIZJA University in Warsaw, Poland, email: justas.streimikis@ekvi.lt; https://orcid.org/0000-0003-2619-3229

ARTICLE INFO

ABSTRACT

This study evaluates the circular economy (CE) performance of the Benelux countries—Belgium, the Netherlands, and Luxembourg—through a comparative analysis of five core indicators derived from the European Commission's CE monitoring framework: material footprint, waste generation per capita, circular material use rate, recycling rate of municipal waste, and greenhouse gas emissions from production activitiesAnalysis of Eurostat data for the years 2013–2022 illustrates marked divergence in circular economy performance among Belgium, the Netherlands, and the EU27 average. Belgium and the Netherlands exhibit comparatively elevated rates of circular material use and recycling, thereby establishing themselves as regional frontrunners in material circularity. Nevertheless, the three coun-tries continue to exhibit pronounced material consumption and waste gen-eration, underscoring stagnation in advancing upstream circularity. These results advocate for intensified policy emphasis on the reduction of con-sumption, the promotion of innovation, and the alignment of circular econ-omy initiatives with overarching climate and sustainability objectives. The research further delineates avenues for subsequent investigation, high-lighting the imperative for more disaggregated, sector-specific, and social-domain analyses to support transitions towards circular economies that are both effective and equitable.

INTRODUCTION

Across Europe, the principle of circular economy has become the organisational core of the sustainable-development strategy, demonstrating that enhanced resource efficiency can underpin long-term economic resilience. The model intentionally decouples value generation from the consumption of finite materials, thereby protecting natural systems, elevating resource efficiency, and reducing net greenhouse-gas emissions (Henrysson and Nuur, 2021). In pursuit of these objectives, the European Union has enacted a tailored Circular Economy Action Plan, which is complemented by transparent performance metrics that track the progress of every Member State.

Within this Union, the Benelux trio-Belgium, the Netherlands, and Luxembourg-has deliberately sought lead status, drawing on dense transport networks, mature legislation, and high public concern for the planet (Hild, 2023; Claudio-Quiroga and Poza, 2024). Even so, although they share borders and similar incomes, their journeys toward circularity have unfolded along different pathways and with uneven

results. A side-by-side look at their performance thus reveals both the forces that propel some policies forward and the barriers that still stall others (Kasztelan, Kijek and Kijek, 2025).

To guide policy evaluation and regional benchmarking, the European Commission has introduced a standardised monitoring framework comprising eleven indicators grouped into thematic areas such as production and consumption, waste management, secondary raw materials, competitiveness, and innovation (European Commision, 2023). While each indicator contributes to a comprehensive understanding of CE performance, this study focuses on five core indicators that most directly capture circularity outcomes and offer measurable, policy-relevant trends over the past decade: Material footprint (resource consumption), Waste generation per capita, Circular material use (CMU) rate, Recycling rate of municipal waste, and Greenhouse gas emissions from production activities. This focus aligns with recent scholarship that encourages moving beyond narrow interpretations of circularity as solely material recovery, toward a broader systemic rethinking of economic design and value creation (Voukkali et al., 2023; Zecca, Pronti and Chioatto, 2023).

The objective of this paper is to assess the circular economy performance of the Benelux countries over the last ten years using these five key indicators, with comparative reference to the EU27 average. In pursuing this examination, we seek to map prevailing trends, discern comparative strengths and weaknesses, and gauge how steadily individual Member States are moving in step with overarching EU objectives. The findings therefore illuminate both the distinctive role that the Benelux countries play in advancing Europes circular economy and the policy gaps that still warrant more deliberate national and cross-border action.

1. LITERATURE REVIEW

In Belgium, the Netherlands, and Luxembourg-the Benelux region-the move toward a circular economy has taken centre stage on Europes sustainability agenda. Because the countries enjoy high incomes, dense infrastructure, and mature institutions, they are well placed to replace the old linear model with a system that keeps materials in steady use. The circular economy thus emerges not simply as an environmental necessity but also as a chance to build resilience, lower reliance on virgin resources, and spark enduring, resource-smart innovation (Kirchherr et al., 2018) (Claudio-Quiroga and Poza, 2024).

The European Union has woven the idea of a circular economy into its most important policies, especially the Circular Economy Action Plan and the wider European Green Deal. Together, these documents set an ambitious agenda, asking Member States to cut waste, use resources more wisely, and reach climate neutrality by 2050. To track progress, the European Commission launched a Circular Economy Monitoring Framework that features eleven key indicators grouped into five areas: production and consumption, waste management, secondary raw materials, competitiveness and innovation, and global sustainability and resilience (European Commission, 2023). By using these shared measures, countries can see how they compare, spot weaknesses, and learn from each other's successes.

Academic literature highlights that the CE is inherently multidimensional and subject to varying interpretations depending on whether the focus lies on closed-loop processes, economic value retention, or social innovation (Reike, Vermeulen and Witjes, 2017; Streimikis, 2025). It integrates economic, environmental, and social goals and requires coordinated interventions at multiple levels - ranging from industrial redesign and eco-innovation to behavioral change and policy alignment (de Souza, Fröhling and Pigosso, 2023; Alola, Özkan and Uzuner, 2024; Strapchuk et al., 2024). While macro-level indicators are useful for policy monitoring, their implementation also raises questions of interpretability, regional specificity, and sectoral variation (Jakubelskas and Skvarciany, 2023).

The Benelux countries offer an interesting case study in this regard. Belgium and the Netherlands are often identified as front-runners in Europe's CE transition due to their established recycling systems, high innovation capacity, and supportive legislation. Luxembourg, though smaller, has taken a sectoral leadership role- especially in construction and sustainable procurement- thanks to targeted policies and public-private partnerships (Mihaliková et al., 2018; Hild, 2023).

This study builds upon the broader CE literature by focusing on five key indicators from the EU monitoring framework. These indicators were selected due to their data availability, strong policy relevance, and ability to represent different phases of the circular economy cycle- from input reduction to environmental impact:

1. Material footprint (domestic material consumption per capita) measures the pressure that economic activities place on natural resources. It is considered one of the most comprehensive metrics for assessing resource intensity and decoupling potential (Kulakovskaya et al., 2022).

2. Waste generation per capita reflects consumption patterns and the efficiency of waste prevention strategies. Countries with effective product lifespan extension, reuse systems, and zero-waste strategies tend to score better on this metric (Almansour and Akrami, 2024).

3. Circular material use rate indicates the share of total material inputs that come from recycled waste. It captures the degree to which economies are able to close material loops and reduce dependency on virgin materials (Fura, Stec and Miś, 2020).

4. Recycling rate of municipal waste is critical for measuring the efficiency of end-of-life processes in the circular system. It also reflects local infrastructure, citizen participation, and regulatory effectiveness (Marković, Popović and Marjanović, 2023).

5. Greenhouse gas emissions from production activities per capita establish a link between CE and broader climate objectives. A functioning circular economy is expected to lower emissions by reducing resource extraction, improving energy efficiency, and promoting low-carbon materials (Alola, Özkan and Uzuner, 2024).

Several studies emphasize that CE performance is not only influenced by policies and technology but also by public engagement, education systems, and industrial structure (Uğurlu, 2022; Hild, 2023). For example, countries with high patent intensity in waste management tend to exhibit better CMU rates, while those with decentralized waste governance structures may face challenges in achieving high municipal recycling performance (Kasztelan, Kijek and Kijek, 2025).

Although Belgium and the Netherlands are widely hailed as pioneers of CE policy in Europe (Claudio-Quiroga and Poza, 2024), Luxembourg illustrates how even a compact economy can achieve noteworthy incremental progress by zeroing in on selected industrial segments and value chains (Hild, 2023). Within the Benelux umbrella, cross-border cooperation now serves as a practical platform for sharing lessons, harmonising standards, and mobilising joint capital flows toward climate-smart infrastructure and circular-technology ventures (Mihaliková et al., 2018).

Taken together, the growing CE literature points toward an imperative blend of high-level strategic alignment and finely grained performance tracking at all administrative scales. By isolating five core metrics and benchmarking Benelux countries against the broader EU27 average, the present analysis aims to enrich the regional dialogue on sustainable leadership while providing actionable evidence for future policy adjustment.

2. METHODS AND DATA

2.1. Analytical Framework

This study adopts a comparative performance analysis grounded in the European Commission's *Monitoring Framework for the Circular Economy* (European Commision, 2023). The framework provides harmonized, reliable, and publicly accessible data across five thematic areas and eleven statistical indicators. For the purposes of this study, five key indicators were selected based on relevance, interpretability, and coverage: Material Footprint, Waste Generation, Circular Material Use Rate, Municipal Recycling Rate, and GHG Emissions from Production.

The study applies a descriptive longitudinal analysis approach covering the period from 2013 to 2022, with a focus on the Benelux countries (Belgium, Netherlands, Luxembourg) and EU27 as a benchmark.

2.2. Data Sources and Coverage

All data were retrieved from Eurostat, the statistical office of the European Union. The selected indicators were downloaded in .tsv and .xlsx formats directly from the Eurostat CEI database (Eurostat, 2024). The dataset includes annual values for all five indicators, ensuring full temporal coverage from 2013 to 2022 for each country in the analysis.

Data were cleaned, validated, and transformed using Python (Pandas and Matplotlib) for consistency and visualization. Where multiple data entries for one country existed (e.g., breakdowns by sector), only the aggregate national values were used.

2.3 Indicator Selection and Interpretation

Indicator selection was based on three main criteria:

· Relevance to core CE goals (material efficiency, decarbonization, recycling),
· Comparability across EU Member States and years,
· Availability of consistent time-series data for Benelux countries and EU27.

Each indicator was interpreted in line with European Commission guidelines:

· Material Consumption: Measured in kilograms per capita (kg/cap), reflecting direct and indirect material use.
· Waste Generation per Capita: Total waste produced annually by households and businesses per person.
· Circular Material Use Rate: Share (%) of material inputs derived from recycled or reused sources.
· Recycling Rate of Municipal Waste: Proportion (%) of municipal solid waste recycled.
· GHG Emissions from Production: Total greenhouse gas emissions (CO_2 eq.) per capita from production sectors.

2.4. Comparative Analysis Approach

The empirical analysis relies on visual comparison via bar charts for each indicator across the selected countries and years. This approach helps:
· Trace temporal trends within each country,
· Compare relative performance between Benelux countries and the EU27 average,
· Identify convergence or divergence in circularity trajectories.

Descriptive statistics are supported by qualitative insights from policy literature to contextualize performance differences.

2.5 Limitations

Several limitations should be acknowledged:
· Data gaps or lags may affect consistency, especially in newer indicators.
· Normalisation to a per capita basis fails to differentiate among economic structure and industrial composition, which can yield markedly divergent emission and material flow trajectories.
· The analytic framework intentionally abstracts from direct indicators of policy enactment, innovation outputs, or shifts in individual and collective behaviour, necessitating the integration of qualitative inquiry for a complete assessment.

· The five indicators selected, while comprehensive, do not fully capture social and institutional dimensions of the CE transition.

Despite these constraints, the selected indicators provide a robust empirical foundation for comparative evaluation and offer valuable insights for policy alignment and performance benchmarking.

3. CASE STUDY RESULTS

This section undertakes a systematic comparison of circular economy performance in Belgium, the Netherlands, and Luxembourg for the period 2013 to 2022. The assessment utilises five primary indicators delineated in the European Commission's Circular Economy Monitoring Framework, specifically addressing resource consumption, waste creation, material circularity, recycling efficiency, and emissions from production processes.

Each subsequent sub-section delineates the temporal evolution of these indicators, measured against the EU27 mean. Graphical displays are supplemented by analytical commentary that elucidates intra-regional advancement, relative standing, and coherence with circular economy targets throughout the Benelux area.

3.1 Material Footprint Indicator

The material footprint (MF) is a quantified measure of the global mass of raw materials—comprising biomass, fossil fuels, metal ores, and non-metallic minerals—extracted to satisfy a country's final consumption. It thus enables an assessment of resource use framed by the distribution of consumption rather than production. During the period from 2013 to 2022, the Benelux countries exhibited marked oscillations in MF, reflecting differentiated structural and economic trajectories within the region. The accompanying Figure 1 below contrasts MF trajectories for Benelux with EU27 aggregates over the same interval.

Figure 1. Material Footprint per Capita in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_pc020)

As one can see from the graph above, Luxembourg consistently reported the highest MF per capita in the region — regularly surpassing 30 tonnes per person - a figure more than twice the EU27 average, which fluctuated around 14-15 tonnes during the same period. Luxembourg's elevated material footprint per capita is primarily a consequence of its diminutive population, substantial GDP per capita, and a services-

dominated economy that encompasses resource-intensive infrastructural investments. Although year-on-year figures display limited variation, the national footprint has remained stubbornly high, lacking any clear and persistent decrease over the last ten years.

Belgium and the Netherlands record more moderate, yet consistently elevated, per capita material flows that exceed the EU27 average throughout the entire decade. Belgium's figures cluster between 18 and 20 tonnes, while the Netherlands' range is 15 to 17 tonnes. Both countries register minor absolute reductions in later years, although a pronounced contraction in 2020 correlates with the temporary economic sluggishness induced by the COVID-19 pandemic. Subsequent rebounds in material throughput, however, indicate that the reductions were transitory rather than structural.

The absence of durable decreases across the Benelux trio implies that prevailing circular economy policies are inadequate to sever the linkage between material consumption and GDP expansion. Their sustained divergence above the EU27 average further suggests that, despite leadership in recycling and technological ingenuity, upstream material intensity remains unresolved. A genuinely circular transition requires the region to shift attention from end-of-pipe waste management toward the systemic redesign of consumption patterns and the active promotion of dematerialisation.

3.2. Waste generation per capita

Waste generation per capita reflects the average amount of waste produced by each individual within a country and serves as a key proxy for consumption intensity and resource efficiency. An effective circular economy aims to reduce this value over time through material reuse, reduced consumption, and improved product design. Benelux and EU27 data from 2013 to 2022 are presented in the Figure 2 below.

Figure 2. Waste Generation per Capita in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_pc035

As shown in the graph above, between 2013 and 2022, the Benelux nations produced waste at levels higher than the EU27 mean, which hovered close to 530 kg per inhabitant. Luxembourg remained the highest, with per capita figures that climbed from 660 kg to 780 kg, a reflection of its wealth and persistent difficulties in curtailing waste. The Netherlands produced waste that ranged from 560 kg to 620 kg per inhabitant, while Belgium occupied a tighter band of 570 to 610 kg.

A closer look at the trend data reveals that none of the three countries achieved a persistent decline. Instead, the observed year-on-year changes imply that policy interventions have not yet redetermined

consumption practices or waste generation in the domestic sector. Luxembourg presented the widest annual swings, Belgium registered small reductions toward the end of the period—likely the consequence of public education initiatives and adjustments to waste pricing. Still, these developments fall short of bridging the divide to EU waste reduction benchmarks or of advancing the transition to a circular economy.

In comparison, the EU27 average remained more stable and consistently lower than all Benelux members. This disparity underlines the urgency for more aggressive upstream interventions in product design, packaging regulation, and household awareness in Benelux states, especially if they are to position themselves as regional leaders in circularity.

3.3. Circular Material Use Rate

The circular material use rate measures the proportion of material resources consumed in the economy that originate from recycled waste materials—essentially capturing how efficiently secondary raw materials are reintroduced into economic flows. A higher CMU rate reflects improved circularity, reducing the need for virgin material extraction. Benelux and EU27 data from 2013 to 2022 are presented in the Figure 3 below.
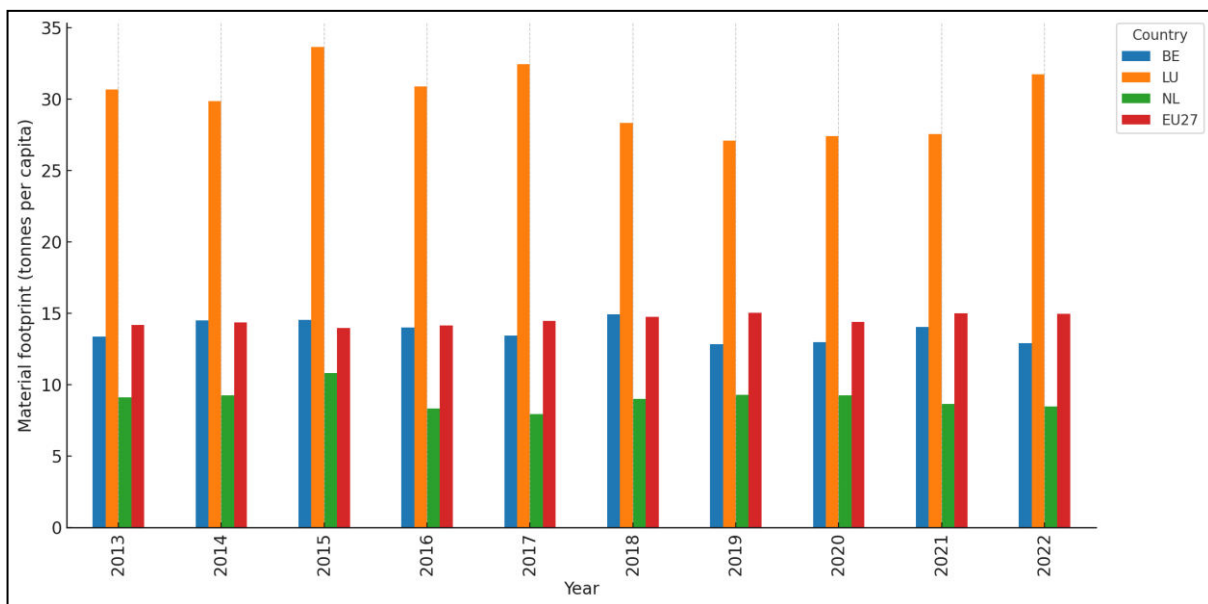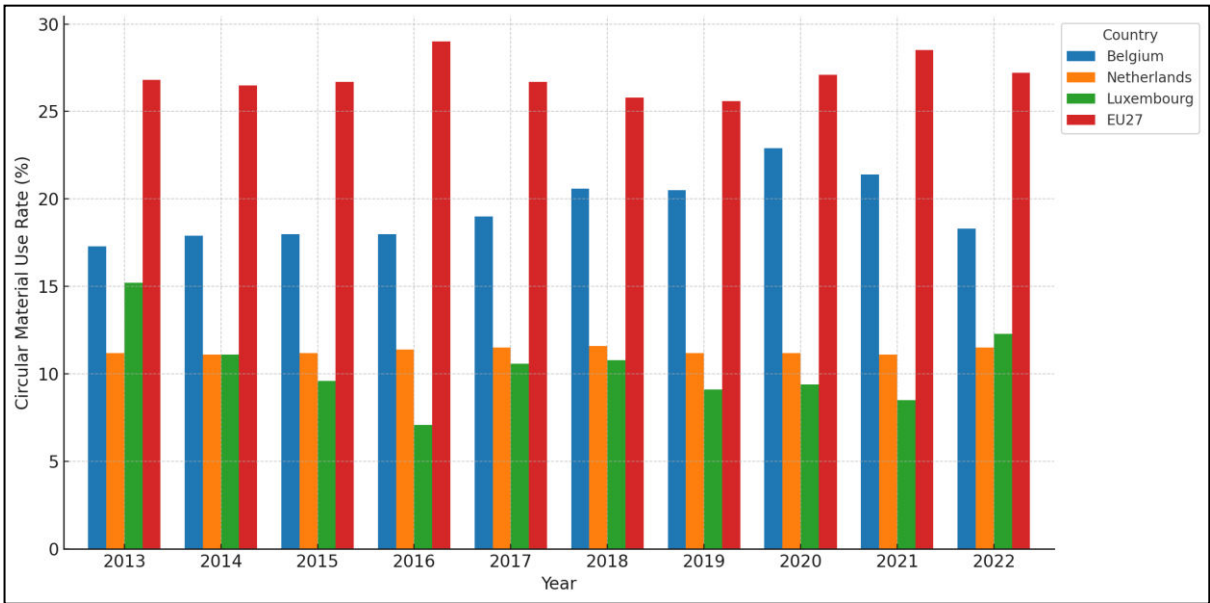

Figure 3. Circular Material Use (CMU) Rate in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_srm030

Among the Benelux countries, the Netherlands registers the highest circular material utilisation (CMU) rates within the EU, consistently recording values between 25% and 31% from 2013 to 2022. This achievement reflects the maturity of the nation's recycling networks and ongoing initiatives to reincorporate recovered materials into production cycles. Belgium's rates, varying from 18% to 23% over the same interval, marginally exceed the EU27 average, which remained stable between 11% and 12%. This above-average performance signals Belgium's continued investment in industrial symbiosis initiatives and the optimisation of material recovery pathways.

Contrastingly, Luxembourg's CMU rates, predominantly between 8% and 10%, lie below the EU27 indicative of weaker circular practices. The limited industrial footprint and reduced volume of waste generated per capita restrict the pool of recyclable material available for domestic processing, contributing to the observed shortfall.

Thus, the Benelux region reveals heterogeneous circular performance: the Netherlands and Belgium set benchmarks above EU27 norms, while Luxembourg's compact dimensions and economic profile attenuate its circular capacity. Enhancing the region's collective CMU outcomes will necessitate targeted

interventions in Luxembourg, particularly in expanding circular public procurement and scaling recovery operations in high-impact sectors such as construction and municipal service delivery.

3.4. Recycling Rate of Municipal Waste

This indicator captures the share of total municipal waste that is recycled, reflecting how effectively household and urban waste streams are managed. Recycling is central to circularity, allowing resources to be kept in use and reducing landfill dependency. Figure 4 below presents Benelux and EU27 data from 2013 to 2022.
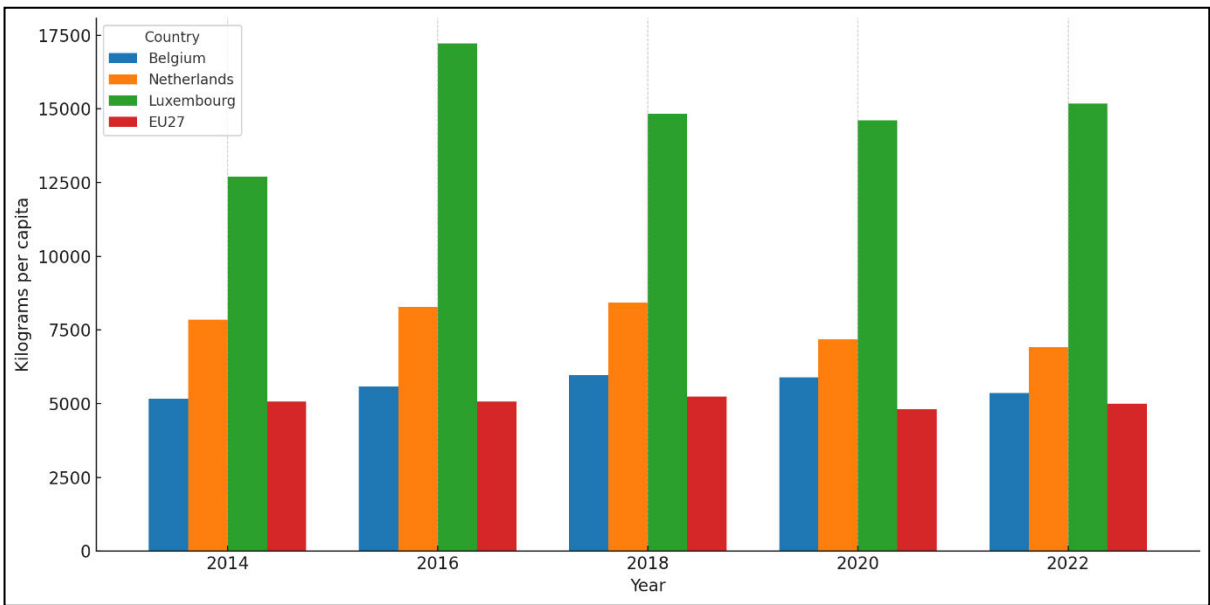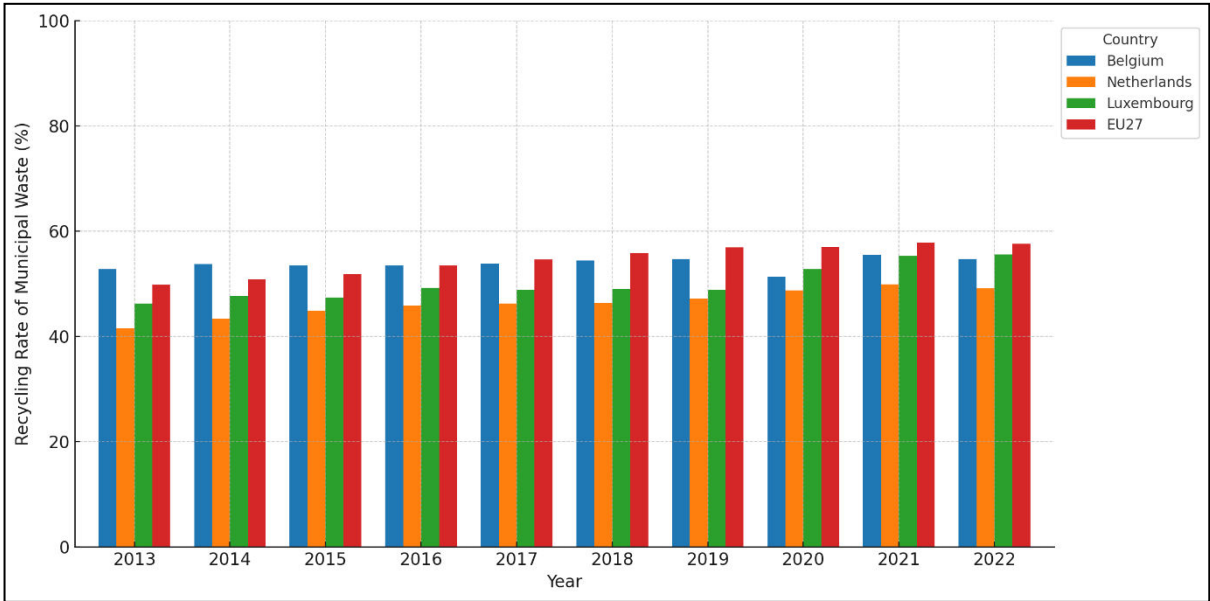

Figure 4. Recycling Rate of Municipal Waste in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_wm011

As one can see from the graph above,from 2013 to 2022, the Netherlands sustained the highest recycling rates in the Benelux region, achieving levels that fluctuated between 53% and 60%. Belgium recorded slightly lower rates, uniformly situated between 50% and 57%, yet both countries surpassed the EU27 average, which edged upward from 42% in 2013 to 49% in 2022. Such persistent performance reflects the impact of calibrated investments in recycling infrastructure, well-organised waste separation networks, and sustained outreach to the public.

Luxembourg, in contrast, reported recycling rates that generally hovered between 45% and 50%, albeit with a discernible upward trajectory over the period. While the country did not match the performance of its immediate neighbours, its rates remained above the EU benchmark and exhibited a slow but steady convergence by 2022.

The data reveals a positive but uneven trend: all three Benelux countries maintained or improved their recycling rates, outpacing the EU average. However, future improvements may require tackling more complex waste streams - such as composites and multi-material packaging - along with further behavioral shifts in households and businesses. Continuous policy innovation and digital tools for waste tracking could enhance recycling quality and consistency across the region.

3.5. GHG Emissions from Production

This indicator reviews the climate impact of national production sectors by quantifying territorial greenhouse gas emissions, explicitly omitting land-use change and international transport emissions. Although emissions accounting does not constitute a measure of circularity per se, greenhouse gas releases deliver

essential information regarding the overall environmental sustainability and production efficiency of economic systems. The Figure 5 below depicts emissions data for the Benelux and for the EU27, covering the period from 2013 to 2022.
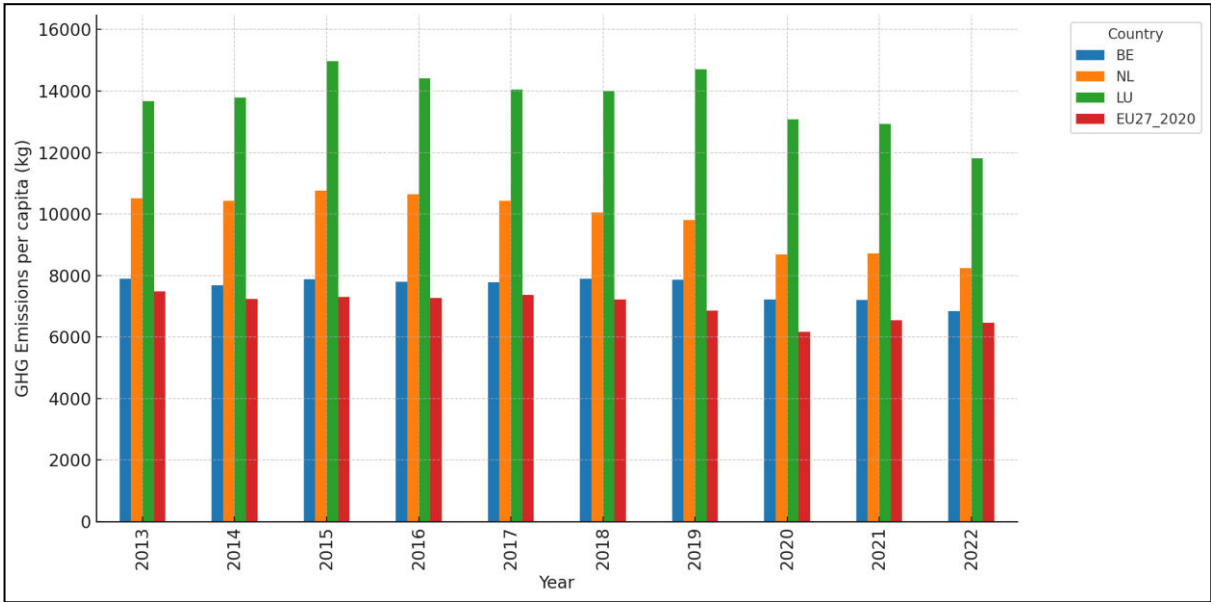
Figure 5. Greenhouse Gas Emissions from Production Activities in Benelux Countries and the EU27 (2013–2022) Source: Made by the author based on Eurostat dataset cei_gsr011.

As shown in the graph above, in 2013, Belgium recorded the highest GHG emissions among Benelux countries at over 95 million tonnes of CO_2-equivalents, followed by the Netherlands at roughly 90 million, and Luxembourg with just under 10 million tonnes. Across the decade, all three countries managed to reduce emissions, though at varying rates.

By 2022, Belgium's greenhouse gas emissions fell to roughly 81 million tonnes, representing an approximate 15 percent drop; the Netherlands reported a decline to 77 million tonnes, corresponding to a reduction of around 14 percent, while Luxembourg posted a minor reduction to 8.5 million tonnes. Collectively, emissions across the EU27 contracted at an approximate rate of 20 percent during the same timeframe, a development partly attributable to sectoral decarbonisation sweeps in energy and manufacturing that were especially pronounced in parts of Eastern and Southern Europe.

Although these countries posted absolute reductions, their emissions remain abnormally high when benchmarked against population numbers, a situation most pronounced in Belgium and the Netherlands. Such outcomes underline a continued dependence on energy-intensive industrial activities and fossil fuel-derived production pathways. To ensure that circular economy initiatives harmonise with long-term climate-neutrality aspirations, the Benelux nations must hasten the deployment of low-carbon production technologies and deepen circular practices in emissions-intensive domains, notably construction, transportation, and the energy sector.

4. DISCUSSION

Assessment of circular economy metrics across the Benelux region discloses a stratified, dynamic, and occasionally fractious landscape with respect to compliance with EU sustainability frameworks. Belgium, the Netherlands, and Luxembourg exhibit well-articulated policy architectures and supportive circularity-oriented infrastructures; however, the velocity and character of advancement diverge markedly across the employed metrics.

The reported material footprint data highlight a persistent disjunction between GDP growth and resource productivity. All Benelux countries maintained per capita figures above the EU27 mean during the past decade, with Luxembourg recording especially elevated levels. These outcomes indicate that, even as circular programmes continue to unfold, upstream resource extraction and consumption have yet to be decisively curtailed. Such conclusions corroborate earlier investigations documenting the persistent challenge of dissociating material throughput from the growth trajectories of affluent economies (Claudio-Quiroga and Poza, 2024; Kasztelan, Kijek and Kijek, 2025). They also align with scholar's findings, that stress that circular economy policies still struggle to decouple economic expansion from environmental degradation at the EU level (Zecca, Pronti and Chioatto, 2023; Radivojević, Rađenović and Stanojević, 2024). Likewise, per capita waste generation in the Benelux countries consistently exceeded the EU average, with Luxembourg registering the highest per capita total. The stable or upward trajectory observed in both Belgium and Luxembourg indicates that advancements in waste processing are insufficiently complemented by declines in waste generation. This divergence signals an imperative for augmented policy measures concentrating on sustainable consumption and production patterns (de Souza, Fröhling and Pigosso, 2023; Alola, Özkan and Uzuner, 2024).

In contrast, the circular material use rate suggests a more encouraging trajectory. The Netherlands stands out as the clear leader, achieving a CMU rate that is almost three times the EU27 mean. Belgium achieved slight, yet notable, advancements, while Luxembourg's rate remained comparatively low and unchanged. The exceptional Dutch result is attributed to robust policy frameworks that promote industrial symbiosis, the use of secondary raw materials, and the design of circular products. These outcomes corroborate earlier analyses identifying the Netherlands as the foremost European nation in comprehensive circularity (Alola, Özkan and Uzuner, 2024).

The recycling rate of municipal waste reinforces the observation that the Benelux countries excel in the latter stages of waste management. Belgium and the Netherlands consistently exceed the EU average, with recycling rates either stable or trending upward. Luxembourg, despite ranking below the other two, has recorded recent improvements, suggesting that ongoing investments in recycling infrastructure and in public education initiatives are beginning to yield dividends (Hild, 2023).

In summary, emissions associated with industrial production reveal interplay between underlying economic composition and prevailing energy regulation regimes. The Netherlands and Belgium recorded marginal declines in gross GHG output, yet these reductions lag behind the EU-wide trajectory. By contrast, Luxembourg's steeper, sustained decrease is noteworthy. Such divergent patterns imply that energy-dependent industries continue to impose elevated environmental loads within the broader Benelux region, underscoring the necessity of co-integrating circular economy initiatives with low-carbon energy transformation pathways (Jakubelskas and Skvarciany, 2023).

Taken together, these results suggest that while the Benelux countries exhibit strong performance in recycling and circular material use, they struggle with reducing overall resource consumption and waste generation. This imbalance indicates a partial circular transition- focused more on end-of-life recovery than on rethinking production and consumption systems. Achieving greater circularity will require a systemic approach, including more aggressive eco-design standards, green public procurement, and incentives for waste prevention and reuse (Kennedy and Linnenluecke, 2022).

Moreover, the sustained gaps between Luxembourg and its Benelux neighbours across multiple metrics underscore the role of economic scale, sector mix, and innovation capability in determining circular economy performance. Coordinated regional initiatives centred on data standardisation and joint investments stand to mitigate such divergences and amplify the collective circular-economy potential of the Benelux partnership.

CONCLUSION

This analysis examined the circular economy performance of the Benelux states through the EU's five operational indicators, measuring resource potency, waste dynamics, material reincorporation, recycling efficacy, and emissions intensity. Comparative trends since 2012, set against the EU27 baseline, indicate that the region is on a cautiously encouraging, albeit asymmetric, circular-path trajectory.

Belgium and the Netherlands have each realised meaningful enhancements in the sophistication of their circular structures, particularly regarding recycling metrics and the utilisation of reclaimed materials. These gains rest on resilient institutional ecosystems, dynamic public-private alliances, and a culture of eco-innovation. The Netherlands distinguishes itself as a regional high performer in material reincorporation, while Luxembourg, notwithstanding concentrated policy interventions, continues to trail on nearly every indicator, the shortfall traced largely to its size and sector-specific structural rigidities.

However, the assessment reveals notable deficiencies, particularly in material footprint and waste generation, with all three nations surpassing the EU27 benchmark. Such results imply that circular economy policies are presently skewed toward terminal recovery stages, inadequately addressing earlier levers like product design, reuse, and the promotion of sustainable consumption practices. Furthermore, the sluggish trajectory of greenhouse gas emissions decline in manufacturing underscores the necessity of synchronising circular economy measures with more stringent climate governance.

Future research directions should aim to:
· Investigate the sector-specific drivers of circularity in Benelux countries, such as construction, manufacturing, and agriculture;
· Assess the effectiveness of policy instruments, including fiscal incentives, procurement policies, and regulatory frameworks that aim to reduce resource use;
· Explore the social dimensions of circularity, including consumer behavior, education, and labor market impacts;
· Develop composite indicators or CE indexes that integrate environmental, economic, and social outcomes to better assess the quality of circular transitions;
· Conduct longitudinal and scenario-based modelling to anticipate future pathways and trade-offs in CE performance under different policy and market conditions.

To summarise, the Benelux countries constitute an advanced subgroup within the EU's movement towards a circular economy; however, continued advancement will require integrated approaches, improved transnational coordination, and a sharpened emphasis on alleviating resource consumption from the outset. Embedding circular principles within the wider sustainability framework - including climate adaptation and social justice - remains critical to achieving durable ecological integrity and economic viability over the long term.

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Fiscal Policy's Role in Achieving Economic Saudi Arabia Diversification: New Evidence from an ARDL Approach

MUSTAPHA BEN HASSINE[1] (Corresponding author) and SARRA ALOMRAN[2]

[1]Associate Professor, email: benhassinemustapha@yahoo.fr, https://orcid.org/0000-0002-2267-9478
[2]Assistant Professor, email: saraalomran@gmail.com, https://orcid.org/0009-0001-6837-1305
[1-2] Department of Economics, College of Business, Imam Mohammad Ibn Saud Islamic University, P.O. Box 5701, Riyadh 11432, Saudi Arabia.

ARTICLE INFO

ABSTRACT

The study analyses the role of fiscal policy in promoting economic diversification in the Kingdom of Saudi Arabia. To assess this relationship, it employs both descriptive and econometric approaches, utilising the autoregressive distributed lag (ARDL) model for data spanning from 1980 to 2023. The findings reveal a significant cointegrated relationship among the variables, indicating that they move together over time. Importantly, there is a negative and significant unidirectional causality between the Herfindahl-Hirschman index (HH) and government expenditure. Specifically, a 1% increase in government expenditure results in approximately a 0.63% decrease in the economic diversification index, suggesting that rising government spending is associated with reduced diversification. The large proportion of total government expenditures allocated to current rather than capital spending, which may limit investments in new sectors, explains this counterintuitive outcome. These results carry important policy implications. They suggest that policymakers should reconsider the structure of government expenditures to better support diversification efforts. This could involve increasing investments in sectors that contribute to economic diversification, optimizing operational expenses, and offering targeted tax incentives to promote growth in priority sectors. By aligning fiscal policy more closely with the objectives of economic diversification, Saudi Arabia can work toward building a more resilient and varied economy, thereby reducing its dependence on oil revenues and fostering sustainable growth.

INTRODUCTION

Economic diversification significantly influences economic structure, positively impacting growth rates and sector development (Hare, 2008). Recognizing this, the Saudi Arabian government has prioritized diversifying its economy as a core strategic goal in its development plans. Ongoing efforts in this direction are essential to achieving the objectives outlined in the Kingdom's Vision 2030. Recently, Antwi-Boateng and Al Jaberi (2022) confirm that opening the Saudi Arabian economy to investments and business will boost production and facilitate its transformation into one of the world's largest economies. The Saudi authorities have implemented various fiscal policy tools to promote economic diversification, recognizing

their critical role in economic development and stability, which in turn influences the structure of the national economy.

Countries adopt normally various strategies to diversify their economies based on their unique specifies. These strategies typically focus on increasing income sources and developing economic sectors. Key approaches include encouraging private sector involvement, attracting foreign investments, and establishing a solid industrial foundation. Sustaining this diversification often requires the implementation of economic reform programs (Antwi-Boateng & Al Jaberi, 2022).

The development of economic sectors in a country relies on sufficient financial resources to support the process. Saudi Arabia faces the significant challenge of reducing its dependence on oil exports. Over the past five decades, economic authorities have worked to refine their strategies, with fiscal policy serving as a key tool to achieve economic goals. Government expenditure influences the contributions of various sectors to GDP; thus, sectors with lower GDP participation are prioritized for development to enhance their effectiveness and contributions.

This study addresses the previously unexplored analysis of fiscal policy's contribution to economic diversification in Saudi Arabia. It focuses to measure and analyze the relationship between fiscal policy variables and economic diversification from 1980 to 2023. We structure this paper as follows. Section 2 summarizes the theoretical framework of fiscal policy. Section 3 is briefly reviewing of previous empirical studies on economic diversification and the impact of fiscal policy on it. Section 4 analyses the current state of financial policies and economic diversification in Saudi Arabia. Section 5 describes the econometric approach used and presents preliminary empirical statistics. Section 6 discusses the econometric estimates. Finally, Section 7 concludes the study and offers policy implications for policymakers.

1. FISCAL POLICIES: THEORETICAL FRAMEWORK

In relying on fiscal policy tools, countries effect economic activity, indicators, and stability. Andolfatto (2008) defined fiscal policy as the government collecting and spending money in order to achieve economic, social, and political goals. This definition emphasizes tools used by public finance to achieve economic stability, such as government expenditures (Barro et al., 1994), revenues (Taylor, 1949), and budget (Taylor and Mcgoldrick, 1930). According to Easterly and Rebelo (1993), fiscal policy is indispensable for economic stability. It mitigates fluctuations in production and prices while promoting high-level development. It creates a favorable environment for increasing investments, employment, and economic resources (DeLong et al., 2014), and improves living standards. It expedites the redistribution of income and wealth to enhance social justice, contributing to economic, social, and political stability (Şener, 1995).

Economic diversification is crucial in enhancing the economic structure and achieving sustainable development. To strengthen their economic conditions, countries aim to broaden their production base by reducing risks, improving income levels, and increasing investment volumes (Hare, 2008). Markowitz's theory of portfolio diversification constructed the theoretical foundation for economic diversification. Markowitz (1999) suggested that investors could mitigate risk by investing in a variety of assets with different risk levels. This approach emphasizes the advantages of holding multiple types of financial assets. Additionally, Leontief and Strout (1963), and Leontief (1986) analyzed economic diversification through input-output associations. They highlighted how sectors are interconnected and how changes in one sector can affect the rest of the economy.

Romer (1987) emphasized the link between endogenous growth theory, diversification, and quality. He proved that technological progress could enhance the diversity of goods produced or consumed. He argued that innovation results in new products or industries that are neither direct substitutes nor complements to existing ones. It means that new discoveries do not render existing products obsolete. He concluded that achieving diversification necessitates significant investment in research and development.

Production diversification refers to how various economic sectors contribute to GDP and income. Dhir and Dhir (2015) categorize it into horizontal diversification, which involves creating new products within a sector, and vertical diversification, which spreads investments across sectors to enhance value. This diversification affects GDP structure, income, production, exports, and state revenues. Shediac et al. (2008) argue that promoting diversification is vital for growth and sustainable development, improving living

standards. It also helps mitigate risks during economic downturns, as reliance on a single income source increases vulnerability to market fluctuations (Uzonwanne, 2015).

Furthermore, export diversification enhances and develops exports by encouraging investors to boost the competitiveness of domestic goods in foreign markets, thereby fostering economic growth. Additionally, it mitigates the risk associated with fluctuating prices of exported goods and improves trade exchange rates. Countries with limited range of exports, declines in product prices reduces their export revenues and foreign exchange. The state's ability to finance imports and support economic development will be constrained.

By developing production, economic diversification will reduce investment risks. Thereby, it promotes investment and contributes to reach higher returns and stable economic growth. Furthermore, it leads the private sector to contribute significantly in economic development, reducing dependency on government involvement (Mishrif, 2018). Additionally, diversification leads to create job opportunities in the private sector through the development of different economic sectors (Callen et al., 2014).

2. A BRIEF LITERATURE REVIEW

This study focuses on a selective literature review analysing the role of fiscal policy in achieving economic diversification. The relationship between fiscal policy and economic diversification has gained attention in the literature, as both public expenditure and revenues influence production diversification. Investment expenditures, a key component of aggregate demand, significantly affect production growth; they are directed toward public projects in sectors like industry and agriculture (Khan and Kumar, 1997). Additionally, these expenditures support social initiatives in human capital and health. By boosting an increase in economic production, investment expenditures promote diversification (Callen et al., 2014). Public expenditures also aid export development by providing subsidies to domestic and foreign investors, sustaining competitiveness against foreign markets (Gruenspecht, 1988).

Public revenues, particularly tax policies, are crucial tools for achieving economic diversification. Tax policy plays a significant role in directing and encouraging investment by offering various incentives to attract local and foreign capital while reducing the tax burden on investors. This encourages investment in targeted sectors that the state aims to develop (Avi-Yonah, 2000). Additionally, public revenues help diversify exports by increasing state income, allowing for support of various economic sectors, and enhancing their resilience and competitiveness in foreign markets.

Bokhari (2017) asserted that successful economic diversification in Saudi Arabia necessitates comprehensive reforms of the overall economic framework, utilizing flexible economic models. These models should promote integrated economic policies to achieve the desired goals. He emphasized that the development of the private sector and human capital are key determinants of effective economic diversification. Hvidt (2013) found that economic diversification is essential for GCC countries. He argued that these countries must require the development of multiple income sources and the use of various economic policy tools to achieve diversification process. Thereby, he suggested resorting to the private sector and foreign direct investment since they act crucially in diversification efforts. They should re-evaluate their spending policies to reduce reliance on volatile oil prices.

To investigate the relationship between the degree of diversification or concentration and a country's development stage, Imbs and Wacziarg (2003) have used cross-sectional data from group countries between 1969 and 1997. They found that diversification correlates with the level of development: in the early stages of development and at low per capita income, countries tend to diversify across all sectors. As per capita income rises to a certain level, countries begin to concentrate their resources, shifting from agriculture to industrial and service sectors. Abdel Rahman (2002) argued that the Saudi government should apply a comprehensive strategy involving the private sector, which well conducts implementation. As a key factor in the diversification process, foreign direc investment is needed, especially in natural gas, mining, and tourism sectors.

Economic diversification in Iraq requires the government to implement effective public policies. Kadhim and Hasan (2022) examined the impact of fiscal policy on this diversification using the ARDL method. They found that current public expenditures overshadow investment expenditures in the budget, providing

external savings that encourage private investment and support long-term growth. However, the effect of fiscal policy is still weak due to the economy's heavy reliance on oil for revenues and expenditures, which hampers necessary diversification efforts.

Kolawole et al. (2018) examined the effectiveness of fiscal policy, specifically government expenditure and tax revenues, in promoting economic diversification in Nigeria from 1981 to 2018. They found that Nigeria's economy, heavily dependent on oil, shows a negative relationship between the diversification index and both petroleum gains tax and capital expenditures. To foster diversification, the government should wisely utilize expenditures to promote production and improve infrastructure, thereby reducing costs for exportable goods and services and enhancing sustainable development across all sectors.

3. SAUDI ECONOMIC DIVERSIFICATION REALITY: EMPIRICAL FINDING OVER THE PERIOD 1980-2023

Fiscal policy plays a vital role in Saudi Arabia's economy, allowing the government to manage public finances and allocate resources effectively. According to Hasanov et al. (2022), it primarily facilitates the transfer of revenues from the oil sector to the non-oil sector. Figure 1 illustrates the evolution of government expenditure from 1980 to 2023, including both current and capital expenditures. In the early 1980s, expenditures peaked at 236.7 billion riyals due to the oil boom. However, by the mid-1980s, spending dropped to 137.4 billion riyals because of declining oil prices. The early 1990s saw a 25% increase in military spending during the second Gulf War, raising expenditures to 214.1 billion riyals. Yet, by the late 1990s, spending significantly decreased, resulting in a budget deficit and a low of 183.8 billion riyals. From 2004 to 2014, the oil boom led to a surge in government expenditure to 1,140.6 billion riyals, enabling the approval of numerous Greenfield projects that boosted spending, created jobs, and fostered economic development.
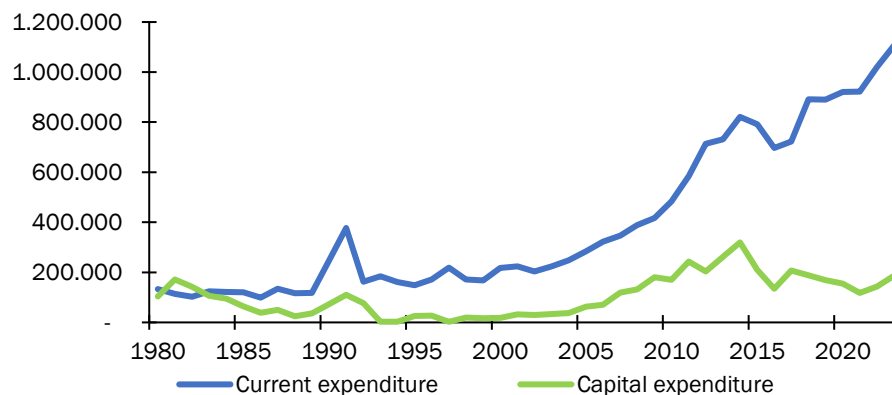
Figure 1. Evolution of Government Expenditure in Saudi Arabia
Source: from Central Bank of Saudi Arabia database

In 2015, the Saudi government allocated 1,001.2 billion riyals, even as oil prices fell. Military spending surged in 2016 due to the conflict in Yemen. In 2017, the government introduced monetary policy reforms to enhance spending efficiency and boost non-oil production as part of Vision 2030 goals. Figure 1 indicates that current expenditures significantly outpace capital expenditures in total government spending.

Saudi Arabia's revenues are divided into two categories: oil and non-oil revenues. The following Figure 2 illustrates that the majority of Saudi Arabia's income comes from oil. Nevertheless, non-oil revenues increased since 2016 due Vision 2030.
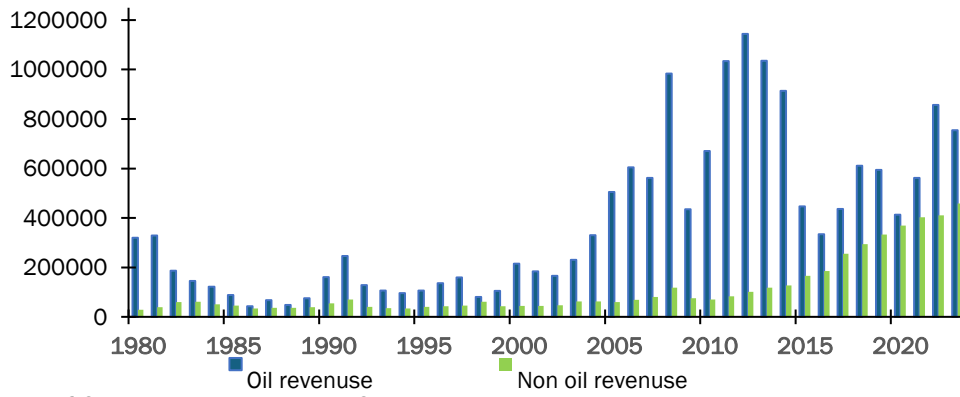
Figure 2. Evolution of Government Revenus in Saudi Arabia
Source. from Central Bank of Saudi Arabia database)

From 1980 to 2023, Saudi Arabia used its oil wealth to enhance living standards and boost per capita income through significant government investments in infrastructure and equipment. However, the government recognized that overdependence on oil for GDP could pose economic risks due to market volatility. Consequently, economic diversification has become a key strategic objective to mitigate these risks. This focus leads to reducing the oil sector's contribution to GDP to 29.9% in 2023, while the non-oil sectors have seen growth. Figure 3 illustrates this shift, exhibiting increases in contributions from sectors such as industry, government services, and trade.
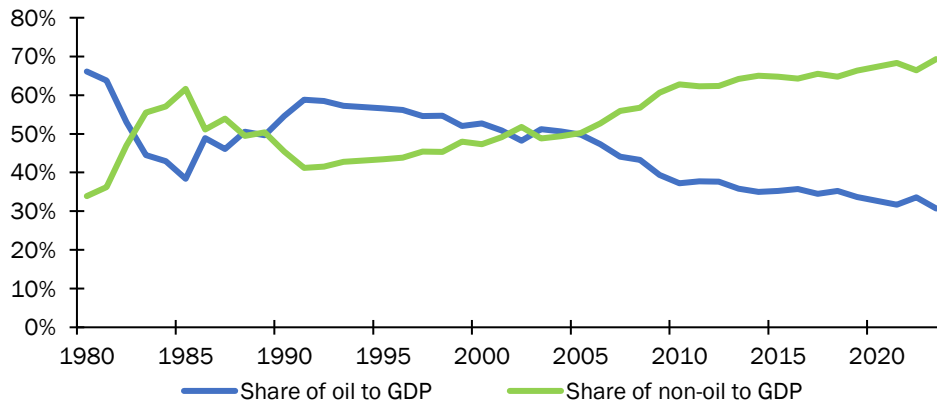
Figure 3. Percentage of oil non-oil sectors participation in GDP (constant prices)
Source: from Central Bank of Saudi Arabia database)

By different alternating indexes, Berthelemy (2005) and Agosin et al. (2011) found similar results. To measure economic diversification degree in our study, we adopt the Herfindahl-Hirschman index. Its value ranges between zero and one. It means that a higher value indicates that the economy is concentrated on a small set of products, and vice versa. This index is calculated as follow:

$$H = \frac{\sqrt{\sum_{i=1}^{n}\left(\frac{x_i}{Gdp}\right)^2} - \sqrt{\frac{1}{n}}}{1 - \sqrt{\frac{1}{n}}} \tag{1}$$

Where (*n*) is the number of sectors, (x_i) is the total real output per sector, and (*Gdp*) is the real gross domestic production are measured in billions of constant 2010 Saudi riyals. If it is zero, there is complete diversity in the economy, but if it is one, there is no diversification, and then the output is concentrated in one economic activity.

Figure 4 retraces the evolution of the economic diversification index based on sector contributions to GDP at constant prices. The index fell in the early 1980s and then rose to 0.40 in 1992, caused by political

conditions in the Arab Gulf region. However, it has since declined continuously, reaching 0.10 in 2023. This decline is the result of the implementation of various transformational programs aimed at supporting diversification under the Kingdom's Vision 2030.
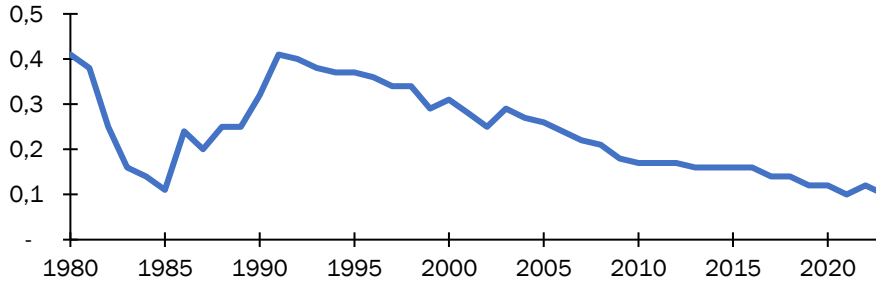
Figure 4. Evolution of Economic Diversification Index
Source: own

4. ECONOMETRIC MODEL AND PRELIMINARY EMPIRICAL ANALYSIS

4.1 Econometric model

According to Pesaran and Pesaran (1997) and Pesaran et al. (2001), we attempt to study and analyze the fiscal policy-diversification economy nexus both short and long run. For this goal, we use Saudi Arabia yearly data over the period 1980-2023, and we adopt econometric approach used recently by Mazengia et al. (2023). We specify the following time series ARDL(*p,q*) model:

$$H_t = \beta + \sum_{i=1}^{p} \alpha_i H_{t-i} + \sum_{j=0}^{q} \mu_j' \Delta Y_{t-j} + \omega_t \qquad (2)$$

Where H_t the Herfindahl-Hirschman index, $Y_t = [Ge_t,\ Cpi_t, Fdi_t, Gdp_t]$ is the independent variables vector, β is the intercept, and ω_t is the stochastic error term. This ARDL specification has orders *p* and *q* describe the time lag number that are selected automatically by the Akaike Information Criteria (AIC).

Furthermore, the short-run and long-run analysis requires the following error correction model:

$$\Delta H_t = \beta + \left(\sum_{i=1}^{p} \alpha_i - 1\right)(H_{t-1} - \gamma' Y_{t-1}) + \sum_{i=1}^{p-1} \alpha_i^* \Delta H_{t-i} + \sum_{j=0}^{q-1} \mu_j^{*'} \Delta Y_{t-j} + \omega_t \qquad (3)$$

Where Δ denotes the first difference operator, and the long-run and short-run parameters for this dynamic model are γ, α^*, and μ^*. These parameters are defined, respectively, as follows:

$$\gamma = \frac{\sum_{j=0}^{q} \mu_j}{1 - \sum_{i=1}^{p} \alpha_i} \qquad \alpha_i^* = -\sum_{m=i+1}^{p} \alpha_m \qquad \mu_j^* = -\sum_{m=j+1}^{q} \mu_m$$

We assume that the error correction term is described by $(H_{t-1} - \gamma' Y_{t-1})$, and its coefficient $\left(\sum_{i=1}^{p} \alpha_i - 1\right)$. According to Pesaran and Pesaran (1997) and Pesaran et al. (2001), the $\left(\sum_{i=1}^{p} \alpha_i - 1\right)$ term indicates the diversification index adjustment speed towards its long-run equilibrium state for any disturbance situation in the independent variables. Furthermore, it must be statically negative.

4.2 Preliminary empirical analysis

To study the role of fiscal policy in Saudi Arabia's economic diversification, we elaborated database upon the Saudi Central Bank and the World Development Indicators. All observations are annual frequency over the period 1980-2023. H is the Herfindahl-Hirschman Index in order to measure the economic diversification degree. The Government capital expenditures (Ge), real Gross domestic product (Gdp), and Foreign direct investment (Fdi) are measured in billions of constant 2010 Saudi riyals. The Consumer price index (Cpi) is given as a percentage (2010=100) to measure inflation.

Table 1. Summary statistics

Variables	Mean	Maximum	Minimum	Std. Dev.
H	0.253409	0.430000	0.120000	0.094079
Ge	492159.2	1293236.	137422.0	373266.5
Cpi	0.889261	1.323644	0.670404	0.2098878
Fdi	-5895.056	43914.46	-99383.74	27698.36
Gdp	1975872	3495059	1034099	782442.1

Source: Author's calculations using the World Development Indicators and Saudi Central Bank data

To analyze the stationarity of variables, we have applied unit root tests summarized in the following Table 2, especially the augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test with intercept, and intercept and deterministic time trend. The null hypothesis of ADF and PP tests is a unit root and the alternative hypothesis is no unit root. All variables are transformed into the napierian logarithm except for the Foreign direct investment variable.

Table 2. Unit root tests

Variables	ADF		PP	
Model with Intercept	(I)	(II)	(I)	(II)
LH	-1.4127	-7.1185***	-1.5404	-7.1105***
LGe	0.2252	-4.7019	0.2172	-5.5982***
Fdi	-4.4012***		-4.5265***	
LCpi.	0.4694	-3.2575**	0.6835	-3.2790**
LGdp	1.0342	-4.0398***	0.3988	-4.1181***
Model with Intercept and Trend				
LH	-1.8410	-7.0319***	-2.0171	-7.0259***
LGe	-2.4629	-4.9499***	-2.0637	-5.9013***
Fdi	-5.2607***		-5.3669***	
LCpi.	-2.8805	-3.6744**	-1.6014	-3.7177**
LGdp	-4.3588***		-4.3273***	

Notes: The (I) and (II) indicate to the level and the first difference. Prob. indicates critical probability value. We have not included the statistic values of tests in column (II) for variables that have already reached a stationary state, corresponding to column (I). *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The results, summarized in columns (I) and (II), represent the checking for the stationarity on the level and on the first difference, respectively. No series are stationary at level, except for foreign direct investment (*Fdi*) is I(0) in level at 1% significance level for both models, and for both types of tests. Furthermore, the reel gross domestic product ($LGdp$) is I(0) in difference at 1% significance level for the model with intercept for both types of tests, but it is stationary at 1% significance level for the model with intercept and trend, and for both types of tests. Nevertheless, Herfindahl-Hirschman Index (*LH*) and consumer price index (*LCpi*) series are I(0) at 1% and 5% significance level , respectively, for both models, and for both types of tests. According to these results, the bounds testing for cointegration should be conducted as long as no series contains more than one unit root.

5. ECONOMETRIC ESTIMATES OUTCOMES

5.1 Tests panoply for ARDL application

The results conducted in Table 2 permit the recourse to a suitable ARDL approach. Following to Pesaran et al. (2001), the cointegration test reposes on the comparison of the jointly computed F-statistic of the bounds test to the tabulate two critical values sets for the cases when the variables are all stationary and all non-stationary. If the calculated F-statistic is superior to the upper critical bound value, we will conclude that all variables are cointegrated. Nevertheless, all variables are not cointegrated if the calculated F-statistic is inferior to the lower critical bound value. The ARDL order p and q are automatically defined according to Akaike Information Criteria (AIC)[1]. According to Pesaran and Shin (1999), a goodness adjustment for the ARDL model leads to simultaneously correcting for residual serial correlation and endogeneity problems. These findings are corroborated by statistical tests computed in the following table.

Table 3. Diagnostic tests and F- test for cointegration

LM	ARCH	JB	RESET	F-statistic	Selected model
0.3359	0.2976	0.6253	0.7376		
[0.7189]	[0.5887]	[0.7315]	[0.3986]	11.5687***	ARDL(4,0,0,1,4)

Notes: The values in brackets indicate the *p*-values. For *F*-statistics, the lower bound critical values are 2.2 ($p < 0.1$), 2.56 (P-value < 0.05) and 3.29 ($p < 0.01$), and the upper bound critical values are 3.09 ($p < 0.1$), 3.49 ($p < 0.05$) and 4.37 ($p < 0.01$). *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

According to Table 3, the computed F-statistic is 11.5687, and corroborates long-run association among the variables at the 1% significance level. Moreover, the Breusch-Godfrey LM test and the Jarque-Bera normality test indicate that residuals are independent and normally distributed. The homoscedasticity hypothesis for residuals is not refuted in accordance with the ARCH statistic. Finaly, the hypothesis of the correct functional specification of Equation 3 is accepted in accordance with the RESET test.
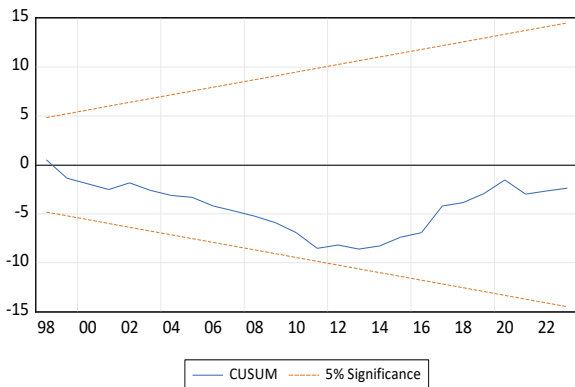
Figure 5. Plot of Cumulative Sum of Recursive Residuals
Source: own
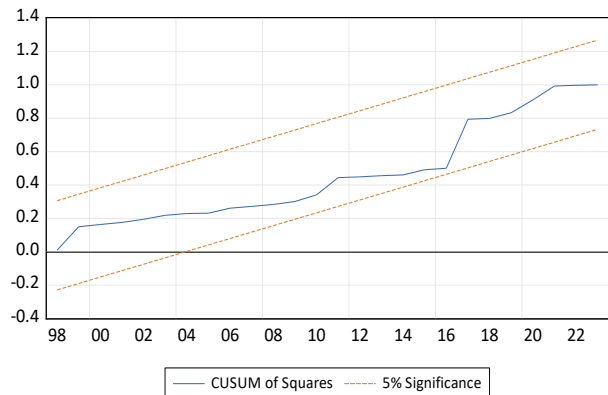
Figure 6. Plot Cumulative Sum of Squares of Recursive Residuals
Source: own

Figures 5 and 6 are plotted according to the tests based on cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of recursive residuals. The results indicate the absence of any instability of coefficients because the plots of CUCUM and CUCUMSQ statistics fall inside the critical bounds of the 5% confidence intervals of parameter stability. Therefore, the stability of the long-run and short-run parameters over the period 1980-2023 is confirmed.

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[1] Lütkepohl (2006).

5.2 Short and long run outcomes

Table 4 presents the short-run estimates, highlighting a negative and statistically significant error correction term [ECT(-1)] at the 1% level. This term acts as an adjustment parameter, indicating how deviations of the dependent variable from its long-run equilibrium are corrected. It confirms the existence of a long-term equilibrium between the economic diversification index and the independent variables related to fiscal policy in Saudi Arabia. Additionally, 89.74% of the variations in the diversification index are corrected by short-run discrepancies towards the long-term trajectory each year. This suggests that the long-term equilibrium will be reestablished after approximately one year and two months.

Table 4. Short-run estimated coefficients

Variables	Coefficients	Std.Error	P-value
D(*LH*(-1))	-0.1800	0.114320	0.1274
D(*LH*(-2))	-0.2479*	0.126271	0.0604
D(*LH*(-3))	-0.4616***	0.132907	0.0018
D(*Fdi*)	7.08E-07	7.07E-07	0.3257
D(*LGdp*)	1.5152***	0.454707	0.0026
D(*LGdp* (-1))	2.8959***	0.654292	0.0002
D(*LGdp* (-2))	1.8585***	0.488177	0.0008
D(*LGdp* (-3))	3.0160***	0.625649	0.0001
ECT(-1)	-0.8974***	0.098269	0.0000

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.
Sources: own

According to Pesaran et al. (2001), the long-run relationship was measured by the ARDL model. More precisely, the set of the long-run estimated coefficients ($\gamma' Y_{t-1}$) associated to the independent variables is summarized in the following Table 5.

Table 5. Short-run estimated coefficients

Variable	Coefficient	Std.Error	Prob.
LGE	-0.6354***	0.0890	0.0000
LCPI	1.3452***	0.3614	0.0010
Fdi	2.64E-06**	1.00E-06	0.0143
LGdp	-0.7066***	0.2361	0.0060
Intercept	16.837***	3.2056	0.0000

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.
Source: own

The coefficients of all variables turned out to be highly significant and exhibit a unidirectional causality between the economic diversification index and Saudi Arabian fiscal policy. A 1% increase in government expenditure results in a 63.5% decrease in the economic diversification index, suggesting that the economy is becoming less diversified as current expenditures dominate total spending. Similarly, a 1% increase in GDP leads to a 70.7% decrease in diversification, reflecting a trend towards less economic diversification. In contrast, a 1% increase in the consumer price index results in a 1.35% increase in the diversification index, indicating a slight positive effect.

To address these issues, the government must rapidly implement large social programs and investment projects while strengthening fiscal policy tools like subsidies and taxes to achieve price stability. Additionally, the government should sustain an intensive program to manage public finances, in order to enhance expenditure efficiency, increase production, and promote non-oil growth to meet the objectives of Vision 2030.

CONCLUSION AND POLICY IMPLICATIONS

This study analyzes the impact of fiscal policy on economic diversification in Saudi Arabia using an ARDL model with data from 1980 to 2023. The results show a significant cointegrated relationship between fiscal policy variables and the economic diversification index. Since 2016, the government has focused on diversification efforts to align with Saudi Arabia's Vision 2030, aiming to reduce production costs for exports and boost output across all sectors, thereby supporting sustainable development.

The Saudi Arabian economy's dependence on oil revenues exposes it to global price fluctuations, which impact imports and domestic prices. Recognizing the risks associated with relying on oil for GDP, the government has prioritized economic diversification as a strategic goal. To reduce the effects of oil price volatility, it must accelerate diversification reforms. The economic diversification index fell from 0.41 at the start of the study to 0.10 in 2021, despite various programs supporting diversification. While the mining sector has traditionally been the largest GDP contributor, its share has decreased since Vision 2030 was implemented. Meanwhile, contributions from sectors such as manufacturing, trade, government services, financial services, insurance, and real estate have increased, reflecting a trend toward greater economic diversification. Moreover, the government must initiate an industrial strategy sector by promoting local and foreign direct investment to stimulate economic diversification and create job opportunities.

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Exploring the Dynamic Interplay between Globalization, Renewable Energy, Economic Growth, and Environmental Impact: Insights from the Saudi Arabian Development Perspective

MOHAMED NEFFATI[1] (Corresponding Author), BADR ABDULAZIZ BINZAID[2], MOUNIR BEN MBAREK[3] and FAHAD ABDULLAH ALDUBAYAN[4]

[1]Assistant Professor, Economics Department, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), email: mrnafati@imamu.edu.sa /neffati.med1@gmail.com
[2]Assistant ProfessorEconomics Department, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), email: bazaid@imamu.edu.sa
[3]Assistant ProfessorEconomics Department, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), email: mounirbenmbarek@isggb.u-gabes.tn
[4]Assistant ProfessorHigher Institute of Management, university of Gabes, Tunisia, email: fadobyan@imamu.edu.sa,

ARTICLE INFO

ABSTRACT

It is important to note that the relationship between energy use and economic growth within the framework of globalization for any economy can vary depending on national contexts, energy policies, technological advances, and environmental pressures. Sustainable and energy-efficient approaches are increasingly seen as essential to reconciling economic growth with environmental conservation. This paper studied the dynamic links between globalization, renewable energy consumption, industry evolution, economic growth, and pollution in the Saudi economy during 1990–2019. We found varied and mixed results by using causality tests based on the VECM model, supported by unit-root tests and co-integration. We developed this study by adding the impulse response function in order to detect the periodic effect of each variable. The main findings show that there are bi-directional links between energy consumption and pollution, as well as between renewable energy consumption and economic growth. The framework of sustainable development presented numerous policy recommendations aimed at achieving a green and sustainable economy for Saudi Arabia.

INTRODUCTION

Because of their interdependence and implications for the economy, environment, and society as a whole, people often discuss globalization and sustainable development together. The link between globalization, renewable energy, economic growth, and pollution is complex and deserves special attention. Globalization, by promoting trade on an international scale, has contributed to significant economic growth in many regions of the world. However, increased energy consumption and greenhouse gas emissions often accompany this economic growth, exacerbating pollution and climate change issues. Renewable energy plays a crucial role in the fight against pollution and climate change. By providing a clean, sustainable

alternative to fossil fuels such as coal, oil, and natural gas, renewable energy helps reduce greenhouse gas emissions and mitigate the harmful effects of pollution on human health and the environment.

Additionally, renewable energy often provides economic benefits by enhancing total factor productivity creating local jobs and spurring technological innovation. Several studies support these arguments. Sohag et al. (2021) demonstrated that renewable energy drives long-term TFP growth through various macroeconomic channels, whereas fossil fuels show an inconclusive impact. In OECD countries, human capital and technological advancements play a pivotal role in boosting TFP. Similarly, Neffati et al. (2023) identified a strong positive long-term relationship between renewable energy and TFP growth in G20 countries but noted a negative relationship in G7 nations due to environmental repercussions. Granger causality tests reveal differing causal directions, highlighting the critical need for global investment in renewable energy to enhance productivity and ensure sustainable development.

In recent decades, there has been a growing focus among researchers and policymakers on the relationship between energy consumption, economic growth, and environmental pollution. Global society has also expressed growing concern about the escalating threats of global warming and climate change, both of which are closely linked to patterns of energy consumption. The heightened awareness of climate change gained significant momentum with the Kyoto Protocol's adoption in 1997. This international agreement mandated industrialized nations to curtail their greenhouse gas emissions, prompting a shift away from reliance on fossil fuels, particularly coal and oil, toward the adoption of renewable energy sources (RES) characterized by their minimal carbon footprint. As a result, the emphasis on increasing the proportion of renewable energy in overall energy consumption becomes paramount, as it proves to be highly effective in mitigating greenhouse gas emissions, as noted by Elliott in 2009.

According to seminal work by Sadorsky (2009), energy availability plays a crucial role in driving economic activity. Traditionally, coal, natural gas, and petroleum have been the predominant and most effective energy sources, contributing significantly to economic development (Ellabban et al., 2014). The demand for these conventional energy sources has surged over the past fifty years due to global economic and social advancements (Aslan et al., 2014). Traditional sources generated approximately 65% of the world's energy in 2013 (IEA, 2015). Nevertheless, in the early 21st century, countries worldwide have grappled with diverse energy-related challenges, marking a global concern regarding reliance on conventional energy sources (Sadorsky, 2009a). This dependence on traditional energy sources has given rise to issues such as energy poverty, fluctuations in energy prices, and an increase in carbon emissions (Destek and Aslan, 2017; Koçak and Şarkgüneşi, 2017).

In addition, climate change on a global scale refers to alterations in long-term weather patterns (Vijaya Venkata Raman, Iniyan, and Goic 2012). This phenomenon may arise from substantial shifts in the frequency of natural climate events or from various climate events triggered by human activities. Climate and weather factors primarily influence these events. Consequently, climate change emerges as a worldwide concern impacting all nations (Chinowsky et al. 2011). In various countries, observational studies examining the relationship between energy consumption, CO2 emissions, and economic development have yielded conflicting results. According to Chinowsky et al., there is a positive correlation between advanced technological development and increased atmospheric pollution, particularly in regions experiencing sophisticated economic growth.

Many countries are exploring alternative energy sources in production, such as renewable energy, to address environmental concerns and reduce carbon footprints. In this regard, the government of the Kingdom of Saudi Arabia (KSA) has formulated an energy policy with the goal of diversifying energy sources and suppliers, as well as fostering private sector involvement. This policy places particular emphasis on the development of renewable and nuclear power generation. The government has devised and implemented several energy efficiency projects, aiming to increase efficiency in the industrial, transportation, and residential sectors. In response to the escalating demand for power, the kingdom has launched a renewable energy program strategically aimed at reducing reliance on fossil fuels to ensure the country's sustainable future. Recognizing that depending on fossil fuels for future economic growth is not a viable and lasting option, the Saudi Arabian government is actively pursuing alternatives. Indeed, Saudi Arabia boasts abundant energy resources such as petroleum, natural gas, and solar energy. The country's diverse geological features and environments present promising opportunities for harnessing other forms of

energy, such as wind energy, nuclear energy, and geothermal energy (Rehman and Shash, 2005). The Kingdom of Saudi Arabia deems the development of solar, wind, and thermal energy plants essential to meet its electrification needs.

The Gulf countries have a large abundance of solar energy throughout the year, which puts them in a privileged position to develop solar energy projects. The United Arab Emirates and Saudi Arabia, for example, have launched huge projects to harness this energy. Some Gulf countries have excellent potential to generate energy through wind energy projects. For example, Kuwait and Oman have begun to explore wind energy potential in the region. Some countries in the Gulf have expressed their desire to develop nuclear energy to meet the growing demand for electricity. The United Arab Emirates, for example, has begun construction of a nuclear power plant. The region faces environmental challenges, including high temperatures and water consumption. These challenges may affect the efficiency of renewable energy generation. The shift to renewable energy sources requires a change in the economic structure that relies heavily on oil and gas exports. Building renewable energy projects requires significant investments, and financing can be particularly challenging in light of low oil prices. In fact, Gulf countries aim to diversify their energy sources and take advantage of their natural resources to meet the growing demand for energy while reducing their environmental impact.

However, to our knowledge, few national and international studies on the link between globalization, total renewable energies, and the growth nexus, including industry evolution, are available in the literature review. Furthermore, in the case of Saudi Arabia, there is no study that has explored this relationship by including industry evolution. This is why we are going to use different estimates, like the Vector Error Correction Model (VECM) and impulse response function (IRF), to look into the connections between short- and long-term CO_2 emissions, economic indicators (GDP per capita), and the use of renewable and nonrenewable energy from 1990 to 2019. In fact, the KSA ranks 6th and 13th, respectively, in producing solar and wind energy.

We organize the rest of the paper as follows: Section 2 provides a literature review that examines the relationship between energy consumption and economic growth. Section 3 presents an overview of the energy sector in Saudi Arabia. Section 4 develops the theoretical VECM model and discusses the data set, including empirical results; and finally, section 5 concludes and offers some policy discussion for the Saudi context.

1. LITERATURE REVIEW

The link between economic growth and energy has been extensively examined, yielding empirical results that are often diverse and conflicting. Variability exists in the identification and direction of the causal link, as well as in the short-term and long-term implications for energy policy. The nature of this causality, whether unidirectional or bidirectional, plays a crucial role in determining the implications for energy consumption and growth rates (Ozturk, 2010). The lack of consensus in studies, even within the same country or geographical area, can be attributed to methodological disparities and differences in the considered databases. For instance, Kraft & Kraft (1978) analyzed annual data from 1947 to 1974 using the Granger method and found that growth "Granger causes" energy in the United States. However, Yu & Hwang (1984), using Sim's technique, found no such link between 1947 and 1979. Hwang & Gum (1991), employing the error correction method in Taiwan from 1961 to 1990, revealed a bidirectional relationship between energy and growth. In contrast, Cheng & Lai (1997) found a unidirectional relationship from GDP to energy in Taiwan between 1954 and 1993. Lee (2005) and Lee & Chang (2007) presented opposing results for developing countries. Lee (2005) discovered that energy "Granger causes" growth from 1975 to 2001, while Lee & Chang (2007) suggested a growth-to-energy relationship from 1965 to 2002 using the VAR and GMM method.

In studies on Korea, Glasure (2002) observed a bidirectional relationship with annual data from 1961 to 1990, where energy and GDP influenced each other. On the other hand, Oh & Lee (2004) found a unidirectional causal relationship, where energy causes GDP between 1970 and 1999. Soytas & Sari (2006) explored G-7 countries and identified three forms of links during 1960-2004: GDP causing energy in Germany, energy causing GDP in France and the United States, and mutual influence in Italy, Canada, Japan, and England. In contrast, Narayan & Smith (2008) found a unidirectional relationship where energy

causes GDP in the G-7 countries over the period 1972-2002. Aspergis & Payne (2009) demonstrated that the causal relationship between energy and the product may evolve over time. Their study on commonwealth countries revealed a unidirectional link in the short term, where energy causes the product, and a bidirectional relationship in the long term.

Additionally, Apergis and Payne (2010) propose that a notable increase in renewable energy presents a viable alternative energy source. Al-Mulali et al. (2013) suggest that augmenting the share of renewable energy can diminish reliance on traditional sources, thereby ensuring energy security. The International Energy Agency (IEA) reported that there is an approximately 3% annual growth rate in renewable energy consumption, marking it as the fastest-growing global energy source (IEA, 2015). Recent trends reveal that governmental initiatives, such as incentives, tax credits, and subsidies, play a pivotal role in propelling the development of renewable energy. Presently, nations prioritize technology advancements and energy production from renewable sources, shaping the predominant elements of energy policy formulation. Some researchers have examined how structural changes in the economy, such as the shift from an industrial to a service economy, can influence the relationship between energy consumption and growth.

Several notable studies have delved into the relationship between energy and economic growth, providing compelling insights. One such study outside of Africa is conducted by Apergis and Payne (2010), who investigate the impact of renewable energy consumption on economic growth in twenty OECD countries from 1985 to 2005. Apergis and Payne (2010) extend this analysis to 13 Eurasian countries, and in a separate study, they explore six Central American countries, utilizing the same production function. Expanding their scope, Apergis and Payne (2011) incorporate non-renewable electricity consumption into their production function, focusing on 16 emerging market economies. Although the estimated coefficient on renewable electricity consumption is positive, it is not deemed statistically significant. In a broader study spanning 80 countries from 1990 to 2007, Apergis and Payne (2012b) find that a 1% increase in renewable energy consumption correlates with a 0.371% rise in real GDP.

Al-mulali et al. (2014) compare the roles of renewable and non-renewable electricity consumption in driving economic growth across 18 Latin American countries from 1980 to 2010. Granger causality tests indicate that renewable electricity consumption plays a more substantial role in boosting output than its non-renewable counterpart. Shahbaz et al. (2015) employ an auto-regressive distributed lag (ARDL) method to explore the connection between renewable energy consumption and economic growth in Pakistan from 1972 to 2011. Inglesi-Lotz (2016) analyzed the impact of renewable energy consumption and its proportion in the total energy mix on economic growth in OECD countries, finding a positive and statistically significant effect. Bhattacharya et al. (2016) extend the analysis to 38 top renewable energy countries, while Paramati et al. (2017) focus on the role of renewable energy in economic growth for the Next 11 developing countries from 1990 to 2012.

Jebli and Youssef (2015) integrated international trade into their production function, examining the effects of capital, labor, renewable, and non-renewable energy on output for 69 countries from 1980 to 2010. OLS, DOLS, and FMOLS results suggest that the elasticity estimate of renewable energy is approximately 4%. Halicioglu and Ketenci (2018) employed the same production function for EU-15 countries from 1980 to 2015, using both ARDL and GMM methods. Their findings reveal that renewable and non-renewable energy affect output differently in each country. In the context of examining the links between renewable energy use and economic growth in developing countries, Ben Mbarek et al. (2018) provide valuable insights into the relationship between these two critical factors. Their study, focused on Tunisia, demonstrates the significant role that renewable energy consumption plays in fostering economic growth. By utilizing advanced econometric techniques, they show a positive and long-term association between renewable energy use and economic performance, which highlights the importance of transitioning to cleaner energy sources for sustainable development in emerging economies. This research underscores the broader implications for other developing nations aiming to enhance growth while minimizing environmental impacts.

In response to growing environmental concerns, a body of research integrates the analysis of the interplay among three variables: growth, energy, and pollution. Noteworthy investigations employing this approach include studies by Soytas et al. (2007), Akbostanci et al. (2009), Soytas & Sari (2009), Zhang & Cheng (2009), Jalil & Mahmud (2009), Ozturk & Acaravci (2010), Apergis & Payne (2010, 2014), Alam et

al. (2011), and others. For instance, Izyan et al. (2013) examined the causal links between energy consumption, economic growth, and CO_2 emissions in three Association of Southeast Asian Countries (ASEAN) nations like Malaysia, Indonesia, and Singapore during 1975-2011. Results varied across countries. In Malaysia, two unidirectional causal relationships were identified: from CO_2 emissions to energy consumption and from energy consumption to economic growth. In Indonesia, economic growth caused CO_2 emissions, while energy caused growth. In Singapore, no causal relationship among the three variables was observed.

Arouri et al. (2012) investigated the Environmental Kuznets Curve (EKC) in 12 Middle East and North Africa (MENA) countries from 1981 to 2005. They found that the EKC was not validated, concluding that MENA countries cannot reduce CO_2 emissions without slowing down economic growth. Through unit root and panel cointegration tests, they established a significantly positive long-term impact of energy consumption on CO_2 emissions for the entire region. The relationship between growth and CO_2 emissions was identified as quadratic. Alam et al. (2011) studied the causal links among energy consumption, carbon dioxide (CO_2), and income in India from 1971-2006. Their results indicated a long-term bidirectional relationship between energy consumption and CO_2 emissions. However, the relationship was neutral between income and both energy consumption and CO_2 emissions. Wang et al. (2011) affirmed the existence of causal relationships between economic growth, energy consumption, and CO_2 emissions in their study of 28 Chinese provinces from 1995 to 2007. Using a Vector Error Correction Model (VECM), they identified bidirectional relationships between CO_2 and energy, as well as between growth and energy, in the short term. In the long term, energy and growth influenced CO_2 emissions, and vice versa.

Al-Mulali (2011) demonstrated, in a study covering the Middle East and North Africa (MENA) countries from 1980-2009, a long-term relationship between CO_2 emissions, oil consumption, and economic growth. Short-term results revealed a bidirectional relationship among CO_2, oil consumption, and economic growth. Apergis & Payne (2010) focused on 11 Commonwealth countries during 1992-2004, studying the causal links between energy consumption, real GDP and CO_2 emissions. In the short term, bidirectional relationships existed between energy consumption and real GDP, and two unidirectional relationships from real GDP to CO_2 emissions and from energy consumption to CO_2 emissions. In the long term, a bidirectional relationship between energy and CO_2 was identified. Additionally, the relationship between real GDP and CO_2 exhibited an inverted "U" shape, with CO_2 emissions initially increasing with real GDP and then decreasing after reaching a certain threshold. In the context of developing and emerging economies, our literature review reveals a notable gap in research. The existing studies predominantly focus on major Asian economies, particularly China and Pakistan, as well as Latin American countries. However, limited attention has been directed toward emerging petroleum nations, particularly those in the Middle East, such as Saudi Arabia.

2. OVERVIEW ON ENERGY SECTOR IN SAUDI ARABIA

Saudi Arabia, historically recognized for its extensive oil reservoirs and impact on worldwide petroleum markets, faces the urgent need to shift towards more eco-friendly energy sources amid the critical challenges posed by climate change. The global trend is leaning towards cleaner energy solutions to mitigate greenhouse gas emissions and address the issue of global warming. Against this backdrop, it becomes crucial for the kingdom to assess and channel investments into viable sustainable energy alternatives.

Saudi Arabia is one of the world's largest oil producers and exporters, and the oil and natural gas energy sector forms the backbone of the national economy. This sector plays a crucial role in determining the Kingdom's economic growth paths. This topic addresses the role of the energy sector in economic growth in the Kingdom of Saudi Arabia and the efforts made by the government to promote economic diversification and achieve sustainable development. In fact, the Kingdom of Saudi Arabia is considered one of the largest oil producers and exporters in the world, and possesses huge reserves of oil and natural gas. The energy sector plays a vital role in the Kingdom's economy. Oil is a major source of national revenue. The Kingdom is working to diversify its energy sources, and is investing in areas such as solar and wind energy. There is a shift towards using renewable energy sources to meet growing electricity needs. The Kingdom is investing in major projects in the energy field, including the NEOM project, which aims to develop a special economic zone for energy, technology and sustainability.

The Saudi Kingdom's reliance on gas for electricity generation has become increasingly significant. In 2017, over 64% of its electricity was generated from natural gas, with only 36% from oil—a share that has sharply declined. Due to the gradual development of its renewable energy sector, Saudi Arabia is actively working on enhancing both its conventional and unconventional gas production. The Kingdom has set an ambitious goal of doubling its total production within the next ten years. Unlike the UAE, Saudi Arabia meets its domestic gas consumption needs through its own production, which amounted to 112 Gm3 in 2018. Furthermore, it aspires to become a net exporter. Despite this declared intention, uncertainties persist regarding Saudi Arabia's ability to export gas in the coming decades. Both the UAE and Saudi Arabia share a common objective of diversifying their energy mix by harnessing alternative energies. They aim to capitalize on the region's vast potential in renewable energies, particularly solar power. This move signifies a strategic effort to reduce dependence on traditional energy sources and align with global trends in sustainable and environmentally friendly energy production.

3. METHODOLOGY AND RESULTS

Our objective in this paper is to determine the dynamic links between renewable energy consumption, industry evolution, economic growth and pollution for Saudi economy during 1990-2019 using granger causality tests based on VECM model and supported by unit-root tests and co-integration. In addition, VECM is an extension of the Vector Auto-regression (VAR) model which makes it possible to model co-integration relationships between several time series (variables). It is particularly useful when the time series are non-stationary and exhibit a long-term relationship. The VECM model begins with a VAR model that captures short-term relationships between variables. A p-order VAR model specifies how each variable depends on its own lags and the lags of other variables.

$$Y_t = \alpha + \sum_{i=1}^{p} p A_i Y_{t-1} + \varepsilon_t$$

where Y_t is the vector of endogenous variables at the time (t). The matrices A_i are the coefficients, α is the intercept vector, and ε_t the error vector for each model. VECM includes the possibility of co-integration between variables, meaning that there is a stable long-term relationship between these variables. This is detected by the Engle-Granger test or the Johansen test. VECM incorporates co-integration errors through error correction terms. These terms adjust short-term variables toward their long-term equilibrium.

3.1 Descriptive statistic

Table 1 present the annual data used in this the paper which are taken from the World Development Indicator (WDI, 2022-CD-ROM) for Saudi Arabia, and cover 1990–2019. The analyzed variables are: the economic growth (measured by Gross Domestic Product Growth Per capita, annual %), globalization (GLI) measured by index, CO2 emissions (measured in metric tons per capita), energy use (EU) (measured in kilogram (kg) of oil equivalent per capita), and Renewable energy consumption RE by % of total final energy consumption (measured in 1000 metric tons of oil equivalent). In fact, the descriptive statistics for the variables in this study provide valuable insights into their central tendencies, variability, and distributional characteristics, essential for understanding the underlying data patterns. The mean CO2 emissions per capita stand at 13.32 metric tons, with a median of 12.80, indicating a slight positive skewness (0.43) and moderate variability (standard deviation of 2.12). The distribution is relatively flat, as evidenced by the kurtosis of 1.73, and does not significantly deviate from normality, as shown by the Jarque-Bera test (p = 0.227). Energy consumption per capita (EC) exhibits a mean of 99.88 kg of oil equivalent, with a median close to this value (99.99), indicating a nearly symmetrical distribution. However, it is significantly negatively skewed (-1.86) with very low variability (standard deviation of 0.24) and a leptokurtic distribution (kurtosis of 5.04). The Jarque-Bera test confirms a significant deviation from normality (p = 0.00001).

The economic growth variable (GDPGPC) has a mean of 0.79%, with a median substantially lower at 0.27%, highlighting a positive skew (0.66). This variable exhibits substantial variability, as indicated by the standard deviation of 4.47%, and a distribution that is approximately normal (kurtosis of 2.90), with no significant deviation from normality (p = 0.33). Industrial activity (IND) presents a mean of 3.24, with a

median of 2.57, indicating positive skewness (1.22) and significant variability (standard deviation of 7.18). The distribution is leptokurtic (kurtosis of 4.35) and deviates significantly from normality (p = 0.0077).

Renewable energy consumption (RE) is characterized by a very low mean (0.0146) and median (0.01000), with a strong positive skewness (1.76) and low variability (standard deviation of 0.0093). The distribution is sharply peaked (kurtosis of 4.64) and significantly deviates from normality (p = 0.00008). Finally, the globalization index (GLI) shows a mean of 0.1059 and a median of 0.0886, indicating moderate positive skewness (0.75) and variability (standard deviation of 0.0604). The distribution is nearly normal (kurtosis of 2.99) and does not significantly deviate from normality (p = 0.24). Collectively, these statistics underscore the variability and distributional characteristics of the data, providing a foundational understanding for subsequent analyses in the context of the study's focus on economic growth, globalization, environmental impact, and energy consumption. The descriptive statistics Mean, Median, Maximum, and Minimum of these variables are recorded below in Table 1. The correlation test is also attached by this table. According the correlation test by table (1), starting with CO_2 emissions (CO2), it shows a moderate positive correlation with energy consumption (EC) (0.525), indicating that higher energy consumption is associated with increased CO_2 emissions. This relationship aligns with expectations, as greater energy use typically leads to more emissions. However, CO_2 emissions have a weak positive correlation with GDP per capita growth (GDPGPC) (0.066), suggesting that economic growth is not strongly linked to changes in CO_2 emissions in this context. Interestingly, CO_2 emissions are weakly negatively correlated with industrial activity (IND) (-0.113), which may reflect efficiency improvements or shifts towards less carbon-intensive industries. The negative correlation between CO_2 emissions and renewable energy consumption (RE) (-0.414) suggests that greater reliance on renewable energy sources tends to reduce CO_2 emissions, highlighting the environmental benefits of renewable energy adoption. Finally, the correlation between CO_2 emissions and the globalization index (GLI) is moderately negative (-0.597), implying that higher levels of globalization are associated with lower CO_2 emissions, which might be due to increased access to cleaner technologies or stricter environmental regulations associated with globalization.

The energy consumption (EC) variable exhibits a very weak positive correlation with GDPGPC (0.117) and an almost negligible correlation with industrial activity (IND) (0.004). These weak correlations indicate that, within this dataset, energy consumption is not strongly driven by economic growth or industrial activity. The correlation between energy consumption and renewable energy consumption (RE) is also low (0.101), suggesting that the overall energy consumption levels are not heavily influenced by the share of renewables. However, there is a modest positive correlation between energy consumption and the globalization index (GLI) (0.325), indicating that more globalized economies tend to consume more energy, possibly due to increased economic activities linked to globalization.

GDP per capita growth (GDPGPC) has a strong positive correlation with industrial activity (IND) (0.968), indicating that economic growth in this context is closely tied to industrial expansion. This is a common finding in many economies where industrial output is a significant driver of GDP growth. The correlation between GDPGPC and renewable energy consumption (RE) is moderate (0.289), suggesting that economies with higher growth rates may also be increasing their use of renewable energy, although this relationship is not particularly strong. Additionally, the positive correlation between GDPGPC and the globalization index (GLI) (0.627) indicates that more globalized economies tend to experience higher economic growth, reflecting the benefits of globalization on economic expansion.

Industrial activity (IND) is strongly positively correlated with GDPGPC (0.968) and also shows moderate positive correlations with renewable energy consumption (RE) (0.449) and the globalization index (GLI) (0.669). These correlations suggest that industrial growth is associated with both economic growth and increased use of renewable energy, as well as higher levels of globalization, which could be due to industrial sectors benefiting from global markets and investments. Renewable energy consumption (RE) shows moderate positive correlations with industrial activity (IND) (0.449) and the globalization index (GLI) (0.675). This suggests that more industrialized and globalized economies are likely to adopt renewable energy sources. The relationship between renewable energy consumption and GDPGPC is weaker (0.289), but still positive, indicating that economic growth might be somewhat conducive to renewable energy adoption. Finally, the globalization index (GLI) is positively correlated with all the variables except CO_2 emissions. The strongest positive correlations are with industrial activity (IND) (0.669) and renewable energy

consumption (RE) (0.675), indicating that globalization is linked with industrial expansion and the adoption of renewable energy. The positive correlation with GDPGPC (0.627) further supports the idea that globalization promotes economic growth. The negative correlation with CO2 emissions (-0.597) suggests that globalization might contribute to reducing CO2 emissions, potentially through the diffusion of cleaner technologies and practices.

In summary, the correlation analysis reveals that industrial activity and globalization are key drivers of economic growth, with significant positive correlations across related variables. Renewable energy consumption is positively associated with industrialization and globalization, while CO2 emissions are negatively correlated with globalization and renewable energy use, highlighting the potential environmental benefits of these trends.

Table 1. Descriptive statistic and correlations between variables

	CO2	EC	GDPGPC	IND	RE	GLI
Mean	13.320	99.878	0.7933	3.2370	0.0146	0.1058
Median	12.798	99.995	0.2679	2.5747	0.0100	0.0885
Maximum	17.257	99.996	10.522	22.845	0.0400	0.2560
Minimum	10.709	99.203	-6.2234	-6.9587	0.0100	0.0150
Std. Dev.	2.1195	0.2404	4.4730	7.1835	0.0093	0.0604
Skewness	0.4322	-1.8552	0.6637	1.2193	1.7600	0.7546
Kurtosis	1.7277	5.0391	2.8983	4.3534	4.6354	2.9959
Jarque-Bera	2.9574	22.407	2.2154	9.7235	18.832	2.8477
Probability	0.2279	0.0000	0.3303	0.0077	0.0001	0.2407
Sum	399.61	2996.3	23.801	97.112	0.4400	3.1760
Sum Sq. Dev.	130.28	1.6760	580.23	1496.5	0.0025	0.1057
Observations	30	30	30	30	30	30
Correlation	CO2	EC	GDPGPC	IND	RE	GLI
CO2	1.0000	-	-	-	-	
EC	0.5252	1.0000	-	-	-	
GDPGPC	0.0657	0.1171	1.0000	-	-	
IND	-0.1128	0.0038	0.9679	1.0000	-	
RE	-0.4142	0.1006	0.2888	0.4486	1.0000	
GLI	-0.5968	0.3251	0.6265	0.6693	0.6754	1.0000

Source: own

3.2 Stationary analysis

We begin our empirical study by analyzing the stationarity of each variable and by applying the unit root tests at level and first difference (table (2)); first, we apply the Augmented Dickey Fuller (ADF) test introduced by Dickey & Fuller (1979). In practice, stationarity tests, including the Phillips & Perron (1988) (PP) test, are often used as a preliminary step in time series analysis before choosing an appropriate model. In fact, the optimal approach for ascertaining the integration order of a series relies on employing unit root tests. These tests are designed to identify the existence of a unit root within a series. Typically, two commonly utilized unit root tests include the ADF test, and the PP test.
Taking the ADF test on the CO2 series as an example, we express the test equation with the constant term, as well as the trend and intercept terms, as follows:

$$\Delta CO2_t = \alpha + \beta_t + \delta CO2_t + \sum_{i=1}^{k} \beta_i CO2_{t-i} + \varepsilon_t$$

where α, β, and δ are coefficients; ε is a residual term; and k is the lag length, which transforms the residual term into a stochastic variable. The null hypothesis H0 is $\delta = 0$; meaning that there is at least one-unit root, causing non-stationarity in the series. The test is conducted with three formulations: ($\alpha \neq 0$, $\beta \neq 0$), ($\alpha = 0$, $\beta \neq 0$), and ($\alpha = 0$, $\beta = 0$). The Unit root test presented in next table (2) confirms that all variables have the same degree of integration (are stationary in first difference).

Table 2. Unit root tests

Variables	Level		1st Difference	
	(i)	(ii)	(i)	(ii)
ADF Test				
CO2	6.6435	-2.4231	-4.8998*	-3.1011**
EC	-0.4477	-1.4374	-5.0320*	-4.8835*
GDPGPC	1.7320	-0.3742	-3.6748*	-4.4378*
IND	3.3443	-0.9669	-4.2721*	-6.3627*
RE	1.9666	-2.1325	-2.7598*	-3.7179**
GLI	0.7326	-4.448927	-4.132565*	-4.8838*
PP test				
CO2	5.4596	-2.4231	-4.8938*	3.8808**
EC	-0.3114	-1.4374	-5.0350*	-4.8865*
GDPGPC	3.7622	0.7243	-3.6790*	-4.5698*
IND	5.9720	-1.4528	-4.2843*	-9.1356*
RE	1.9066	-2.1366	-2.6980*	-2.9135*
GLI	0.7456	-4.3565	-4.8656*	-4.6958*

Note: Without constant, (ii): with a constant. * and **: asterisks denote p-value less than 1% and 5%. Critical levels in the model: (i) -2.60 (1%) and -1.95 (5%).
Source: own

3.3 Co-integration analysis

The Toda and Yamamoto Granger causality analysis does not necessitate the existence of co-integration. However, for the examination of long-run estimates using the VECM model, the presence of co-integration becomes essential. The Johansen co-integration test employs trace statistics and max-eigenvalue statistics, with the null hypothesis requiring rejection at a 5% significance level to confirm long-run co-integration among variables. The equation for the Unrestricted Cointegration Rank Test (Trace) is as follows:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{k} \ln{(1 - \hat{\lambda}_i)}$$

The trace statistic, denoted as $\lambda_{trace}(r)$, tests the null hypothesis that there are at most (r) cointegrating vectors among the variables. In this context, T represents the number of observations, while $\hat{\lambda}_i$ refers to the estimated eigenvalues, also known as characteristic roots, derived from the model's estimation. The test is conducted for different values of (r), ranging from $(r = 0)$ to $(r = k - 1)$, where (k) is the total number of variables in the system. The null hypothesis H_0 asserts that there are at most (r) cointegrating relationships within the dataset.

Table 3 reveals that both trace and max-eigenvalue tests signify 1 and 2 co-integration relationships, respectively, among the selected variables at a 5% significance level. In fact, The Unrestricted Cointegration Rank Test (Trace) indicates a strong long-term relationship among the variables CO2 emissions, energy consumption (EC), GDP per capita growth (GDPGPC), industrial activity (IND), renewable energy consumption (RE), and globalization index (GLI). The test rejects the null hypothesis of no cointegration at the 5% significance level for up to three cointegrating equations. Specifically, the trace statistics for the first three ranks are 102.32, 55.529, and 31.458, each exceeding their respective critical values, with associated p-values of 0.0000, 0.0081, and 0.0319. This suggests that there are up to three cointegrating relationships among these variables, indicating a stable and long-run equilibrium among them.

The identification of long-run co-integration lends support to the assertion of Granger causality between the variables. The co-integration test solely indicates the existence of Granger causality among the chosen variables without specifying the direction of this causal relationship. Subsequent tests were employed to investigate the causality among the selected variables.

Table 3. Co-integration test

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value (0.05)	Prob.**
None *	0.8120	102.32	69.818	0.0000
At most 1 *	0.5766	55.529	47.856	0.0081
At most 2 *	0.5117	31.458	29.797	0.0319
At most 3	0.3029	11.382	15.494	0.1890
At most 4	0.0445	1.2763	3.8414	0.2586

Note: Trace test indicates 3 cointegrating equ(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values
Source: own

3.4 VAR Lag Order Selection Criteria

The number of lags to include in a vector autoregressive (VAR) model depends on several factors, including the structure of the data, the complexity of the underlying system, and the modeling objectives. In general, to determine the optimal number of lags in a VAR model, several approaches can be used. In fact, the lag length selection criteria indicate that one lag is optimal for estimating the VAR and VECM models, as evidenced by multiple measures: the LR test shows the highest statistic at lag 1 (102.7370), the FPE is minimized at one lag (4.92e-06), and both the SC (3.368706) and HQ (2.357021) criteria also reach their lowest values at this lag. Although the AIC reaches its minimum at lag 3, it still shows a notably low value at lag 1 (1.928887). The consistency across these criteria suggests that using one lag is appropriate for capturing the dynamics among the variables CO_2, energy consumption (EC), GDP per capita growth (GDPGPC), industrial activity (IND), and renewable energy consumption (RE), balancing model complexity with explanatory power for robust and reliable results.

Table 4. VAR model

Endogenous variables: CO2 EC GDPGPC IND RE						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-62.085	NA	9.90e-05	4.9692	5.2092	5.0406
1	3.9600	102.73*	4.92e-06*	1.9288	3.3687*	2.3570*
2	22.655	22.157	9.71e-06	2.3958	5.0355	3.1808
3	54.753	26.154	1.09e-05	1.8700*	5.7096	3.0117

Note: * indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.
Source: own

3.5 Causality analysis based on VECM model

In the Granger sense, one time series "causes" another series if knowledge of the history of the first improves the prediction of the second. According to Sims (1980), a series can be recognized as causing another series if the innovations in the first contribute to the variance of the forecasting error in the second. Since the development of this statistical hypothesis test, some studies on the properties of various testing methods have been published, such as Belloumi (2009), Mantalos and Shukur (2010), Sung and Song (2013), BenMbarek et al (2016) and Koondhar et al (2021).

The mathematical representation of Granger causality can be formulated using autoregressive (AR) models. Let's assume we have the following AR models:

$$Y_t = \alpha + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{j=1}^{q} \gamma_i X_{t-j} + \epsilon_t$$

$$X_t = \delta + \sum_{k=1}^{r} \mu_k X_{t-k} + \sum_{l=1}^{s} \emptyset_l X_{t-l} + v_t$$

In these equations, the coefficients γ_j and $\emptyset_l$ measure the impact of the delays of X and Y respectively on the current values of Y and X.

- $\Delta GDPGPC_t = \alpha_1 ECT_{t-1} + \sum_{k=1}^{p-1}\beta_{11k}\Delta GDPGPC_{t-k} + \sum_{k=1}^{p-1}\beta_{12k}\Delta EC_{t-k} + \sum_{k=1}^{p-1}\beta_{13k}\Delta RE_{t-k} + \sum_{k=1}^{p-1}\beta_{14k}\Delta IND_{t-k} \sum_{k=1}^{p-1}\beta_{15k}\Delta CO2_{t-k} + \sum_{k=1}^{p-1}\beta_{16k}\Delta GLI_{t-k} + \mu_{1t}$

- $\Delta EC_t = \alpha_2 ECT_{t-1} + \sum_{k=1}^{p-1}\beta_{21k}\Delta GDPGPC_{t-k} + \sum_{k=1}^{p-1}\beta_{22k}\Delta EC_{t-k} + \sum_{k=1}^{p-1}\beta_{23k}\Delta RE_{t-k} + \sum_{k=1}^{p-1}\beta_{24k}\Delta IND_{t-k} \sum_{k=1}^{p-1}\beta_{25k}\Delta CO2_{t-k} + \sum_{k=1}^{p-1}\beta_{26k}\Delta GLI_{t-k} + \mu_{2t}$

- $\Delta RE_t = \alpha_3 ECT_{t-1} + \sum_{k=1}^{p-1}\beta_{31k}\Delta GDPGPC_{t-k} + \sum_{k=1}^{p-1}\beta_{32k}\Delta EC_{t-k} + \sum_{k=1}^{p-1}\beta_{33k}\Delta RE_{t-k} + \sum_{k=1}^{p-1}\beta_{34k}\Delta IND_{t-k} \sum_{k=1}^{p-1}\beta_{35k}\Delta CO2_{t-k} + \sum_{k=1}^{p-1}\beta_{36k}\Delta GLI_{t-k} + \mu_{3t}$

- $\Delta IND_t = \alpha_4 ECT_{t-1} + \sum_{k=1}^{p-1}\beta_{41k}\Delta GDPGPC_{t-k} + \sum_{k=1}^{p-1}\beta_{42k}\Delta EC_{t-k} + \sum_{k=1}^{p-1}\beta_{43k}\Delta RE_{t-k} + \sum_{k=1}^{p-1}\beta_{44k}\Delta IND_{t-k} \sum_{k=1}^{p-1}\beta_{25k}\Delta CO2_{t-k} + \sum_{k=1}^{p-1}\beta_{46k}\Delta GLI_{t-k} + \mu_{4t}$

- $\Delta CO2_t = \alpha_5 ECT_{t-1} + \sum_{k=1}^{p-1}\beta_{51k}\Delta GDPGPC_{t-k} + \sum_{k=1}^{p-1}\beta_{52k}\Delta EC_{t-k} + \sum_{k=1}^{p-1}\beta_{53k}\Delta RE_{t-k} + \sum_{k=1}^{p-1}\beta_{54k}\Delta IND_{t-k} \sum_{k=1}^{p-1}\beta_{55k}\Delta CO2_{t-k} + \sum_{k=1}^{p-1}\beta_{56k}\Delta GLI_{t-k} + \mu_{5t}$

- $\Delta GLI_t = \alpha_6 ECT_{t-1} + \sum_{k=1}^{p-1}\beta_{61k}\Delta GDPGPC_{t-k} + \sum_{k=1}^{p-1}\beta_{62k}\Delta EC_{t-k} + \sum_{k=1}^{p-1}\beta_{6k}\Delta RE_{t-k} + \sum_{k=1}^{p-1}\beta_{64k}\Delta IND_{t-k} \sum_{k=1}^{p-1}\beta_{65k}\Delta CO2_{t-k} + \sum_{k=1}^{p-1}\beta_{66k}\Delta GLI_{t-k} + \mu_{6t}$

The Error Correction Term (ECT) reflects long-run causality; if the coefficient α_i is significant, it indicates that the variable adjusts in response to deviations from the long-run equilibrium. Meanwhile, the β_{ijk} coefficients capture short-run Granger causality, where their significance indicates whether the past values of one variable can help predict changes in another, thus revealing the presence of short-term predictive relationships among the variables.

Among the main results in Table 5, there is bidirectional causality between globalization and economic growth with a significance level of 5% at short run.

The Vector Error Correction Model (VECM) Granger causality results reveal a complex network of relationships among the examined variables, characterized by both unidirectional and bidirectional causality in the short and long run, with varying levels of statistical significance. These results provide a nuanced understanding of how energy consumption, economic growth, industrial activity, environmental impact, and globalization are interrelated in the context of Saudi Arabia's economic landscape.

In the short run, several unidirectional causal relationships emerge, each significant at different levels. Energy consumption (EC) exhibits a significant unidirectional influence on GDP per capita growth (GDPGPC) at the 5% level, emphasizing the critical role of energy in driving economic expansion. Furthermore, EC significantly influences renewable energy consumption (RE) and carbon dioxide emissions (CO2) at the 1% level, suggesting that increases in energy consumption lead to higher adoption of renewable energy and greater carbon emissions. This relationship underscores the tension between promoting economic growth through energy use and managing its environmental consequences.

Industrial activity (IND) also displays unidirectional causality, affecting GDPGPC and CO2 at the 5% () and 1% level, respectively. The significant influence of IND on GDPGPC highlights the importance of industrial sectors in boosting economic performance, while the strong link between IND and CO2 emissions points to the environmental challenges posed by industrial growth. These results indicate that as industrial activity intensifies, it not only drives economic growth but also contributes significantly to environmental degradation, necessitating careful management of industrial expansion to minimize its ecological impact.

Moreover, GDP per capita growth (GDPGPC) is found to unidirectionally cause changes in the globalization index (GLI) at the 1% level, indicating that economic growth in Saudi Arabia is a key driver of the country's increasing integration into the global economy. This finding suggests that as the economy grows, it becomes more interconnected with global markets, reflecting the influence of domestic economic performance on globalization trends.

In addition to these unidirectional relationships, bidirectional causality is observed between certain variables, signifying reciprocal interactions. The bidirectional causality between GDPGPC and EC in the short run, significant at the 5% level, suggests a reinforcing loop where energy consumption drives economic growth, and economic growth in turn increases energy consumption. This interdependence highlights the challenge of balancing energy demand with sustainable economic development. Similarly, the bidirectional causality between EC and IND at the 5% level underscores the dynamic interplay between industrial output and energy consumption, with each influencing the other. This relationship reflects the close connection between energy use and industrial activity, suggesting that energy policies must be aligned with industrial strategies to ensure sustainable growth.

In the long run, the VEC term indicates significant causality affecting GDPGPC and IND. The long-term causality running from the exogenous variables to GDPGPC is significant at the 1% level, indicating that GDPGPC is influenced by long-term equilibrium relationships with the other variables, such as EC, IND, and GLI. This finding suggests that sustainable economic growth in Saudi Arabia depends on the careful management of these variables over time. The significant long-run causality to IND at the 1% level implies that industrial activity is particularly sensitive to long-term changes in energy consumption, economic conditions, and possibly environmental regulations. This sensitivity indicates that industries may need to adapt to evolving economic and environmental landscapes to sustain their growth over the long term.

Overall, these results provide a comprehensive understanding of the intricate relationships between energy consumption, economic growth, industrial activity, environmental impact, and globalization in Saudi Arabia. The identified unidirectional and bidirectional causal links, significant at various levels, suggest that policymakers must carefully coordinate energy policies, industrial strategies, and globalization efforts to support sustainable economic growth while managing environmental impacts. This integrated approach is essential for achieving long-term development goals in the context of globalization and economic transformation.

Table 5. Short- and long-term results by VEC Granger causality

		Exogenous variables						
		Short run						Long run
		D(GDPGPC)	D(EC)	D(RE)	D(IND)	D(CO2)	D(GLI)	VEC
Exogenous variables	D(GDPGPC)	-	5.477** (0.0193)	1.6138 (0.2040)	4.3725** (0.0365)	2.4458 (0.1178)	8.213** (0.0165)	1.913*** [4.1245]
	D(EC)	5.685** (0.0171)	-	1.6679 (0.1965)	4.5343** (0.0332)	2.8317* (0.0924)	2.9882 (0.2244)	-0.01463 [-0.5432]
	D(RE)	0.3986 (0.5278)	14.916*** (0.0001)	-	0.1471 (0.7013)	10.31*** (0.0013)	20.931 (0.0000)	0.0135 [0.2881]
	D(IND)	0.3130 (0.5758)	1.3532 (0.2447)	0.0003 (0.9872)	-	0.432712 (0.5107)	1.7635 (0.4140)	3.2021*** [4.947]
	D(CO2)	0.1872 (0.6652)	14.836*** (0.0001)	0.0259 (0.8719)	10.732*** (0.0011)	-	1.2408 (0.5377)	0.0255 [0.5237]
	D(GLI)	11.47** (0.0032)	0.6712 (0.7149)	2.4471 (0.2942)	1.0139 (0.6023)	0.2420 (0.8860)	-	0.2078 [0.9576]

Note: H0 Rejected (***) the null hypothesis at 1% level, H0 rejected (**) the null hypothesis at 5% significant level, H0 Rejected (*) the null hypothesis at 10% level.
Source: own

3.6 Impulse response function

In the context of Granger causality, one can examine the impulse response function (IRF) to assess the response of one time series to a shock or impulse in another time series. However, it is important to note that the term "impulse response function" may be more frequently associated with linear dynamic systems and signal theory rather than Granger causality, which is typically based on statistical methods. In fact, the impulse response function (IRF) is an important concept in signal processing and systems theory. It describes the output of a system in response to a unit impulse, which is an idealized mathematical function that is zero everywhere except at a single point where it takes the value of 1.

The Kingdom is committed to promoting sustainability and environmental preservation in the energy sector, as it has an ambitious vision to achieve sustainable development and reduce carbon emissions. The Kingdom seeks to enhance innovation in the field of energy and use the latest technologies to improve oil and gas production and enhance the efficiency of energy consumption.

The Kingdom seeks to enhance international cooperation in the field of energy by establishing partnerships with international companies and participating in global projects to develop energy sources. The Kingdom of Saudi Arabia occupies an important position in the global energy market, and is trying to direct its attention towards achieving sustainable development and diversifying energy sources with the aim of maintaining the sustainability of its economy in the future.

Interpretation:

The Impulse Response Functions (IRFs) derived from the Vector Error Correction Model (VECM) offer a detailed view of how shocks to one variable influence the dynamics of other variables over time. Each response reflects the significance and duration of the impact, providing a deeper understanding of the relationships within the model, particularly in the context of Saudi Arabia's economic and environmental landscape.
Starting with the response of GDP per capita growth (GDPGPC) to a shock in energy consumption (EC), the impact is significant and positive, particularly in the early periods, before gradually declining as the system returns to equilibrium. This suggests that an increase in energy consumption initially boosts economic growth, but the effect diminishes after about five periods, reflecting a short-term boost that tapers off as the economy adjusts. The significance of this response, particularly in the first few periods, underscores the central role of energy in driving economic activity.

Figure 1. Impulse Response combined graphs (Cholesky One S.D. (d.f. adjusted)
Source: author's elaboration

The response of GDPGPC to a shock in renewable energy consumption (RE) is also noteworthy. Initially, there is a positive response, significant at the 5% level, indicating that renewable energy contributes positively to economic growth. However, this effect turns negative in subsequent periods before stabilizing, suggesting potential short-term inefficiencies or adjustment costs associated with the transition to renewable energy. The overall significance of this response highlights the complex relationship between economic growth and renewable energy, where initial benefits may be offset by transitional challenges.

In the case of industrial activity (IND), its shock leads to a positive and significant response in GDPGPC, particularly in the early periods. This indicates that industrial expansion significantly drives economic growth, but like the impact of EC, this effect diminishes over time, stabilizing after around four to five periods. The significance of this response, especially in the initial periods, reinforces the critical role of industrial sectors in shaping economic outcomes.

When examining the response of GDPGPC to a shock in CO2 emissions, the results are mixed. Initially, there is a positive response, significant at the 10% level, suggesting that economic activities contributing to CO2 emissions may temporarily boost growth. However, this effect quickly turns negative, highlighting the detrimental long-term impact of environmental degradation on economic performance. This response stabilizes after six to seven periods, indicating that the economy eventually adjusts, but the initial negative impact of higher emissions is significant.

The response of GDPGPC to a shock in the globalization index (GLI) is positive and sustained, particularly in the first few periods, where the impact is significant at the 5% level. This indicates that globalization has a lasting positive effect on economic growth, driven by increased trade, investment, and integration into global markets. The significance and persistence of this response suggest that as Saudi Arabia becomes more globally integrated, the benefits to economic growth are both substantial and enduring.

Turning to the response of EC to GDPGPC, the impact is significant and positive in the early periods, indicating that economic growth increases energy consumption. This response is particularly strong in the first three periods, after which it begins to stabilize. The significance of this relationship underscores the bidirectional causality between energy consumption and economic growth, where each reinforces the other.

The response of EC to a shock in RE is negative, especially in the first two periods, where the impact is significant at the 1% level. This suggests that an increase in renewable energy leads to a reduction in overall energy consumption, likely due to improved efficiency or substitution effects. This response stabilizes after three periods, reflecting the economy's adjustment to the increased use of renewables.

The response of EC to IND shocks is positive and significant, particularly in the first two periods. This indicates that industrial activity drives energy consumption, reinforcing the strong link between industrial output and energy demand. The response stabilizes after four periods, reflecting the steady state that the economy reaches after the initial shock.

The response of EC to a shock in CO2 emissions is more complex, with an initially negative and significant response, especially in the first two periods. This suggests that efforts to reduce emissions might involve decreasing energy consumption. However, the response stabilizes relatively quickly, indicating that the economy adjusts to these changes within three periods.

Finally, the response of renewable energy consumption (RE) to shocks in other variables, such as GDPGPC, EC, IND, CO2, and GLI, reveals a generally positive and significant impact, especially in the early periods. The response to GDPGPC is positive and significant, particularly in the first two periods, indicating that economic growth promotes the adoption of renewable energy. Similarly, the response to EC shocks is positive, suggesting that increased energy demand leads to higher renewable energy consumption. The response to IND shocks, though initially negative, becomes positive and significant after two periods, reflecting a shift towards more sustainable energy sources in industrial sectors. The positive response of RE to CO2 emissions, significant in the first three periods, highlights the role of renewables in mitigating environmental impacts. Lastly, the response of RE to GLI is positive and sustained, indicating that globalization facilitates the adoption of renewable technologies over time.

In summary, the Impulse Response Functions illustrate the dynamic interactions between key economic and environmental variables, with each response characterized by its significance level and duration. These results underscore the critical importance of energy consumption, industrial activity, and globalization in driving economic growth, while also highlighting the growing role of renewable energy in addressing environmental challenges. The varied response periods and levels of significance across the variables suggest a complex and interconnected economic system, where policy interventions must carefully balance the trade-offs between growth and sustainability.

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.
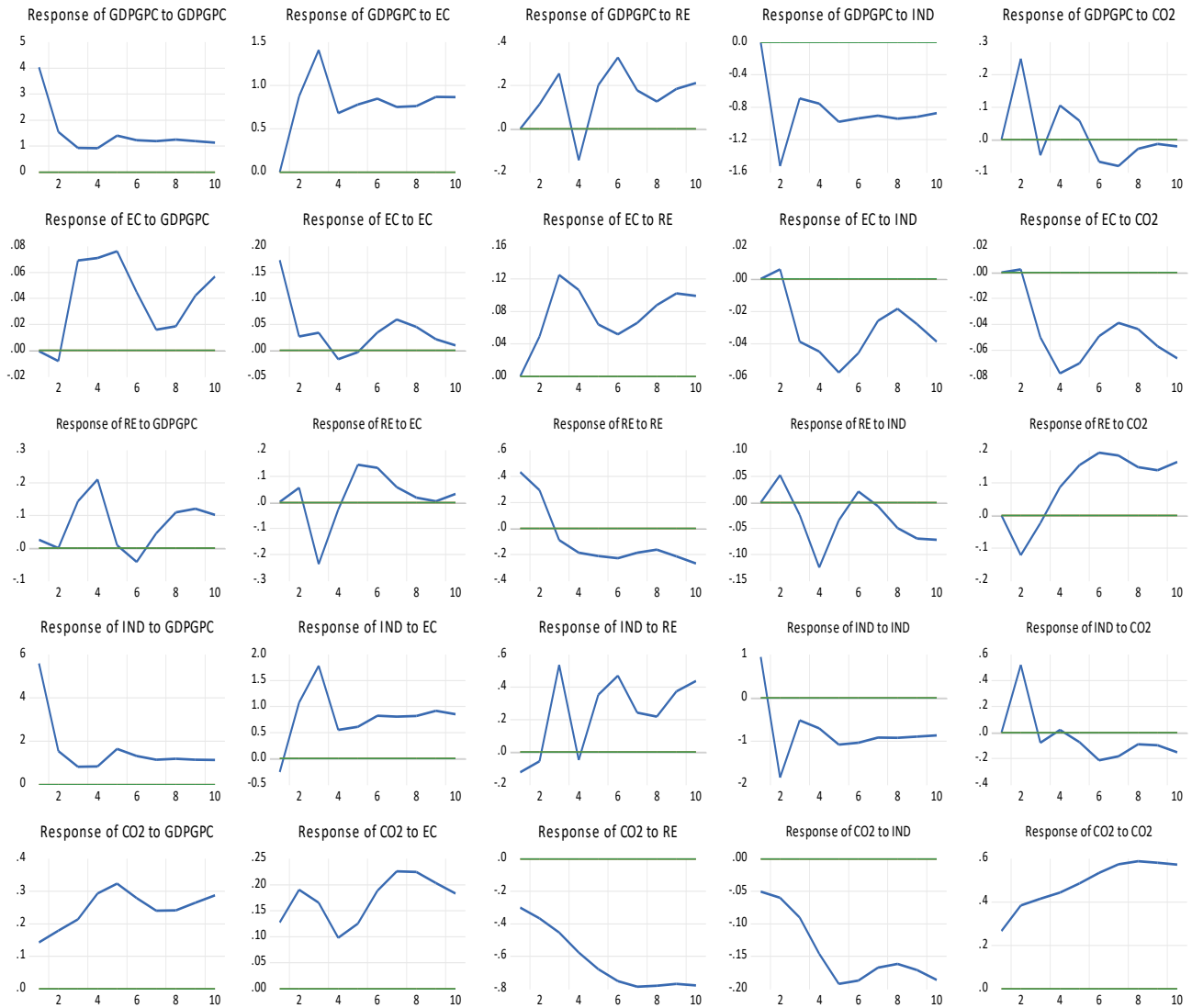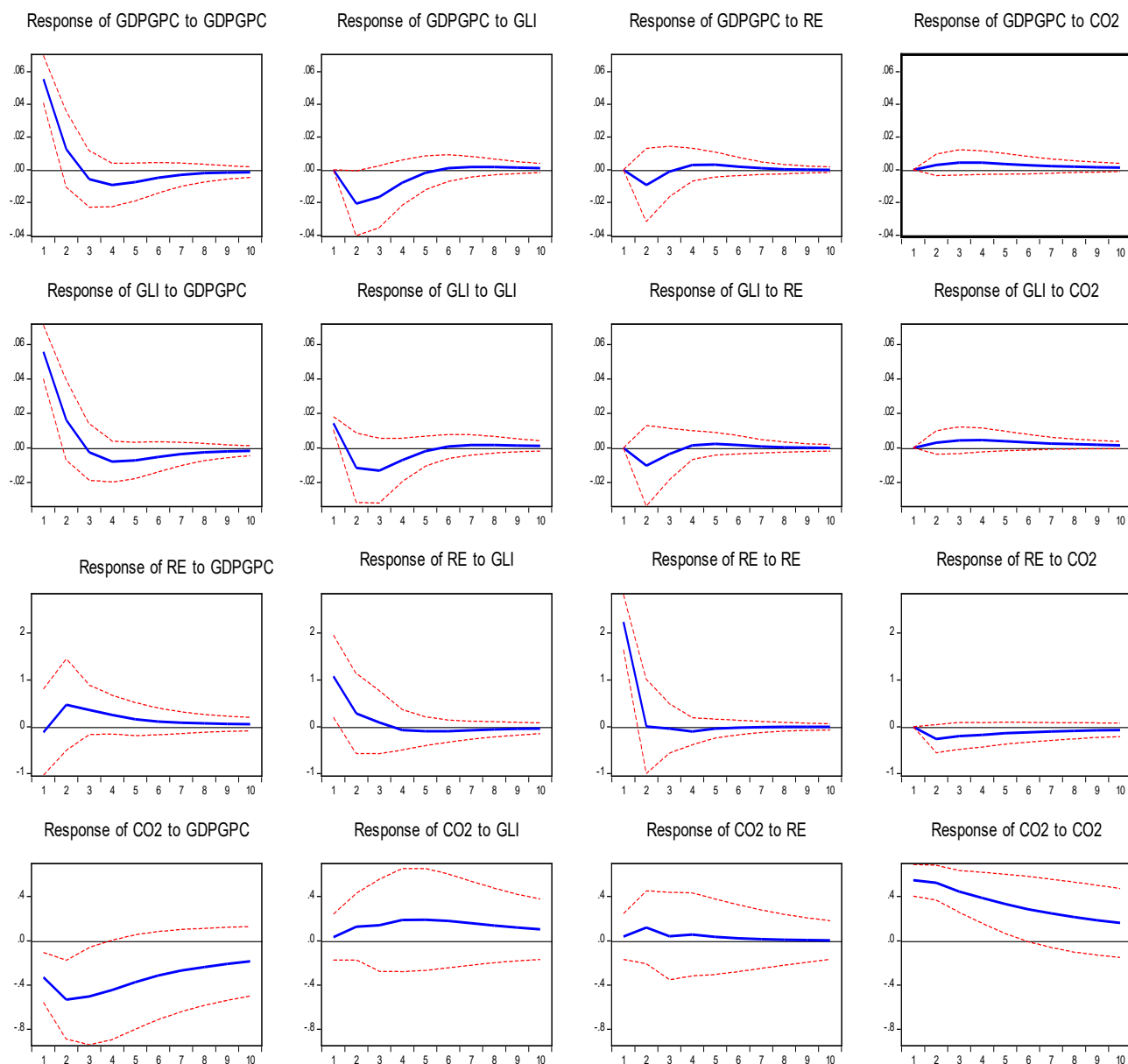

Figure 2. Impulse Response combined graphs (Cholesky One S.D. (d.f. adjusted)
Source: author's elaboration

The results displayed by the impulse response function *Figure 2* show that economic growth positively affects globalization in the short run; this effect disappeared after two periods. Globalization also has a positive and significant effect on the use of renewable energies in the short term. The estimation of the impulse response function confirms an important result, which describes that GDP negatively affects CO_2 in the short and long term (i.e. 4 periods). Although GDP may initially be correlated with CO_2 emissions, an economy can take steps to mitigate this relationship by adopting policies and technologies aimed at reducing emissions while supporting economic growth.

To overcome these challenges and realize the potential benefits of renewable energy for economic growth and pollution reduction, it is necessary to put in place coherent energy policies and financial incentives to encourage the adoption of clean energy. This can include subsidies for clean technologies, stricter emissions standards, carbon prices and investments in clean energy distribution infrastructure. Additionally, international cooperation is essential to address global challenges related to climate change and pollution, promoting the sharing of best practices, technologies and financial resources.

As a recommendation, the transition to renewable energy can play an important role in achieving economic growth while reducing pollution, but this requires globally coordinated action and concerted efforts to overcome technical barriers, economic and energy policies.

CONCLUSION AND RECOMMENDATIONS

The primary objective of this study was to explore the connection among globalization, renewable energy consumption, environmental pollution, and economic growth spanning the years 1990 to 2019. The stationarity of each variable was assessed using ADF and PP unit root tests. The Granger causality test also confirms the results using the impulse response function. The initial differencing rendered all variables stationary. Consequently, a Vector Error Correction Model (VECM) was employed to examine the cointegration between the series in both the short and long run. The main results show that there are bidirectional links between energy consumption and pollution, and between renewable energy consumption and economic growth.

A particularly promising option in this regard is green hydrogen. In fact, green hydrogen is indeed a very promising option for reducing CO2 emissions and promoting a more sustainable economy.

However, to become competitive with conventional hydrogen production methods, green hydrogen production still requires significant investments in infrastructure, technologies, and supporting policies, all of which are available in the Kingdom. However, with technological advancements and a growing commitment to the energy transition, green hydrogen is certainly an option to closely monitor in order to decarbonize our economy.

The results of the VECM estimation, supported by the impulse response function, confirmed that globalization contributes to economic growth, and vice versa. Globalization can serve the green economy in several ways, including technology transfer, trade in green goods and services, sustainable investments, international standards and regulations, international collaboration, and the sharing of best practices. In summary, globalization can play a crucial role in promoting the green economy by fostering innovation, trade, investment, and collaboration on a global scale to address the environmental challenges we face.

The Impulse Response Functions (IRFs) derived from the VECM offer critical insights into the dynamic relationships between key economic and environmental variables in Saudi Arabia. The findings highlight the significant but transient positive impact of energy consumption on GDP per capita growth, underscoring the central role of energy in driving economic activity. However, the diminishing effect over time suggests the need for strategies that sustain growth beyond the initial energy-driven boost. The complex relationship between renewable energy consumption and economic growth, where short-term benefits are offset by transitional inefficiencies, indicates that careful management of the renewable energy transition is crucial to minimize adjustment costs. Additionally, the positive and significant response of GDP to industrial activity reaffirms the industrial sector's pivotal role in economic development, though its energy demands necessitate balanced policies to mitigate environmental impacts. The mixed effects of CO2 emissions on economic growth further emphasize the importance of sustainable practices to avoid the long-term detrimental effects of environmental degradation. Finally, the sustained positive impact of globalization on economic growth underscores the importance of continued global integration for Saudi Arabia's economic future. Based on these insights, policymakers should focus on sustaining long-term economic growth through balanced energy policies, strategic management of the renewable energy transition, and continued global integration, while also addressing the environmental challenges associated with industrial expansion and energy consumption. These strategies will be crucial in achieving the broader goals of Saudi Arabia's Vision 2030, ensuring both economic prosperity and environmental sustainability.

Following the positive and significant impact of globalization in both economic growth and renewable energy use for Saudi context, this study highlights this positive and significant impact of globalization on economic growth and renewable energy use in Saudi Arabia, while also revealing the critical role of industrial activity in driving nonrenewable energy consumption. Policymakers should leverage globalization through trade liberalization, technology investment, and international collaborations to sustain economic growth, integrating these strategies with environmental sustainability initiatives. Simultaneously, addressing the significant energy demands of industrial activity is crucial for transitioning toward more sustainable

energy practices. By investing in renewable energy infrastructure and fostering global partnerships, Saudi Arabia can position itself as a leader in regional sustainability efforts, contributing to the broader goals of Vision 2030. Future research should explore the impact of globalization and industrial activity on other sectors, consider the role of digitalization, and analyze the long-term causal relationships in different contexts. Ultimately, this study underscores that when effectively harnessed, globalization, alongside careful management of industrial energy consumption, can drive both economic prosperity and sustainable energy practices, offering valuable insights for other emerging economies.

FUNDING

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Exploring the Impact of Auditor Tenure on Audit Quality: A Study of China's Audit Practices

DIEP NGUYEN THI THANH[1] and THU VU THI MINH[2] (Corresponding Author)

[1]Lecturer, School of Accounting and Auditing, National Economics University, Hanoi, Vietnam, email: diepnt@neu.edu.vn
[2]Lecturer, School of Accounting and Auditing, National Economics University, Hanoi, Vietnam, email: vuminhthu.neu@gmail.com; thuvtm@neu.edu.vn

ARTICLE INFO

ABSTRACT

This study empirically examines the relationship between auditor tenure and audit quality, adopting a positivist stance and a deductive research approach. A quantitative methodology is employed to explore this relationship within the context of the Chinese audit market, which implemented mandatory audit rotation policies in 2004. The research investigates the trade-off between two competing dynamics: on one hand, the enhancement of auditor independence and objectivity through mandatory rotation, and on the other hand, the effectiveness and efficiency derived from auditors' accumulated knowledge and long-term familiarity with their clients. The findings reveal a positive and significant relationship between audit tenure and earnings management, suggesting that excessively prolonged auditor-client relationships can impair audit quality by reducing auditor independence. This highlights the critical role of mandatory auditor rotation policies in safeguarding audit integrity and mitigating risks associated with extended tenures. Furthermore, the study examines the influence of additional firm-specific factors on audit quality. It finds that audit firm size and client firm size are negatively, though insignificantly, associated with discretionary accruals, indicating a tendency towards better audit quality for larger entities. Conversely, firm leverage and profitability exhibit a positive and significant relationship with earnings management, underscoring their roles as critical determinants in financial reporting practices.

INTRODUCTION

Research Background

Following notable accounting failures in the early 2000s, such as Enron/Arthur Andersen and WorldCom, regulators worldwide became increasingly concerned about the risks of prolonged auditor-client relationships potentially compromising audit independence and reducing audit quality. In response, numerous countries have taken steps to strengthen auditor independence by legislating interventions in the auditor-client relationship, including mandatory auditor rotation.

Since October 1, 2006, for example, Australia has mandated auditor rotation, as part of a policy to bolster audit objectivity (Auditor rotation, 2007). Similarly, the China Securities Regulatory Commission

(CSRC) mandates that auditors of companies listed on Chinese securities markets must rotate every five years (Firth, 2012). In the United Kingdom, the U.K. Competition and Markets Authority requires public companies to rotate their statutory auditors after a maximum of twenty years, with a mandatory tendering at the ten-year midpoint, effective from 2016 (PwC, 2016). However, in the U.S., while the Sarbanes-Oxley Act of 2002 proposed mandatory audit rotation, the Public Company Accounting Oversight Board (PCAOB) ultimately decided against implementing it in 2014 (Chasan & Emily, 2014).

Despite these regulatory efforts, the effectiveness of mandatory auditor rotation remains contested. Advocates argue that mandatory rotation can prevent the potential conflicts of interest and loss of objectivity that may arise in long-term auditor-client relationships. Studies such as those by DeAngelo (1981), King (1994), and Carey & Simnett (2006) indicate that extended auditor tenure correlates with decreased audit quality. Monroe and Hossain (2013) further propose that mandatory auditor rotation could enhance audit quality by prompting auditors to issue more independent and qualified opinions, especially for long-term, financially distressed clients.

Conversely, skeptics suggest that mandatory rotation could disrupt the continuity and in-depth client knowledge that auditors accumulate over time, potentially reducing audit effectiveness. Thus, whether mandatory auditor rotation consistently improves audit quality remains an open question that this research aims to explore.

Research Objectives

This study will examine the association between auditor tenure, mandatory auditor rotation, and audit quality in the Chinese audit market, where a mandatory rotation policy was enacted in 2004. Specifically, the research focuses on the balance between auditor independence and the efficiency gained through the continuity of the auditor-client relationship.

China provides a unique empirical setting for this research for several reasons. First, Chinese law requires firms to rotate signing auditors every five years, and audit partners' names must be disclosed in audit reports, unlike in countries such as the U.S. This requirement allows for clear identification of mandatory rotation cases. Additionally, since 2006, audit firms in China must report annual pre-audit profits for publicly listed clients to the Ministry of Finance (MOF), enabling researchers to examine audit adjustments in reported profits (Lennox et al., 2014).

This study is driven by two main motivations: (1) heightened market demand for improved audit quality following a series of corporate scandals, and (2) a gap in research on the relationship between mandatory audit rotation and audit quality in China, especially given that the disclosure of audit partner names is required in jurisdictions like Australia and Taiwan but not widely studied in the Chinese context.

Research Question

Does auditor tenure have an effect on audit quality in the Chinese audit market?

Research Objectives

A. To investigate the impact of audit tenure on audit quality in Chinese firms.

B. To provide insights into future policy considerations in the Chinese audit market. If mandatory audit rotation proves to have minimal impact on audit quality, regulators may consider alternative policies, such as mandatory rotation of the entire audit firm, to enhance audit independence.

1. LITERATURE REVIEW

1.1 Audit quality

The concept of audit quality lacks a standardized definition, as noted by Krishnan et al. (2013) and Kilgore et al. (2014). This absence of consensus has made measuring audit quality a persistent challenge in academic research. Various proxies have been used to approximate audit quality, with definitions generally grouped into three categories: compliance with accounting standards (Hodgdon et al., 2009; Street

& Gray, 2002), the likelihood of detecting a breach (Beck & Wu, 2006; Defond & Zhang, 2014; Deangelo, 1981), and stakeholder responses reflecting perceived audit quality (Aloke & Doocheol, 2005; Teol & Wong, 1993; Libby et al., 2002).

Stakeholder perceptions, often measured through responses to the quality of financial reports, serve as an indirect gauge of audit quality. When shareholders and other stakeholders lack direct insights into management and governance practices, they rely heavily on the reliability and transparency of financial reports. Consequently, a common approach to assessing audit quality is to evaluate financial reporting efficacy or earnings quality (Behn et al., 2008).

Given the complexity of capturing reporting or earnings quality directly, researchers have developed various proxies. Common dimensions include neutrality (measured by deviations in discretionary accruals), credibility (measured through the association between earnings and market returns), and earnings conservatism. Discretionary accruals and accounting conservatism, in particular, have emerged as primary proxies in the literature (Bing et al., 2014).

Research consistently suggests an inverse relationship between audit quality and discretionary accruals. Since managers may manipulate earnings to serve their own objectives, large discretionary accruals are generally viewed as indicative of low-quality earnings. Lin et al. (2008) support this finding, showing that higher discretionary accruals correlate with reduced audit quality. Francis et al. (2013) found that audit offices with a higher incidence of past restatements exhibit elevated discretionary accruals among clients, indicating a higher risk of audit failures and subsequent auditor litigation. Poor earnings quality, as measured by discretionary accruals, tends to correlate with audit issues, underscoring its value as a proxy.

1.2 Auditor tenure and audit quality

Research generally agrees that the length of the auditor-client relationship can significantly impact audit quality. Consequently, studies on audit tenure are often intertwined with evaluations of audit quality. The debate around auditor tenure typically revolves around two opposing arguments: shorter tenure may limit auditors' familiarity with their clients, while longer tenure may compromise auditors' objectivity.

Studies in this area have yielded mixed findings, showing both positive (Lin et al., 2008; Chi et al., 2009) and negative (Carey & Simnett, 2006) correlations between auditor tenure and the quality of financial reporting. Some research compares the insights of long-tenure auditors with those of new auditors, with inconclusive results. For instance, Gates (2007) found that financial information often inspires greater confidence following audit rotation. However, Aloke and Doocheol (2005) found that debt and capital markets tend to place more trust in long-tenure auditors than in new auditors. Additionally, studies have linked longer auditor tenure to reduced levels of discretionary accruals, suggesting potential benefits for financial transparency (Myers et al., 2003; Johnson et al., 2002).

Moreover, factors such as auditor size, specialization, and tenure have been identified as influential to accounting quality (Krishnan et al., 2013). The IAASB further categorizes audit quality within a triangular model, encompassing outputs, inputs, and contextual factors, emphasizing the multifaceted nature of audit quality. While there is some research on auditor tenure in the Chinese market, few studies adequately explore the impact of China's regulatory environment on audit quality. A robust accounting and audit regulatory framework is fundamental to ensuring audit quality. However, China currently faces challenges in this area, including a fragmented regulatory landscape with multiple agencies and a lack of centralized oversight. This disparity in regulatory strength can lead to variations in audit quality, with regions under stricter regulatory systems likely to achieve higher audit quality compared to those with weaker systems.

Recognizing this issue, this study will examine not only the impact of auditor tenure on audit quality but also the role of regional regulatory differences within China. By addressing both tenure and regulatory context, this research aims to provide a more comprehensive understanding of the factors influencing audit quality in the Chinese market.

2. RESEARCH METHOD

2.1 Research design

This research investigates the causal relationship between mandatory auditor rotation, auditor tenure, the regulatory environment, and audit quality. Guided by its research philosophy, objectives, and approach, the study adopts a mixed-method strategy combining experimental and documentary designs. The experimental component involves hypothesis development and statistical testing to examine the relationships between key variables. The primary hypothesis tested is:

H: There is a negative relationship between auditor tenure and audit quality.

To test this hypothesis, a pooled regression model is employed. The model utilizes audit tenure as the independent variable and audit quality as the dependent variable. Additionally, the research incorporates other factors identified in previous studies that influence audit quality. These include the regulatory environment, audit firm classification, company size, leverage, and profitability. The formula for the regression model is structured as follows, with audit quality measured by the absolute value of discretionary accruals (DA):

- Dependent variable: Audit quality (DA).
- Explanatory variable: Auditor tenure (TENU).
- Control variables:

  - Regulatory environment: Classified into direct-controlled municipalities (DCMs) of China versus other regions.
  - Audit firm: Whether the firm belongs to the Big Four (Big4).
  - Company size: Represented by total assets (Size).
  - Leverage: Measured by the debt-to-assets ratio (Lev).
  - Profitability: Measured using the return on assets (PROFITABILITY).

This approach allows for a comprehensive examination of the interplay between auditor tenure and audit quality while accounting for the influence of contextual and firm-specific factors. By incorporating regulatory distinctions between China's direct-controlled municipalities and other regions, the study addresses the unique characteristics of the Chinese audit environment. Table 1 defines all the research variables. The regression model is contructed as follows:

$$DAC| = \beta_0 + \beta_1\ TENU + \beta_2\ DCM + \beta_3\ AUDITFIRM + \beta_4\ FIRMSIZE + \beta_5\ DEBT + \beta_6 + PROFITABILITY + \varepsilon \quad (1)$$

Table 1. Variables and Description

Coding	Variables	Definition
│DAC│	Discretionary accruals	Calculated using modified Jones' (1991) model
TENU	Auditor tenure	The duration of time (years) an auditor has consistently worked with a client firm.
DCM	Direct-controlled municipalities	DCM = 1 if the company is from a direct-controlled municipality (such as Beijing, Shanghai, Tianjin, or Chongqing), which are areas under stricter regulatory control by the central government. DCM = 0 if the company is from any other area in China that is not a direct-controlled municipality.
AUDITFIRM	Audit firm	AUDITFIRM = 1 if the company is audited by one of the Big 4 audit firms (Deloitte, EY, KPMG, or PwC). AUDITFIRM = 0 if the company is audited by a non-Big 4 audit firm.
FIRMSIZE	Company size	Total asset
DEBT	Firm's debt	Defined as the proportion of total liabilities relative to total assets

PROFITABILITY	Profitability	The ratio of income before tax to total assets

Source: own

Audit quality is assessed based on the value of discretionary accruals, as outlined by Dechow et al. (1995) and Jones (1991), using the following formula:

+ *Value of a_0, a_1, a_2, and a_3 is estimated through the Eq. (2):*
$$TA_t / A_{t-1} = a_0 + a_1 (1/TA_{t-1}) + a_2 [\triangle Rev / TA_{t-1} - \triangle Recc / TA_{t-1}] + a_3 FA_t / TA_{t-1} \qquad (2)$$

Table 2. Illustration for Variables in modified Jones' (1991) Model

Code	Variable
TA_t	Net operating income minus (-) operating cash flow
A_{t-1}	Firm's total assets at the end of the last year
$\triangle Rev$	Changes in orperating sales
$\triangle Recc$	Changes in accounts receivables
FA	Firm's total fixed assets
$NonDAC_t$	Non-discretionary accrual

Source: own

+ Value of N*on-discretionary accruals is estimated using Eq. (3) and coefficients a_0, a_1, a_2, and a_3 (Eq.(2))*
$$NonDAC_t = a_0 + a_1 (1/TA_{t-1}) + a_2 [\triangle Rev / A_{t-1} - \triangle Recc / TA_{t-1}] + a_3 FA_t / TA_{t-1} \qquad (3)$$

+ *Discretionary accruals (DAC) is calculated by Eq. (4):*
$$DAC = TA_t/TA_t - NonDAC_t/TA_t \qquad (4)$$

2.2 Data collection

The study examines 11 key sectors in China, including technology, healthcare, retail, manufacturing, energy and others. From each sector, 20 companies are randomly chosen, leading to a total of 2,200 companies from the Shanghai Stock Exchange (SSE) and 220 companies from the Shenzhen Stock Exchange (SZSE). Data is gathered over a five-year period, from 2019 to 2023, resulting in a final sample of 440 companies and 5,500 observations.

Notably, the sample includes companies located in direct-controlled municipalities of China, which are subject to stricter regulatory controls. This ensures alignment with location classification requirements, adding robustness to the study's findings.

The research relies on two primary data sources: The first one is Annual Reports: These are used to collect financial data and information on signing auditors, which are publicly disclosed on company websites or via the SSE and SZSE platforms; And the second one is CNINF Database: This official website and database, authorized by the China Securities Regulatory Commission (CSRC), provides comprehensive data access.

3. ANALYSIS AND FINDING

3.1 Data descriptive statistics

Table 3 presents the statistical summary of the chosen sample for this research, covering a five-year period from 2019 to 2023. The lowest audit quality (measured by DAC) in the Chinese stock market during this period is 0, indicating the best possible audit quality. Conversely, the highest value of DAC is 4.338, suggesting that certain companies might have experienced significantly poor audit quality. On average, the DAC value stands at 0.115, which is within an acceptable range and reflects relatively good audit quality across the sample during the observed years.

Table 3. Variable description

Variable	Min	Max	Mean	SD
DAC	0.000	4.338	0.115	0.018
TENU	1.000	6.000	2.308	0.042
DCM	0.000	1.000	0.266	0.023
AUDITFIRM	0.000	1.000	0.081	0.019
FIRMSIZE*	6.409	2,078,154	69,703	8,041
DEBT	0.027	6.490	0.488	0.019
PROFITABILITY	-7.005	9.124	0.042	0.035

Source: own
* Million CNY

Audit quality in China over the past five years has significantly improved compared to earlier studies using the same modified Jones model. According to the research by Chen et al. (2008), discretionary accruals were notably higher during the period from 1999 to 2006, with mean and maximum audit quality values estimated at 7.28 and 48.35, respectively. These outcomes imply that recent changes in the regulatory environment and practices have had a positive effect on audit quality.

Furthermore, the tenure range of auditors in the sample spans from one to six years, indicating that most Chinese companies are adhering to the mandatory rotation policy. The inclusion of six years in the range may reflect cases where a one-year cooling-off period has been applied. The mean tenure of 2.308 years aligns with findings from previous research, demonstrating that the average auditor tenure in China typically hovers around three years (Bandyopadhyay et al., 2014).

Table 4 presents the correlations between the variables. Strong correlations are observed between firm size (FIRMSIZE) and audit firm (AUDITFIRM), as well as between firm size (FIRMSIZE) and leverage (DEBT), indicating a potential issue with collinearity. This issue is assessed using the Variance Inflation Factor (VIF) values presented in Table 7. However, since all VIF values in Table 7 are within acceptable limits, it suggests that there is no significant collinearity problem in the model.

Table 4. Correlations Matrix

	DAC	TENU	DCM	AUDITFIRM	FIRMSIZE	DEBT	PROFITABILITY
DAC	1						
TENU	.304**	1					
	0.000						
DCM	-0.007	0.026	1				
	0.389	0.560					
AUDITFIRM	-0.001	0.133**	.217**	1			
	0.977	0.000	0.000				
FIRMSIZE	-0.579**	-0.011	.192**	.538**	1		
	0.000	0.814	0.000	0.000			
DEBT	0.038	-0.002	-0.063	0.012	0.628**	1	
	0.402	0.970	0.161	0.781	0.000		
PROFITABILITY	.613**	0.018	0.010	0.000	0.002	-.407**	1
	0.000	0.691	0.828	0.991	0.964	0.000	
	.						

Source: own
Note: **. Correlation is significant at the 0.01 level (2-tailed)

3.2 Result analysis

Table 5 presents the practical application of formulas (2) through (4), culminating in the calculation of discretionary accruals. This step-by-step process ensures the derivation of accurate discretionary accrual values, which serve as a proxy for audit quality in this study.

Table 5. Value of betas in the Eq. (1)

Beta	Value
a_0	-0.097
a_1	20.32
a_2	-0.019
a_3	0.541

Source: own

As previously discussed, the regression model includes the dependent variable, discretionary accruals (DAC), one explanatory variable (audit tenure), and five control variables: Direct-controlled municipality classification (DCM) firm size (FIRMSIZE), audit firm type (Big 4 or non-Big 4), return on total assets (PROFITABILITY), and firm debt (DEBT). The regression results, which outline the relationships between these variables and audit quality, are shown in Tables 6 and 7.

Table 6. Model Summary

Model	R	R-Square	Adjusted R-Square
1	.512[b]	0.262	0.266
a. Predictors: (Constant), DCM, TENU			
b. Predictors: (Constant), DCM, TENU, PROFITABILITY, FIRMSIZE, DEBT, AUDITFIRM			
c. Dependent Variable: DAC			

Source: own

Table 6 shows that the coefficients of determination for the linear regression results, R-square and adjusted R-square, are 0.262 and 0.266, respectively. This means that 26.% of the variance in the dependent variable, audit quality (DAC), is explained by the six explanatory and control variables included in the model. Overall, the linear regression model exhibits a good fit and is highly significant, with a significance level of 1%.

Table 7. Regression results

Model	Unstandardized coefficients		Sig.	Collinearity statistics	
	B	Std. Error		Tolerance	Vif
(Constant)	-0.536	0.053	0.063		
TENU	0.012	0.029	0.028	0.927	2.100
DCM	-0.106	0.013	1.340	0.903	1.334
AUDITFIRM	-0.222	0.063	0.577	0.837	2.007
FIRMSIZE	-9.43E-09	0.048	0.141	0.714	1.581
DEBT	0.087	0.005	0.019	0.690	1.019
PROFITABILITY	0.256	0.009	0.025	0.752	2.047
Dependent variable: DAC					

Source: own

The results reveal a positive and significant impact of audit tenure on discretionary accruals, indicating that longer audit tenure is associated with higher discretionary accruals, which correspond to lower audit quality. This supports the conclusion that audit tenure negatively affects audit quality, confirming and accepting H1. Regular changes in auditors can help prevent overly close relationships with clients and mitigate the pressure to retain clients, thereby enhancing audit independence, as discussed in the literature

review. Similar findings are reported in prior studies, such as Monroe and Hossain (2013), who identified a strong association between audit partner tenure and audit quality using going-concern opinions as a proxy, and Firth et al. (2012), who found a positive relationship between mandatory audit partner rotation and audit quality.

The regulatory environment shows a negative but insignificant impact on discretionary accruals. Companies located in direct-controlled municipalities (DCM) tend to exhibit lower discretionary accruals, indicating higher audit quality. However, this effect is not statistically significant. This finding aligns with Li (2010), which notes a positive relationship between high audit concentration in regulated areas of China and audit quality. Nevertheless, being located in a DCM does not appear to have a significant influence on audit quality in this study.

Additionally, both audit firm (AUDITFIRM) and firm size (FIRMSIZE) exhibit a negative and insignificant relationship with discretionary accruals, implying a positive association with audit quality. Previous research on these factors has yielded mixed results. While the Big 4 are generally perceived as providing higher-quality audit services, Monroe and Hossain (2013) found no strong evidence to suggest that clients of Big 4 firms consistently achieve better audit quality. This may reflect improvements in the audit industry as a whole and the relatively low proportion of Big 4 firms in the sample.

Furthermore, leverage (DEBT) and return on assets (PROFITABILITY) are found to have positive and significant effects on discretionary accruals, signifying a negative and significant effect on audit quality. Higher leverage and profitability appear to be associated with greater discretionary accruals, which can indicate poorer audit quality.

CONCLUSION

In conclusion, this research employs a quantitative methodology to investigate the relationship between auditor tenure and audit quality, while also examining the association between the regulatory environment and audit quality. The findings indicate a positive and significant relationship between audit tenure and discretionary accruals, suggesting that prolonged tenure undermines audit quality. This highlights the necessity of maintaining mandatory auditor rotation policies to mitigate the negative effects of long tenure on auditor independence and quality. Additionally, the study reveals a strong impact of leverage and profitability on audit quality, underscoring their significance as influential factors.

Despite the importance of its findings, the research has several limitations. Firstly, the exclusive reliance on a quantitative approach, consistent with the positivist philosophical stance, may introduce rigidity and limit flexibility in understanding the nuanced cause-effect relationships that could be influenced by human interpretation and judgme. A mixed-methods approach could offer a more holistic understanding by combining quantitative rigor with qualitative insights.

Secondly, the use of proxies for measuring variables presents inherent challenges. For instance, audit quality is often assessed through discretionary accruals, but alternative measures—such as compliance with accounting standards or the likelihood of breach detection—could provide different perspectives. Similarly, profitability can be evaluated through various proxies, such as the return on assets (ROA) or the return on equity (ROE). The choice of proxies, therefore, inevitably involves trade-offs and may not fully capture the complexity of the variables.

To address these limitations, future research could adopt a mixed-methods approach, incorporating qualitative elements to complement quantitative analysis. Furthermore, expanding the scope to include additional dimensions, such as corporate governance practices, could provide deeper insights into the interplay between auditor tenure, mandatory auditor rotation, and audit quality.

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Corporate Manipulations and Stock Price Movements

DAMIR PIPLICA[1] and IVAN LAŽETA[2]

[1]Professor, University Department of Forensic Sciences, Split, Croatia, email: damir.piplica@gmail..com
[2]University Department of Forensic Sciences, Split, Croatia, email: ivaan.lazeta@gmail.com

ARTICLE INFO

ABSTRACT

Financial markets play a crucial role in modern economies, enabling the efficient transfer of capital from investors to business entities seeking financing. These markets serve as a platform where the supply and demand for capital meet, enabling companies to raise the funds they need to grow and develop, while investors earn a return on their investment. Although financial markets provide many opportunities for growth and value creation, they are also subject to various risks and uncertainties. One of the most serious risks that can undermine the integrity of the market is financial fraud. The conducted study has established that financial frauds cause significant declines in stock prices on financial markets, a finding that holds true across all observed periods. Specifically, it is evident that the stocks of accused companies experience a marked decline from the average ones, on the first day following the allegations, while market indices remain relatively stable. Within the first year, the stocks of these companies continue to lose value, whereas market indices maintain an upward trajectory. After three years, the stocks of all companies in the sample exhibit even greater average declines, while indices continue to rise. The correlation between the stock prices of accused companies and market indices diminishes over time, virtually disappearing in the long term. Market indices demonstrate resilience and sustained growth over time, whereas the affected companies experience a long-term loss of investor confidence and persistent declines in stock prices. The study findings confirm the proposed alternative hypothesis that financial fraud leads to significant stock price declines over time.

INTRODUCTION

Although financial markets offer numerous opportunities for growth and value creation, they are also susceptible to various risks and uncertainties. This study aims to examine the consequences of financial fraud on the stock prices of affected companies and how such events influence broader market trends. Through our study, we will demonstrate how stock prices change following public disclosure of financial irregularities, distinguishing between immediate, short-term market reactions and the long-term impacts that financial fraud can have on stock value. Additionally, we will analyse changes relative to the broader market by comparing stock price movements against a relevant index. In doing so, we aim to illustrate the extent to which financial fraud causes stock price fluctuations and how these fluctuations compare to the performance of the relevant market.

This study primarily utilized data on companies accused of financial fraud, gathered from research firms actively analysing companies suspected of involvement in corporate fraud. Additional data were sourced from Breakout Point GmbH, a specialized German company that monitors news and events related to companies accused of financial irregularities. Stock price movement data over time were collected using Bloomberg Terminal and the S&P Capital IQ database. These platforms provided access to historical stock price and index data, enabling the analysis of changes across various time frames.

The data processing involved analysing stock price changes to determine how many companies in the sample experienced negative versus positive price changes within each time frame. Additionally, a comparison was conducted between stock price movements and relevant market indices to ascertain whether the observed changes were specific to individual companies or part of broader market trends.

1. THE ROLE AND SIGNIFICANCE OF FINANCIAL MARKETS

Financial markets are defined as platforms where the supply and demand for financial resources meet, enabling the trading of financial instruments such as stocks, bonds, currencies, and derivatives (Mishkin, 2019). Their primary purpose is to ensure liquidity, allowing market participants to quickly buy or sell instruments without significantly impacting their price. Bodie et al. (2018) state that stock prices fluctuate in response to changes in market supply and demand, with various factors such as corporate earnings, interest rates, and global economic conditions influencing these prices. The prices of stocks, bonds, and other instruments reflect the collective expectations of market participants regarding future developments.

One of the most critical functions of financial markets is raising capital for businesses. Haugen (2010) emphasizes that financial markets facilitate the efficient allocation of capital within the economy, enabling investors to deploy their funds while providing businesses and governments with the necessary resources for their activities. Financial markets also allow for risk diversification, reducing investors' exposure to individual investments, thereby contributing to the stability of the financial system.

Levine (2005) outlines the functions of financial markets as facilitating the transfer of capital between savings and investments, enabling the pricing of financial instruments, and mitigating risk through diversification and derivative trading. They connect investors, who possess excess capital, with businesses, governments, and other organizations seeking funding for their projects and operations. Mishkin and Eakins (2018) highlight that financial markets play a pivotal role in the efficient allocation of resources, reducing transaction costs, and providing liquidity, enabling investors to easily buy and sell financial instruments. Furthermore, financial markets empower investors to diversify their investments and manage risks.

The transparency of financial markets ensures that all participants have access to relevant information, thereby reducing market uncertainties and improving market efficiency through lower transaction costs and increased confidence (Weller, 2017). Investor confidence in financial markets is built on the perception of stability and fair business practices, and any breach of this trust can lead to widespread capital withdrawals and market destabilization.

Diamond and Verrecchia (1991) argue that transparency in financial markets reduces uncertainty and enhances investor confidence by enabling better decision-making and lowering information and transaction costs. A lack of transparency often results in market manipulation, financial fraud, and market destabilization, which can significantly undermine investor trust.

2. WHITE-COLLAR CRIME AND STOCK MARKET CRIME

White-collar crime refers to illegal actions committed by individuals within business, political, or professional contexts who exploit their positions of power and trust for personal gain. These activities include fraud, embezzlement, and money laundering (Sutherland, 1983). Clinard and Yeager (1980) define white-collar crime as unlawful actions undertaken by individuals or organizations in positions of power or influence, characterized by deception and manipulation rather than physical violence. Such actions typically aim to secure financial gain through fraud, embezzlement, and other dishonest practices.

Piplica (2020) asserts that, at its core, white-collar crime consists of offenses committed by individuals or groups with relatively higher business status, whose illegal use of their professional positions and

influence enables them to obtain unlawful benefits, whether material or immaterial. The author further notes that the ingenuity displayed in unlawfully acquiring others' property often astonishes with its sophistication, speed, efficiency, immorality, and scope. Moreover, the perpetrators of such activities frequently remain "ahead of their time" and the national authorities tasked with detecting and prosecuting them. Benson and Simpson (2015) emphasize that white-collar crime is particularly challenging to prosecute due to its complexity, the high social status of the offenders, and the abstract nature of the harm it causes. Similarly, Le Maux and Smaili (2023) highlight that combating white-collar crime is complicated due to the sophisticated nature of these offenses and the high social status of the perpetrators.

Stock market crime represents one of the most severe forms of financial fraud on a global scale, with far-reaching consequences for financial markets, the economy, and society as a whole. According to Smith (2020), stock market crime encompasses deceptive practices such as insider trading, market manipulation, and the dissemination of false information, all of which can significantly impact the integrity of financial markets and broader economic stability. Brown (2018) identifies insider trading as one of the most well-known forms of stock market crime. This practice involves trading in a company's stocks or other securities by individuals with access to unpublished, materially significant information about the company, thereby undermining market fairness.

According to Smith (2020), history has witnessed some of the most infamous stock market frauds, such as the Enron scandal, where executives employed accounting fraud to artificially inflate stock prices, and Madoff's *Ponzi* scheme, which deceived investors for decades. These cases highlighted the vulnerability of financial markets to manipulation and underscored the need for stronger regulatory oversight. Additionally, they serve as examples of the extent to which certain individuals and organizations are willing to go to deceive, defraud, and achieve financial gain.

Müller (2021) analysed the Wirecard scandal as one of the largest cases of corporate fraud in history, involving the concealment of €1.9 billion. This collapse exposed significant failures in regulatory oversight and auditing, undermining investor confidence in the financial sector and prompting calls for stricter supervision of corporate governance and auditing practices. The Enron business scandal had far-reaching implications for financial markets, investors, employees, and overall trust in corporate integrity. In December 2001, Enron filed for bankruptcy, marking the largest corporate bankruptcy in U.S. history at the time. Furthermore, on June 25, 2002, WorldCom publicly disclosed that it had inflated its reported earnings by nearly $4 billion due to improper accounting practices. The fraud resulted in substantial financial losses for shareholders, including pension funds and individual investors, and led to the loss of jobs for thousands of WorldCom employees.

Activist short sellers are specialized research firms focused on identifying and exposing financial fraud and other forms of corporate misconduct. Their business model relies on taking short positions in the stocks of companies under investigation. These research firms differ from traditional short-selling investors by publicly disclosing their short positions and accompanying these announcements with detailed reports alleging that the targeted company's stock is overvalued, fraudulent, or involved in other irregularities. A critical element of their success is the ability to identify companies with significant issues before these problems become known to the broader market.

Once sufficient evidence is gathered, these research firms take a short position in the company's stock. Subsequently, they publish their findings in the form of reports, often via websites, social media, or media outlets. The goal is to draw public and investor attention to the problems within the company, typically leading to a decline in the stock price. If their investigation proves accurate and the market reacts accordingly, they profit from their short position. One of the primary criticisms of activist short sellers is that they have a financial incentive to drive down stock prices, which may create a conflict of interest. On the other hand, proponents argue that this practice is essential for market health, as it helps uncover fraud that might otherwise go unnoticed.

3. RESULTS

Table 1 List of Companies Accused of Financial Fraud

Company Name	Ticker Symbol	ISIN	Country	Research Company and Number of Reports
Yalla Group Ltd	YALA	US98459U1034	UAE	Citron Research (3)
QUANTUMSCAPE CORP	QS	US74767V1098	USA	Hindenburg Research (2)
JOYY Inc	YY	US98426T1060	Singapore	Muddy Waters Research (2)
GRENKE AG	GLJ	DE000A161N30	Germany	Aurelius Value Research (1)
Nikola Corp	NKLA	US6541101050	USA	Blazing Research (1)
Remark Media Inc	MARK	US75954W1071	USA	Bonitas Research (1)
Gaotu Techedu Inc	GOTU	US36257Y1091	China	Gotham City Research (1)
Ideanomics Inc	IDEX	US45166V1061	USA	Scorpion Capital (1)
iQIYI Inc	IQ	US46267X1081	China	Swan Street Research (1)
Luckin Coffee	LK	US54951L1098	China	Viceroy Research (1)
Jumia Technologies AG	JMIA	US48138M1053	Germany	Wolfpack Research (1)
Xiaobai Maimai Inc	HX	US4282951098	China	EducationEquity Research (1)
Polarityte Inc	RGTPQ	US7310941080	USA	Ash Illuminat. Research (1)
Hailiang Education Group Inc	HLG	US40522L1089	China	MOX Reports (1)
Secoo Holding Ltd	SECO	US81367P1012	China	SoapBox Research (1)
Criteo S.A.	CRTO	US2267181046	France	Unemon Research (1)
Cogobuy Group	00400	KYG225371072	China	Zhongkui Research (1)
Pingtan Marine Enterprise Ltd	PME	KYG7114V1023	China	-
Neurotrope, Inc	NTRP	US64129T2078	USA	-
Cemtrex Inc	CETX	US15130G3039	USA	-
Sinosoft Technology Group	01297	KYG818751094	China	-

Source: Compiled by the authors based on data collected from research companies

Table 1 presents a list of 21 companies accused of financial fraud. The company name provides precise identification of the entity under investigation, while the stock ticker, also known as the *ticker symbol*, serves as a reference for recognizing the company's shares on stock exchanges and in financial reports. Additionally, the table includes the ISIN (*International Securities Identification Number*), a standardized code used for the accurate identification of securities in global markets. For each company, the country of registration is also listed, which is crucial for understanding the context in which the company operates, as well as for analysing the regulatory frameworks and legal systems that may have contributed to the detection or oversight of financial irregularities.

The table also shows the number of reports issued by research companies specializing in monitoring and uncovering financial fraud. Citron Research has the highest number of reports, with a total of three, while Hindenburg Research and Muddy Waters Research each issued two reports. The remaining companies, including Aurelius Value Research, Blazing Research, Bonitas Research, and others, issued one report each. In total, 21 reports were issued by 17 different research firms. The S&P 500, the most used index, is associated with the largest number of companies in the sample, specifically 17 companies are referenced by this index. Other indices, such as NASDAQ, DAX 30, and Hang Seng, are linked to fewer companies. The highest number of reports pertains to the consumer discretionary and healthcare sectors, with five reports each. The industrial and communication services sectors are also significantly

represented, while other sectors, such as finance, information technology, and technology, have a smaller number of reports.
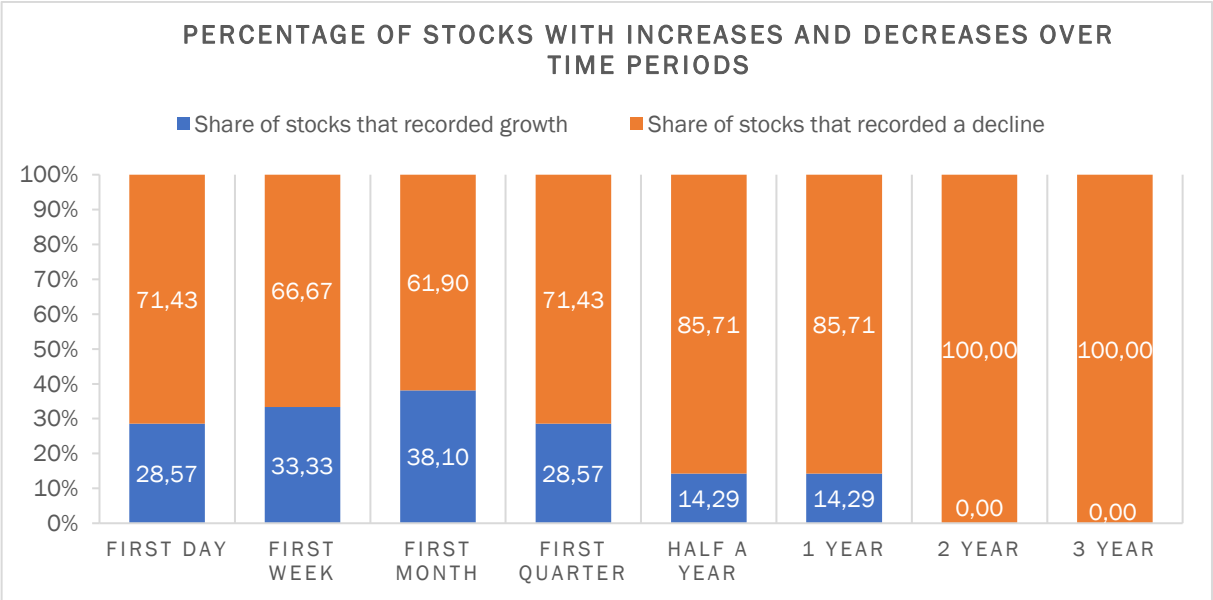
Chart 1. Proportion of Stocks in the Sample that Experienced an Increase or Decrease Over the Observed Time Period
Source: Compiled by the authors based on data collected from financial platforms Bloomberg and S&P Capital IQ

The chart shows that many stocks experienced a decline immediately following the revelation of fraud, with 71.43% of stocks decreasing in value on the first day. This percentage decreases slightly within the first month, where 66.67% of stocks report a decline, while 33.33% record an increase. Over time, the proportion of stocks with declining prices significantly increases. After six months, 85.71% of stocks report a decline, and this percentage rises to 100% after two and three years. The chart illustrates a general trend of decreasing stock values for companies accused of financial fraud, highlighting the long-term negative consequences of such allegations.
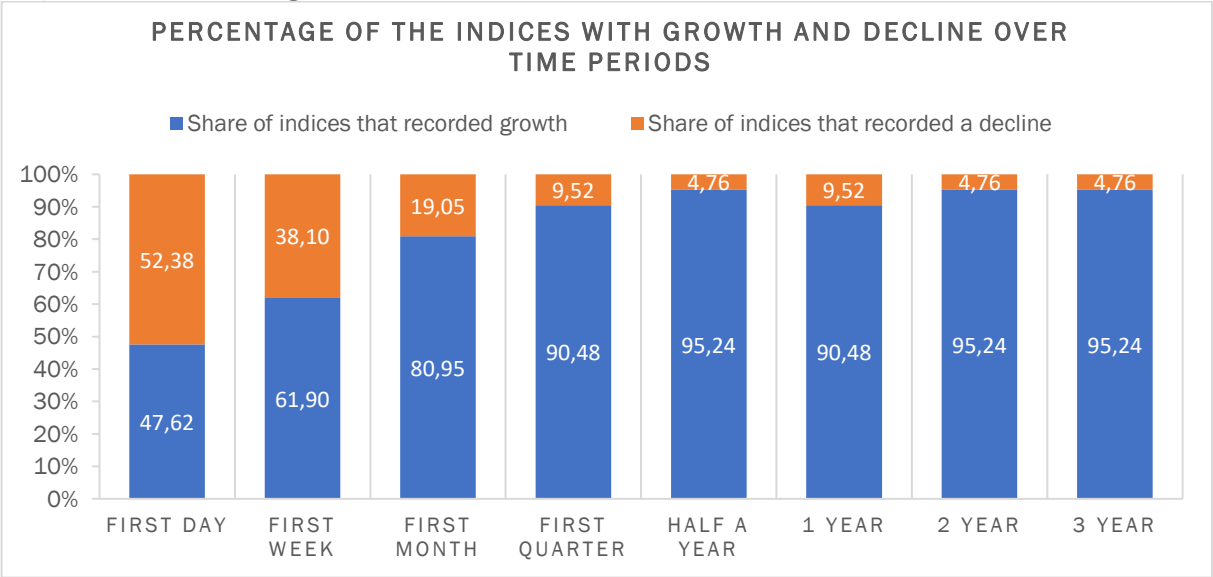
Chart 2. Proportion of Indices in the Sample That Experienced Increases or Decreases Over the Observed Time Period
Source: Compiled by the authors based on data collected from financial platforms Bloomberg and S&P Capital IQ

The chart illustrates the percentage of indices that recorded increases or decreases in value over various time periods following accusations of financial fraud against companies. The data shows that indices exhibited mixed results in the initial periods. For instance, on the first day after the accusations,

52.38% of indices showed a decline, while 42.62% showed an increase. Over time, the proportion of indices recording declines decreases, and more indices begin to show increases. For example, after the first month, 80.95% of indices reported an increase, a figure that rose even higher in later periods, such as the first quarter (90.48%) and half-year (95.24%). Long-term data demonstrates that the proportion of indices with growth remains consistently high, with only 4.76% of indices experiencing a decline in value.
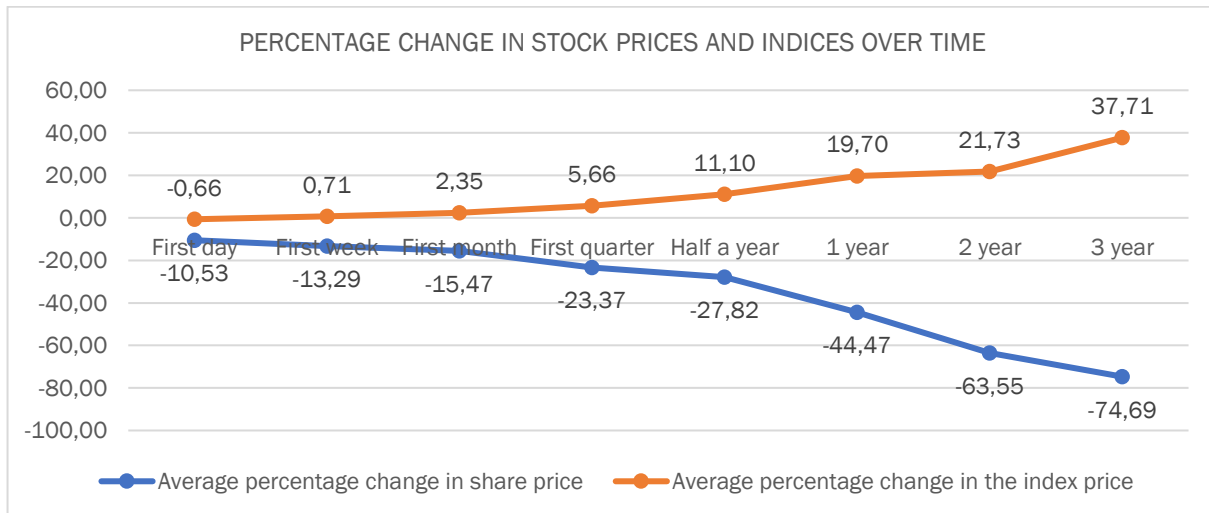
Chart 3. Average Percentage Change in Stock Prices and Benchmark Indices Across Observed Periods
Source: Authors' analysis based on data collected from financial platforms Bloomberg and S&P Capital IQ

Chart 3 presents a comparison of the average percentage change in stock prices of companies accused of financial fraud with the average percentage change in relevant indices over different time periods. The chart demonstrates that the average stock price experiences a significant decline immediately following the disclosure of allegations, beginning with a drop of -10.53% on the first day. This decline deepens progressively over time. By the end of the three-year period, the average stock price records a dramatic decrease of -74.69%, indicating the long-term destructive impact of such allegations on the value of these companies' stocks. In contrast, the orange line, representing changes in indices, displays a markedly different trend. Unlike the stock prices, the indices show growth over time. By the end of the three-year period, the indices report a significant average increase of 37.71%.

While stock prices experience a continuous downward trajectory over time, market indices exhibit growth. This divergence may also suggest a shift in the correlation between stock prices and indices over time, transitioning from a weakened correlation in the initial phases to a potentially negative correlation as the time horizon extends.

Table 2. Shapiro-Wilk test

Shapiro-Wilk	W	p
First day	0.933	0.162
First week	0.942	0.238
First month	0.932	0.154
First quarter	0.906	0.047
Half year	0.829	0.002
One year	0.935	0.172
Two years	0.944	0.262
Three years	0.881	0.015

Source: Authors' analysis based on data collected from financial platforms Bloomberg and S&P Capital IQ

The results of the Shapiro-Wilk test indicate that the data for the first day, first week, first month, one year, and two years are normally distributed, as their p-values exceed the threshold of 0.05. Conversely, the data for the first quarter (p = 0.047), half-year (p = 0.002), and three years (p = 0.015) deviate from normal distribution, as their p-values fall below the 0.05 threshold. The latter suggests significant departures from normality in these periods.

Table 3. Pearsono Correlation Matrix

Correlation	First day	First week	First month	First quarter	Half year	1 year	2 years	3 years
First day	**1.00**	0.730	0.637	0.319	0.411	0.111	0.167	0.279
First week	0.730	**1.00**	0.905	0.584	0.134	-0.062	0.021	0.328
First month	0.637	0.905	**1.00**	0.572	0.056	-0.093	0.071	0.405
First quarter	0.319	0.584	0.572	**1.00**	0.458	0.179	-0.045	0.097
Half year	0.411	0.134	0.056	0.458	**1.00**	0.443	-0.054	-0.097
1 year	0.111	-0.062	-0.093	0.179	0.443	**1.00**	0.406	0.125
2 years	0.167	0.021	0.071	-0.045	-0.054	0.406	**1.00**	0.428
3 years	0.279	0.328	0.405	0.097	-0.097	0.125	0.428	**1.00**

Source: Authors' analysis based on data collected from financial platforms Bloomberg and S&P Capital IQ

Table 3 illustrates the Pearson correlation coefficients between changes in stock prices over different time periods following allegations of financial fraud. The table highlights how the relationship between stock price changes evolves over time, with stronger correlations observed in the short-term periods, which gradually weaken as the time horizon extends.

Table 4. Student's t-Test and Wilcoxon Test Results

	Test	Statistic	df	p
First day	Student	-3.795	20	< .001
	Wilcoxon	31.000		0.001
First week	Student	-2.924	20	0.004
	Wilcoxon	39.000		0.003
First month	Student	-2.282	20	0.017
	Wilcoxon	54.000		0.016
First quarter	Student	-2.681	20	0.007
	Wilcoxon	45.000		0.006
Half year	Student	-2.718	20	0.007
	Wilcoxon	32.000		0.001
1 year	Student	-6.500	20	< .001
	Wilcoxon	8.000		< .001
2 years	Student	-12.771	20	< .001
	Wilcoxon	0.000		< .001
3 years	Student	-15.246	20	< .001
	Wilcoxon	0.000		< .001

Source: Authors' analysis based on data collected from financial platforms Bloomberg and S&P Capital IQ

This table presents the results of two statistical tests—Student's t-test and the Wilcoxon test—applied to several time points: the first day, first week, first month, first quarter, half-year, one year, two years, and three years. Both tests are used to evaluate differences between samples, but they are suited to different assumptions about the distribution of the data. Student's t-test assumes that the data are normally distributed, whilst The Wilcoxon test, being a non-parametric method, is applied when the data distribution deviates from normality.

The results indicate statistically significant differences ($p < 0.05$) at all time points for both tests, signifying that the changes between time points were significant. For instance, on the first day, Student's t-test reports a statistic of -3.795 with a **p**-value of less than 0.001, indicating a substantial difference. Similarly, the Wilcoxon test confirms this difference with a **p**-value of 0.001. As time progresses, the differences become even more pronounced, with extremely low **p**-values, particularly after one year, two years, and three years, where both tests reveal highly significant differences ($p < 0.001$). The table confirms that the differences between time periods are consistent and statistically significant, regardless of whether a parametric or non-parametric test is applied.

4. DISCUSSION

The study examines two hypotheses to determine whether the disclosure of financial fraud has a significant impact on stock prices. The null hypothesis (H_0) posits that financial fraud does not result in a significant decline in the stock prices of the affected companies. In contrast, the alternative hypothesis (H_1) assumes that financial fraud leads to a significant decrease in the stock prices of the affected companies. The purpose of testing the results obtained in this research is to understand how the market reacts to such scandals and what the long-term consequences are for investors. The primary objective was to analyse how stock prices evolved over the three-year period following the disclosure of allegations and to compare these changes with the performance of relevant market indices. The results were evaluated across several time intervals: the first day, first week, first month, first quarter, half-year, one year, two years, and three years.

Companies accused of financial fraud experience a significant loss in value over time, while relevant market indices exhibit the opposite trend of consistent growth. On the first day following the announcement of allegations, the stocks of these companies show an average decline of -10.53%, whereas market indices remain nearly unchanged, with a slight decrease of -0.66%. As time progresses, the disparity between the performance of these stocks and the indices becomes increasingly pronounced. While the stock prices of accused companies continue to decline, registering an average drop of -74.69% after three years, the indices achieve a substantial gain of 37.71%. These findings suggest that allegations of financial fraud not only severely undermine investor confidence in the affected companies but also render these companies significantly less valuable in the long term. On the contrary, market indices, which represent a broader spectrum of companies, not only recover from any initial negative impact but also achieve growth, demonstrating the resilience and stability of the broader market despite individual scandals.

This study analysed key benchmark indices representing broader markets, serving as indicators of general market sentiment. Indices such as the S&P 500, NASDAQ, DAX 30, and Hang Seng reflect collections of stocks from leading companies in developed markets. During the analysed period, the benchmark indices demonstrated stability and growth, while the stocks of companies accused of financial fraud experienced significant declines. This divergence highlights the contrasting performance between stable market segments and individual companies facing allegations of financial misconduct.

When allegations of fraud are disclosed, the market reacts almost immediately, as investors quickly reassess their confidence in the affected company. Such situations often lead to sharp declines in stock prices, driven by panic selling and capital withdrawal. Immediately following the announcement of allegations of financial fraud, the market typically responds with remarkable speed, resulting in significant stock price drops for the implicated company in most cases. Algorithmic trading further amplifies this rapid reaction, as many trading algorithms automatically analyse news and initiate stock sales upon detecting negative sentiment. As a result, the stock price can experience a dramatic decline within just a few hours of the news release, reflecting the immediate shift in market sentiment and trust toward the company.

A week after the disclosure of allegations of financial fraud, the stock price typically continues to reflect the initial market reaction. Following the initial drop, the stock price may stabilize in some cases, although volatility often remains high as investors and analysts further assess the situation. If additional negative information emerges during the week, the stock price may experience further declines. Conversely, if the company demonstrates its ability to manage the crisis or mitigating factors come to light, the market may begin to stabilize the stock price. However, in most cases, the first week following the announcement of allegations sees 66.67% of companies experiencing a decline in stock prices, with an average drop of -13.29%.

Examining the effects during the first month, quarter, and half-year following the announcement of allegations provides insights into how the market stabilizes and shapes its perception of the risks associated with the accused companies. The first month after the disclosure of financial fraud allegations is often marked by significant fluctuations in stock prices as the market seeks to analyse and evaluate the available information. According to the data analysis, 61.90% of stocks experienced a decline during this period, while 38.10% managed to achieve growth. The average decline in stock prices of companies accused of financial fraud was -15.47%. These results indicate an additional drop compared to the first week, suggesting that uncertainty among investors persists. A month after the disclosure, the market continues to adjust to new information, with investors beginning to make more informed decisions based on further analyses and evaluations.

After three months, the market begins to reveal a clearer trend regarding the future of the accused companies. Data indicates that by the end of the first quarter, 71.43% of stocks recorded declines, with an average price drop of -23.37%, while only 28.57% of companies managed to achieve stock price growth. This result suggests that many investors, following a more thorough analysis, have lost confidence in companies under investigation for financial misconduct. The market starts to more realistically assess the long-term risks and potential consequences for the accused companies, which is reflected in a significant reduction in their value. Six months after the allegations were disclosed, the medium-term effects become even more pronounced. According to the data, 85.71% of stocks experienced declines during this period, with an average drop of -27.82%, while only 14.29% of companies managed to achieve growth. These figures suggest that by this point, the market has largely lost confidence in the accused companies. The negative sentiment surrounding these stocks is primarily a result of additional information that has reinforced suspicions about the financial stability and governance practices of these companies.

One year after the allegations were disclosed, the situation remains highly unfavourable for most stocks of the affected companies. According to the collected data, 85.71% of the stocks experienced declines during this period, while only 14.29% showed growth—the same ratio observed at the six-month mark but with a significantly steeper percentage decline in stock prices. The average drop in stock prices increased to -44.47%. This result suggests that investor confidence in these companies has not recovered, despite potential efforts by the companies to mitigate the damage. After two years, the long-term negative effects become even more apparent. The data shows that 100% of the stocks experienced declines, with no stock recording growth during this period. By this stage, investors clearly understand the long-term consequences of the allegations, which may include management changes, restructurings, or even potential bankruptcies. The market no longer anticipates recovery for most of these companies, resulting in further devaluation of their stock. Three years after the disclosure of the allegations, the negative trend remains consistent with the two-year period, with 100% of the stocks experiencing declines and an average price drop of -74.69%. This figure indicates that all companies in the sample have undergone a substantial loss of market capitalization. By this time, investors have almost entirely withdrawn from these stocks.

The relationship between index price movements and stock prices represents the extent to which individual stock prices align with relevant market indices. This correlation is critical for understanding the relationship between individual stocks and the broader market, as it can provide insights into how market trends influence specific stocks and how sensitive they are to macroeconomic changes.

In the short term, immediately following the announcement of allegations, the correlation between the stocks of accused companies and relevant market indices typically remains relatively high. During this phase, the decline in the stock prices of accused companies often coincides with a similar, though less pronounced, drop in market indices, as the market reacts to news of potential irregularities in the

operations of these companies. Short-term market responses may include the sale of not only the accused companies' stocks but also those of similar companies, leading to a temporary correlation between broader market movements and specific stock performance. However, after a few months, as investors have had sufficient time to analyse and assess the situation, the stocks of accused companies generally begin to diverge from the broader market. While relevant indices such as the S&P 500 or DAX 30 may exhibit signs of recovery or stable growth, the stocks of accused companies often remain under pressure and continue to decline. In the medium term, investors start to distinctly separate the performance of these stocks from the broader market, resulting in a progressively weaker correlation.

In the long term, the disparity between the performance of market indices and the stocks of accused companies becomes even more pronounced. After one to two years, the correlation between these stocks and the broader market virtually disappears. While indices may continue to rise, reflecting general economic conditions and positive macroeconomic trends, the stocks of accused companies often persist in declining or stagnating. Three years after the allegations are disclosed, this divergence becomes permanent, indicating that the market no longer sees any connection between overall market sentiment and the fate of these specific stocks. At this point, the market has clearly demonstrated that allegations of financial fraud can have irreversible consequences on stock value, rendering their performance almost entirely independent of general market movements.

The results of this study reveal a strong positive correlation between stock price changes over short time periods. For instance, the correlation between the first week and the first month is 0.905, indicating a strong connection between these two periods. Similarly, the correlation between the first day and the first week is 0.730, also demonstrating significant linkage. However, as longer time periods are observed, these correlations weaken. For example, the correlation between the first day and half-year is 0.411, still positive but notably weaker. Over extended periods, such as one or two years, correlations generally diminish and approach zero, suggesting a weaker linear relationship. These findings suggest that the connection between stock price changes is strongest during short timeframes immediately following the allegations. Over time, this relationship weakens, indicating the increasingly complex influence of various factors on stock price movements in longer time horizons.

The results of the analysis using Student's t-test and the Wilcoxon test consistently indicate a significant decline in the stock prices of all observed companies following allegations of financial fraud across all time intervals covered in the study. The negative t-values obtained from the Student's t-test clearly demonstrate a decline in stock prices. Lower t-values indicate a more pronounced drop compared to the null hypothesis, which posits no significant changes in stock prices. The p-values for all time intervals are notably low, in most cases below 0.001, signalling statistical significance at conventional significance levels (0.05 or 0.01). Even p-values that are slightly higher but still below 0.05 (e.g., 0.004, 0.007, and 0.017) confirm statistically significant declines in stock value. These results suggest that allegations of financial fraud have had a substantial negative impact on stock prices across all analysed time intervals, from the first day to three years after the allegations.

The Wilcoxon test, which is non-parametric and does not assume normality in the data distribution, corroborates these findings. For every time interval, the results of the Wilcoxon test show statistically significant p-values below 0.05, most often below 0.001. This further confirms that allegations of financial fraud significantly affected stock prices. While the Wilcoxon test is less sensitive to distributional assumptions compared to Student's t-test, the results of both tests are consistent, demonstrating significant declines in stock prices. For example, on the first day after the fraud was uncovered, the p-values for both tests are below 0.001, indicating a sharp decline in stock value immediately following the announcement. Similar patterns are observed in subsequent periods, such as the first week and the first month, where the p-values for both tests remain below the 0.05 threshold, confirming continued negative impacts on stock prices. As time progresses, even at one, two, and three years post-allegations, the p-values for both tests remain low, indicating that the decline in stock prices is a lasting consequence of financial fraud.

These results, derived from two distinct statistical tests, consistently reject the null hypothesis that financial fraud does not cause a decline in stock prices. Given the statistical significance of these findings, it can be concluded with great certainty that financial fraud leads to a significant decline in stock prices.

CONCLUSION

The stock values of accused companies experience a sharp short-term decline immediately following the announcement of allegations, while market indices remain almost unaffected. Over longer time periods, the decline in the stock prices of accused companies becomes increasingly pronounced, whereas market indices continue to show steady growth, highlighting the divergence between accused companies and the broader market. After three years, all accused companies record significant losses in value, while market indices demonstrate stable growth, underscoring the negative impact of financial fraud allegations. The correlation between the stock prices of accused companies and market indices decreases significantly over extended periods. Market indices exhibit resilience and growth over time despite scandals involving individual companies, whereas the stocks of accused companies experience long-term value erosion. This study confirms that the disclosure of financial fraud causes a substantial decline in the stock prices of the affected companies.

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The Impact of Corporate Governance and Corporate Social Responsibility on Financial Performance in the Tunisian Banking Sector

IMEN MHAMID[1] and ALI AHMADI[2]

[1]Assistant Professor, Higher Institute of Business Administration, University of Gafsa, Tunisia, email: imenmhamid@yahoo.fr
[2]Assistant Professor, Higher Institute of Business Administration, University of Gafsa, Tunisia, email: ahmadi2402@gmail.com

ARTICLE INFO

ABSTRACT

This study investigates the impact of corporate governance and corporate social responsibility on financial performance in the banking sector. Specifically, it explores the relationship between internal corporate social responsibility, external corporate social responsibility, and three key performance metrics: Return on Assets, Return on Equity, and Tobin's Q. Using a panel data regression model with control variables such as bank size, leverage, age, and macroeconomic factors like inflation and GDP, the analysis reveals that while internal corporate social responsibility has a negative impact on both Return on Assets and Return on Equity, external corporate social responsibility shows a positive and significant effect on these financial performance indicators. The study also highlights the importance of governance mechanisms, with larger board sizes and older banks demonstrating better performance. The findings support stakeholder theory, suggesting that corporate social responsibility practices—both internal and external—enhance a firm's financial performance by improving stakeholder relationships and company reputation. This paper contributes to understanding how corporate social responsibility and governance structures influence financial outcomes in the banking sector.

INTRODUCTION

Since the 1990s, corporate governance has become a focal point of theoretical studies, which subsequently paved the way for best governance practice guidelines and reports. Following major financial scandals in the 2000s, involving companies such as Enron in the United States and Vivendi in France, global awareness around the importance of sound corporate governance intensified. These incidents highlighted the critical role of governance in preventing unethical behavior and ensuring accountability, particularly for publicly traded firms (Aluchna & Kołodkiewicz, 2022). Additionally, the intersection of corporate governance, stakeholder engagement, and firm performance has spurred extensive theoretical and empirical research. Within this framework, stakeholders—defined as individuals, groups, or institutions that influence or are influenced by a company—are integral to corporate governance. They embody a commitment to sustainable, reciprocal relationships, fostering harmony and accountability between a company and its wider environment (Freeman & Reed, 1983; Hillman & Keim, 2001).

This study seeks to investigate the effects of stakeholder-influenced governance on corporate performance. Despite substantial research on corporate governance practices and their direct impact on performance, the specific role stakeholders play in enhancing governance quality remains underexplored (Haque, 2023). While many studies examine stakeholder influence on governance, relatively few consider how stakeholders collectively shape governance practices over time.

The study further connects to a body of literature exploring the correlation between governance practices and corporate performance outcomes. However, most research in this domain, particularly in the Tunisian context, has focused narrowly on specific governance variables without considering the effects of a comprehensive governance index. Limited studies in Tunisia explore how a broader set of governance practices impacts performance across industries (Gani & Jha, 2023). This research seeks to address this gap by developing a governance score that assesses the combined impact of governance mechanisms on firm performance.

Our work also examines the relationship between internal and external Corporate Social Responsibility (CSR) and financial performance while controlling for governance mechanisms. This analysis aims not only to evaluate how governance practices affect the CSR-financial performance link but also to clarify the nature of these relationships within Tunisian banks listed on the stock exchange from 2005 onwards. By answering the question, "What is the impact of governance mechanisms on the relationship between internal and external CSR and financial performance?" this study aims to provide insights into how governance structures facilitate or hinder sustainable performance.

The research examines the extensive body of theoretical and empirical literature on CSR and financial performance relationships and empirically analyzes this relationship using regression models on the Tunisian banking sector. Globalization, increased emphasis on social responsibility, heightened shareholder expectations, and successive financial scandals have all contributed to the growing complexity of corporate governance. Effective governance requires that relationships among executives, shareholders, and other stakeholders are structured to facilitate sustainable and competitive business operations (Jamali & Mirshak, 2022).

Historically, governance referred broadly to the art of governing, encompassing public administration and state management practices. By the late 20th century, however, economists and business scholars began to focus on corporate governance in response to market globalization and the evolving role of firms in society (Aguilera et al., 2019). Since the 1990s, corporate governance has garnered attention for its impact on firm strategy, particularly in the aftermath of scandals that exposed management's critical role in safeguarding stakeholders' interests.

Prominent scholars have provided various definitions of governance, each emphasizing different facets. Monks and Minow (1995) highlighted the strategic role of governance in shaping corporate decisions, defining it as "the network of relationships that bind multiple parties in determining the strategy and performance of the company." Meanwhile, Charreaux (1997) defined governance more restrictively as a system of mechanisms designed to limit executive discretion, ensuring that leaders' actions align with stakeholders' interests.

1. THEORETICAL FRAMEWORK ON CORPORATE GOVERNANCE:

Corporate governance has been a key area of academic research, particularly in the wake of major corporate scandals. Since the 1990s, the academic discourse surrounding corporate governance has evolved, shaped by increasing recognition of the need for stronger regulatory frameworks to prevent financial misconduct. Governance mechanisms have broadened beyond traditional internal controls to embrace a more comprehensive view of stakeholder engagement and corporate responsibility (Zattoni et al., 2023).

At its core, *agency theory*, as articulated by Jensen and Meckling (1976) and Fama (1980), aims to align the interests of shareholders with those of company management through both internal governance mechanisms (e.g., the board of directors) and external forces (e.g., financial markets, labor markets). This theory is rooted in the premise that managerial behavior must be monitored and controlled to ensure the maximization of shareholder wealth, with an emphasis on reducing agency costs.

However, recent developments have challenged this view, incorporating broader stakeholder concerns. For instance, Goranova et al. (2022) argue that an exclusive focus on shareholder value maximization can overlook critical dimensions of corporate responsibility, such as environmental sustainability and social equity. The growing acceptance of stakeholder theory has led to a shift toward a more inclusive understanding of corporate governance, where value creation is considered in the context of social and environmental impact, not just financial returns.

As governance theories evolve, researchers have begun emphasizing the firm's role in generating knowledge and fostering innovation. Charreaux (2002) highlighted this shift by redefining corporate governance as a mechanism for creating value through innovation. More recent research, such as Lambert et al. (2021), reinforces this notion by linking effective governance practices with enhanced organizational learning and knowledge sharing. The focus has expanded to include cognitive and intellectual capital, which are now seen as integral to sustained firm success (OECD, 2023).

1.1 Corporate Social Responsibility (CSR) and the Stakeholder Approach

Corporate Social Responsibility (CSR) has evolved significantly since its early conceptualization in the 1960s. Initially seen as a voluntary set of actions for businesses to "give back" to society, CSR is now understood as an essential part of corporate governance, driven by both external pressures and the strategic interests of the firm (Vilanova et al., 2023). Friedman's (1970) narrow definition of CSR—focused solely on profit maximization for shareholders—has been increasingly criticized. Jones (2021) notes that this view ignores the complexity of modern corporate operations, where businesses are expected to contribute positively to society and the environment while generating profits.

Today, CSR is widely viewed as a set of practices that can drive long-term success by aligning business strategies with stakeholder interests. Leading definitions from organizations like the World Business Council for Sustainable Development (WBCSD) and Business for Social Responsibility (BSR) emphasize the importance of sustainable practices that balance economic, environmental, and social goals (BSR, 2022). These organizations argue that companies that integrate CSR into their core strategy not only improve their public image but also secure long-term competitive advantages.

1.2 Stakeholders in Governance: Roles and Influence

The importance of stakeholders in corporate governance has been increasingly recognized. According to Freeman (2008), a stakeholder approach involves considering the rights and interests of all parties affected by a company's actions. Recent empirical studies further highlight the diverse roles stakeholders play in governance. For instance, Zollinger (2023) categorizes stakeholders into various types, including:

- *Experts*: Offer strategic advice based on their specialized knowledge, contributing to the firm's governance framework.
- *Technical Advisors*: Provide insights on emerging technologies and social risks, particularly in industries with high environmental or societal impacts (Sharma et al., 2022).
- *Special Interest Representatives*: Represent employees or local communities, ensuring that corporate practices align with broader societal interests.
- *Co-producers*: Partner with NGOs or other external organizations to collaboratively address sustainability challenges (Avi-Yonah, 2023).
- *Co-monitors*: Participate in the monitoring of sustainability projects, ensuring transparency and accountability in corporate actions.
  These roles reflect a shift toward more inclusive and participatory governance models, where the relationship between companies and stakeholders goes beyond mere compliance to include active engagement in governance processes.

A significant body of recent research has explored how governance structures influence CSR practices and financial performance. García-Meca et al. (2020) examine the role of governance in shaping CSR strategies and argue that companies with robust governance structures are more likely to adopt effective CSR practices, leading to improved financial performance. Similarly, Goranova et al. (2022) find that corporate governance mechanisms that prioritize stakeholder interests tend to produce more sustainable financial outcomes, aligning business goals with broader societal objectives.

A recent study by Zattoni et al. (2023) explores the relationship between governance reforms and corporate performance, specifically focusing on how CSR initiatives influence firm valuation. They find that companies that actively engage in CSR are better positioned to achieve long-term success by cultivating trust with consumers, employees, and investors.

The evolving theories of corporate governance highlight the importance of integrating stakeholder interests and CSR into the core business strategy. Firms with strong governance frameworks that prioritize innovation and stakeholder engagement are more likely to create value not only for shareholders but for society at large. As the research continues to evolve, it is clear that the traditional view of corporate governance focused solely on profit maximization is being replaced by a more holistic model that balances financial, social, and environmental objectives.

2. METHODOLOGY

2.1 Hypotheses

The relationship between corporate governance, stakeholders, and financial performance has generated significant scholarly attention. While previous studies have primarily explored the positive influence of governance and CSR on organizational outcomes, this research focuses on testing two key hypotheses:

- H_1: There is a positive and significant relationship between internal CSR and the performance of banks through governance mechanisms.
- H_2: There is a positive and significant relationship between external CSR and the performance of banks through governance mechanisms.

These hypotheses are grounded in the assumption that corporate governance mechanisms can mediate the impact of CSR (both internal and external) on financial performance, aligning with recent studies that emphasize the role of governance in enhancing CSR's effectiveness (Liao et al., 2022; García-Sánchez et al., 2021). The focus on banks is relevant given the financial sector's increasing commitment to CSR and governance reforms in the post-financial crisis era (Zattoni et al., 2023).

2.2 Sample and Data

To test the hypotheses and address the main research question of this section, we use regression models applied to a panel sample consisting of 30 Tunisian banks listed on the Tunis Stock Exchange over the period 2007–2018. The data were sourced from multiple channels: accounting data (total assets, revenue, debts, and equity) were derived from financial statements, while stock market data (share price, trading volume, and market capitalization) were collected from the Tunis Stock Exchange website. Corporate governance data were obtained from annual reports, official documents filed with the Financial Market Council (CMF), and CMF-approved prospectuses.

2.3 Variables measurement

Dependent Variables

The study's dependent variables include return on assets (ROA), return on equity (ROE), and Tobin's Q, which measure different aspects of financial performance:

- *ROA (Return on Assets)*: This ratio assesses the profitability of a company's assets by indicating the earnings per unit of assets controlled. It reflects the efficiency of management in utilizing assets to generate income. ROA has been commonly used as a financial performance indicator in prior studies, including Ozili (2021)
- ROA=Net Income/Total Assets
- *ROE (Return on Equity):* ROE measures how effectively a company uses reinvested earnings to generate revenue, offering insight into overall performance.
- ROE=Net Income/Equity

- *Tobin's Q* represents a company's potential for future growth. A Q greater than 1 implies that a company's shares are valued higher than the replacement cost of its assets, signaling overvaluation and an incentive to invest in capital. In contrast, a Q between 0 and 1 suggests undervaluation. Since calculating Tobin's Q directly is complex, approximations are frequently used.

Q = (Market value + Total debts + Preferred shares outstanding) / Total assets

Independent Variable

In our regression model, we will use ROA, ROE, and Tobin's Q as the main variables to show their impact on two derivatives: INT CSR and EXT CSR, which relate to corporate governance.

- INT CSR: Represents the internal CSR component for company i in year t, measured by the sum of scores for employee relations, corporate governance, and diversity categories.
- Formula: INT CSR = Sum (employee relations + corporate governance + other categories)
- EXT CSR: Represents the external CSR component related to the stakeholders of company i in year t, measured by the sum of scores in the product, environment, and community categories.
- Formula: EXT CSR = Sum (product + environment + community categories)
- Control Variables
- Bank Size (TB): Measured by the natural logarithm of the book value of total assets (Ashbaugh-Skaife et al. (2006), Anderson et al. (2004), Chen et al. (2006), and Pittman and Fortin (2004)).
- Formula: TB = Log (Total assets)
- Leverage (LVRG): This ratio represents net debt relative to equity (Net debt / Equity). Leverage is considered a potentially important variable generally related to governance and ownership structure, also used as a risk indicator.
- Formula: LVRG = Long-term debt / Total assets
- Age (AG): The total number of years since the bank's initial public offering.
- Board Size (TCA): Measured by the number of directors sitting on the bank's board of directors.
- Duality (DUA): Duality is defined as the same individual holding both the CEO and board chair positions simultaneously. This variable equals 1 if the company's CEO is also the board chair, and 0 otherwise.
- ADI: The number of external directors as a percentage of total directors.
- Inflation (INFL): Based on the growth rate of the consumer price index. A rise in this rate is expected to reflect an imbalance in the national economic situation, which could affect corporate performance.
- Gross Domestic Product (GDP): The annual GDP growth rate.

Table 1. Variables measuement

Variable Type	Variable Name	Abbrevia-tion	Measurement	Source
Dependent Variable	Return on Assets	ROA	Net income / Total assets	Bankscope
	Return on Equity	ROE	Net income after tax / Equity	Bankscope
	Tobin's Q	Tobin's Q	Debt / Total assets	Bankscope
Independent Variable	Internal Corporate Social Responsibility	INT CSR	Donations / Income	Calculated by the author
	External Corporate Social Responsibility	EXT CSR	(Donations + Off-balance activities) / Income	Calculated by the author
Control Variable	Leverage	LVRG	Long-term debt / Total assets	Annual report
	Age	AG	Total number of years	Annual report
	Inflation	INFL	Annual inflation rate	World Bank
	Gross Domestic Product	GDP	Annual GDP growth rate	World Bank
	Duality	DUA	Binary variable equal to 1 if duality exists and 0 otherwise	Annual report
	Bank Size	TB	Log (total assets)	Annual report
	Percentage of External Directors	ADI	Number of external directors / Total directors	Annual report
	Board Size	TCA	Total number of directors	Annual report

Source. own

3. MODEL SPECIFICATION

This study involves three main models. The first model uses ROA as the dependent variable, the second model uses ROE as the dependent variable, and the third model uses Tobin's Q as the dependent variable. The independent variables in each model are INT CSR and EXT CSR, with control variables including leverage, size, risk, age, inflation, and GDP.

Model 1: When ROA is the dependent variable,
$ROA_{it} = \beta_0 + \beta_1 \, INT \, CSR_{it} + \beta_2 \, EXT \, CSR_{it} + \beta_3 \, LVRG_{it} + \beta_4 \, AG_{it} + \beta_5 \, INFL_{it} + \beta_6 \, GDP_{it} + \varepsilon_{it}$

Model 2: When ROE is the dependent variable,
$ROE_{it} = \beta_0 + \beta_1 \, INT \, CSR_{it} + \beta_2 \, EXT \, CSR_{it} + \beta_3 \, LVRG_{it} + \beta_4 \, AG_{it} + \beta_5 \, INFL_{it} + \beta_6 \, GDP_{it} + \varepsilon_{it}$

Model 3: When Tobin's Q is the dependent variable,
$Q_{it} = \beta_0 + \beta_1 \, INT \, CSR_{it} + \beta_2 \, EXT \, CSR_{it} + \beta_3 \, LVRG_{it} + \beta_4 \, AG_{it} + \beta_5 \, INFL_{it} + \beta_6 \, GDP_{it} + \varepsilon_{it}$
Where: ε_{it} is the error term.

4. ANALYSIS OF RESULTS

We present a linear regression model with two derivatives (INT CSR and EXT CSR). Our sample consists of panel data. For such data, the two standard estimation methods are the fixed-effects model and the random-effects model, as they allow for controlling unobserved company characteristics that may influence performance.

This subsection will present descriptive statistics for the variables in this chapter and the correlation matrix of the different variables. Finally, we outline the estimation method and the resulting outcomes.

4.1 Descriptive Statistics

The average ROA is 0.7201, indicating that banks in this sample have a modest return on assets, it varies widely, from a minimum of -47.148 to a maximum of 33.654, reflecting large performance

disparities across the banks. Negative values suggest that some banks experienced losses during the period, which may reflect operational or economic challenges.

The average ROE is 7.3481, implying a reasonable return for shareholders, although lower than some industry expectations, it also shows a wide range from -44.054 to 218.009, indicating substantial variability in profitability and financial strategies.

With an average of 3.317, the mean Q ratio indicates that, on average, banks' market values are substantially higher than their asset replacement costs, suggesting favorable growth perceptions. A standard deviation of 3.1179 reflects significant dispersion in Tobin's Q, indicating varied market expectations about future growth.

The average INT CSR score is 0.1381, indicating moderate engagement in internal CSR activities related to employee relations and corporate governance. A standard deviation of 0.2300 indicates some variability in CSR commitment levels across the banks, though not as pronounced as financial performance indicators.

The mean EXT CSR score is 0.8877, suggesting that, on average, banks are relatively consistent in addressing external CSR concerns, such as environmental and community involvement.

The average leverage is very low, at 0.0014, suggesting conservative debt usage relative to assets across the banks.

Log of Total Assets varies with a range from 1.8732 to 7.0544, there is considerable variation in bank size, indicating a mix of small and large institutions.

The average bank age is approximately 39 years, suggesting a mix of both well-established and relatively new banks in the sample.

The mean board size (TCA) is 11, aligning with industry norms where boards typically comprise around 10–15 members.

The average value of 0.206 suggests that, in about 20.6% of cases, the CEO also serves as the board chair, a governance structure with potential implications for decision-making autonomy.

With an average GDP growth rate of 2.5410, the economic environment appears to be moderately growing, though with a range from -1.9172 to 6.7096, capturing periods of both recession and growth.

Table 2. Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Standard Deviation
INT CSR	310	0.0004625	3.548129	0.1381092	0.2300151
EXT CSR	310	0.4906628	0.9804809	0.0699355	-
Q	310	0.49	9.691	3.3166610.88	3.117871
ROA	310	-47.148	33.654	0.720061	3.827284
ROE	310	-44.054	218.009	7.348081	18.94399
LVRG	310	4.63e-06	0.0354813	0.0013811	0.0023002
LOTA	310	1.873209	7.05442	4.958455	2.095437
AG	310	14	132	38.85161	22.64709
TCA	310	7	15	11.00667	1.48345
DUA	310	0	1	0.2059801	0.4050894
TP	310	3.452899	7.05442	6.676169	0.4677386
INFL	310	2.966944	5.316236	3.951843	0.664874
GDP	310	-1.917178	6.70962	2.541014	1.997693

Source: own

4.2 Robustness Test

Robustness Test

$$F(9,165)=3.16$$
$$\text{Prob} > F = 0.0015$$

To enhance the robustness of our results, we conducted the following robustness test: we replaced the performance measure ROA with Tobin's Q. The estimates show that the results are consistent with those found previously, with the impact of internal and external CSR remaining significantly positive regardless of the performance measure used.

4.3 Result and discussion

Table 3. Variable Estimation for the Three Models

	Model 1 (ROA)	*Model 2 (ROE)*	*Model 3 (Tobin's Q)*
INT CSR	-0.085046 (0.000)***	-1.317805 (0.008)**	0.2635574 (0.739)
EXT CSR	0.9327858 (0.000)***	8.648956 (0.003)**	-3.116357 (0.365)
AG	-0.0011463 (0.006)**	0.0722312 (0.003)**	0.0289367 (0.007)*
TCA	0.0592119 (0.003)	1.689329 (0.026)	-0.3630245 (0.043)
LOTA	-0.2955369 (0.000)	-2.821802 (0.000)	0.0745503 (0.557)
DUA	-0.1859215 (0.001)*	-2.785544 (0.029)	-1.233415 (0.054)
LVRG	0	6.072278 (0.034)	0
TB	-0.0300812 (0.004)**	-5.410829 (0.012)	0.1746095 (0.700)
INFL	-0.2358348 (0.015)	-2.300419 (0.050)	0.1796726 (0.632)
GDP	0.0018456 (0.001)**	-0.5685823 (0.032)	0.0530768 (0.720)
R^2	0.4681	0.2353	0.1470

Source: own

In Model 1 (ROA), *INT CSR* displays a significant negative effect (coefficient: -0.0850, $p < 0.001$). This suggests that internal CSR activities, focused on employee and governance aspects, may incur short-term costs, reducing profitability. Research by Wang et al. (2022) corroborates this finding, noting that while internal CSR practices improve long-term employee satisfaction, they often result in higher immediate expenses. Similarly, in Model 2 (ROE), INT CSR shows a significant negative effect (coefficient: -1.3178, $p = 0.008$), which aligns with Lins et al. (2019), who found that internal CSR may not yield immediate returns on equity due to associated costs. However, in Model 3, INT CSR's influence on Tobin's Q is insignificant, suggesting minimal impact on market expectations for growth, as seen in Flammer (2020), who noted that internal CSR activities often lack the visibility investors prioritize.

Conversely, *EXT CSR* positively influences ROA and ROE. In Model 1 (ROA), the positive relationship (coefficient: 0.9328, $p < 0.001$) indicates that community- and environment-focused CSR enhances asset profitability, likely by strengthening reputational capital and stakeholder trust, as supported by Ali et al.

(2023). Model 2 (ROE) also shows a strong positive association with EXT CSR (coefficient: 8.6489, p = 0.003), implying alignment with shareholder interests, consistent with Kim et al. (2021), who reported that visible CSR efforts improve investor sentiment. However, EXT CSR has an insignificant negative effect in Model 3 (Tobin's Q), suggesting that these initiatives may not significantly impact market-based growth indicators.

Bank Age (AG): In Model 2 (ROE) and Model 3 (Tobin's Q), AG has a positive effect, indicating that older banks benefit from established reputations, supporting findings by Ahamed et al. (2023). However, AG negatively impacts ROA in Model 1, which might reflect potential inefficiencies in older assets.

Board Size (TCA): Larger board size positively affects ROA and ROE, suggesting enhanced governance, as noted by Kashif et al. (2021). Yet, in Model 3 (Tobin's Q), TCA negatively impacts growth expectations, possibly due to decision-making delays, aligning with Conyon & He (2019).

Duality (DUA): This variable has a consistently negative impact on ROA and ROE, indicating potential governance issues when CEO and board chair roles are combined, as highlighted by Iqbal et al. (2022).

Bank Size (TB): Negative associations with ROA and ROE suggest inefficiencies in larger banks, consistent with Sun et al. (2022).

Leverage (LVRG): Positively affects ROE, indicating that higher leverage enhances returns on equity, though with added risk, as supported by Kim & Yang (2021).

Macroeconomic Factors (INFL and GDP): Inflation negatively impacts ROA and ROE, which aligns with Almeida & Campello (2020), who highlight inflation's role in squeezing margins. GDP growth positively affects ROA, corroborating Zhang et al. (2023), who noted that economic expansion benefits banking profitability.

The R^2 values indicate that Model 1 (ROA) has the highest explanatory power, suggesting that accounting-based measures capture internal performance more effectively than market-based measures like Tobin's Q, which aligns with findings from Ali et al. (2023). In summary, external CSR initiatives positively affect ROA and ROE, whereas internal CSR tends to show short-term costs. Control variables further reveal the influence of governance and macroeconomic factors on performance, with recent research supporting these varied effects across different financial metrics.

In Model 1, there is a significant positive relationship between internal CSR, external CSR, and financial performance. Model 2 confirms this result, with the impact of internal and external CSR remaining positive and significant in the presence of governance mechanisms. The relationship found in Model 3 corroborates the previous findings, confirming Hypothesis 1: there is a positive and significant relationship between internal and external CSR and financial performance when governance indicators are present. Regardless of the performance measure used (ROA, ROE, or Tobin's Q), the result remains unchanged. A bank with strong internal governance mechanisms consequently enjoys a positive reputation, attracting more clients and talent, which can ultimately improve its performance. Globally, companies with the best internal and external CSR reputations are among the top-performing companies. According to econometric results, we accept the hypothesis related to stakeholder theory, which suggests that CSR has a positive impact on financial performance. Internal and external CSR are indicators of the company's ability to effectively meet the demands of various stakeholders.

CONCLUSION

This study explored the relationship between internal CSR, external CSR, and financial performance, controlling for governance mechanisms. The study sought to provide a definitive answer to a fundamental question in this debate: whether there is a relationship between financial performance and internal and external CSR, and if so, the nature of this relationship. To better evaluate the link between these variables in the presence of governance indicators, the study's results showed a relationship between the variables in question. The positive relationship between internal and external CSR and financial performance reflects socially positive behavior among Tunisian companies. Tunisian banks contribute to social well-being, improve living standards by promoting education and better healthcare facilities, and protect the environment

from harmful changes. They also take good care of their employees to build trust. These social expenditures help companies achieve sustainable long-term development and financial benefits.

It provides valuable insights into the relationship between corporate governance, corporate social responsibility, and financial performance in the banking sector. The results indicate that while internal corporate social responsibility practices tend to have a short-term negative impact on profitability, external corporate social responsibility efforts significantly enhance both Return on Assets and Return on Equity, suggesting that banks with strong external CSR initiatives benefit from improved stakeholder trust and market perception. Furthermore, the study highlights the importance of governance structures, such as board size and bank age, in influencing financial performance. Larger and more established banks tend to perform better, reinforcing the role of robust governance in driving long-term success. The findings align with stakeholder theory, demonstrating that addressing the needs of various stakeholders through effective CSR practices can positively influence financial outcomes. Overall, this paper contributes to the understanding of how corporate governance and CSR initiatives, both internal and external, can enhance a bank's performance, offering practical implications for managers and policymakers aiming to improve financial results through responsible corporate practices.

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Montenegrin Journal of Economics

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Portfolio Diversification and Financial Investment Opportunity: Exploring Portfolio Management Through the Dynamic Dependence of Cryptocurrencies

MOHAMED A. M. SALLAM[1], TAREK SADRAOUI[2] (Corresponding author) and AHMED MOHAMED KAMARA

[1]Professor, Department of Economics, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh, Saudi Arabia,
   email: mohamedsallam_2010@yahoo.com, ORCID ID: orcid.org/0000-0002-8753-6128
[2]Professor, Department of Economics, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh, Saudi Arabia,
   email: tsadrawi@imamu.edu.sa, ORCID ID: orcid.org/0000-0002-8753-6128
[3]Associate Professor, Department of Economics, Faculty of Commerce, Kafrelsheikh University, Egypt, email: ahmed.kamara@com.kfs.edu.eg

ARTICLE INFO

ABSTRACT

This study explores the dynamics of portfolio diversification and financial investment opportunities through cryptocurrency assets. The rapid rise of digital currencies in the global financial landscape has raised crucial questions about their relationships with traditional assets and their potential role in effective portfolio management. The primary goal of this research is to assess the interdependence and co-movement of various cryptocurrencies and their suitability for inclusion in traditional investment portfolios. To achieve this, the study employs advanced econometric methods, including the Dynamic Conditional Correlation-Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model, to analyze the volatility and dependency structures among cryptocurrencies, traditional financial assets, and crude oil prices. The research hypothesizes that cryptocurrencies offer diversification benefits due to their distinct return characteristics and weak correlations with traditional asset classes. Empirical results confirm that cryptocurrencies exhibit varying degrees of dependence under different market conditions, influenced by factors such as investor sentiment and macroeconomic shocks. The findings suggest that while some cryptocurrencies function effectively as standalone investments, others enhance the risk-return profiles of diversified portfolios. Notably, the study identifies significant interactions between cryptocurrency returns, traditional financial indices, and crude oil prices, underscoring the interconnected nature of modern financial markets. This research contributes to the discourse on modern portfolio theory by providing new insights into the integration of digital assets in investment strategies. The findings emphasize the importance of timing and market conditions when incorporating cryptocurrencies into portfolios. Ultimately, this study highlights the dual role of cryptocurrencies as both diversification tools and high-risk, high-

reward assets, offering valuable implications for investors and policymakers navigating the complexities of digital finance.

INTRODUCTION

Portfolio management in contemporary financial markets faces new challenges and opportunities with the emergence of cryptocurrencies. These digital assets, secured by cryptography and leveraging block-chain technology, have captured the interest of investors, regulators and the general public (Manjula et al., 2022). Their decentralized nature and promise of secure, intermediary-free transactions have re-shaped the financial landscape, offering new prospects for investment and portfolio diversification.

While cryptocurrencies have grown in popularity since the creation of Bitcoin in 2009, their complex dynamics and relationship with traditional financial markets raise important questions (Aliyev, 2022). Investors seek to understand how the evolution of cryptocurrencies is influenced by global economic events, particularly financial crises, and how they interact with traditional assets in constructing diversified portfolios.

This study aims to explore in depth this complex relationship between cryptocurrencies and traditional assets, focusing on the dynamic dependence between these two financial universes. Through an in-depth literature review and hypothesis development, we will analyze how emerging characteristics of cryptocurrencies, such as volatility and risk, relate to traditional financial markets (Wang et al., 2022). Additionally, a methodological approach based on the ARCH model will be used to illuminate the underlying dynamics and implications for portfolio management.

This exploration aims to fill existing knowledge gaps and open new research perspectives on the mechanisms governing the relationship between cryptocurrencies and traditional investment portfolios (Joseph et al., 2024). By better understanding this complex interaction, investors will be able to make more informed decisions to optimize their portfolios in an ever-changing financial environment.

This document is structured as follows: Section 2 provides a review of the literature. In Section 3, we detail the research methodology. The results and discussions are presented in Section 4. Finally, in Section 5, we present the conclusion.

1. LITERATURE REVIEW

The dynamic relationship between cryptocurrencies and traditional assets has been a growing area of research due to the unique characteristics of cryptocurrencies, such as high volatility and extreme price movements. Several studies have highlighted the diversification benefits that cryptocurrencies provide. For instance, Corbett et al. (2018) demonstrated the relative isolation of cryptocurrencies like Bitcoin, Ripple, and Litecoin from traditional assets, offering significant diversification opportunities, particularly for short-term investors. Similarly, Baumöhl (2019) found near-zero correlations between cryptocurrencies and forex market currencies, further emphasizing their potential for portfolio diversification. Other studies, such as those by Kostika and Laopodis (2019) and Charfeddine et al. (2019), revealed weak long-term interdependence between cryptocurrencies and traditional assets, which vary depending on market conditions and temporal contexts.

Beyond diversification, cryptocurrencies also demonstrate hedging and safe-haven potential. Dyhrberg (2016) showed that Bitcoin acts as a short-term hedge against fluctuations in FTSE indices and the US dollar, underscoring its utility in financial risk management. Bouri et al. (2017a) concluded that Bitcoin is a weak hedge and more suitable for diversification, with time-varying properties that depend on specific market conditions. In a similar vein, Tufan et al. (2022) found a significant relationship between Bitcoin and gold, suggesting that Bitcoin can serve as a hedge, though its link to crude oil is weaker or negligible.

Several studies have also focused on the interdependence and causal relationships between crypto-currencies and traditional assets. Yavuz et al. (2022) discovered bidirectional causality between crypto-currencies and bond markets, highlighting their predictive value for traditional assets. Furthermore, Detthamrong et al. (2024) identified causal interdependence between major cryptocurrencies (e.g., Tether and USD Coin) and global economic assets such as gold, bonds, and equity indices.

Volatility and shock transmission are other critical aspects of the relationship between cryptocurrencies and traditional assets. Kurka (2019) and Ji et al. (2018) found weak unconditional connections between cryptocurrencies and traditional assets but noted significant transmission of shocks during periods of market turbulence. Guesmi et al. (2019) showed that Bitcoin's volatility significantly influences other assets, acting as a hedge during downturns. Bhuiyan et al. (2021), using wavelet analysis, highlighted Bitcoin's leader-follower relationships with gold and the US dollar, showing limited integration with the global financial system.

The temporal and structural dynamics of cryptocurrency relationships with traditional assets have also been studied extensively. Bouri et al. (2017b) demonstrated that Bitcoin's hedging properties depend on time horizons and market conditions, with significant changes observed following the December 2013 crash. Maghyereh and Abdoh (2021) examined the long-term bidirectional dependence between Bitcoin and global stock indices, while Wu (2021) emphasized Bitcoin's unique and complex relationship with gold compared to other assets.

During financial crises, cryptocurrencies exhibit heightened volatility and varying interactions with traditional markets. Doumenis et al. (2021) observed higher volatility in Bitcoin compared to traditional assets, particularly during the COVID-19 period, underscoring its speculative nature. Elsayed et al. (2022) highlighted unidirectional volatility spillovers from Bitcoin to traditional assets, indicating its influence during periods of financial uncertainty.

Overall, the literature suggests that cryptocurrencies provide significant diversification benefits, with limited integration into traditional financial systems. Their hedging capabilities and shock transmission dynamics, however, vary depending on market conditions and temporal factors. These insights provide the foundation for this study, which aims to further explore the complex relationships between cryptocurrencies and traditional assets using advanced econometric techniques.

2. RESEARCH METHODOLOGY

In this subsection, we present the sample data that forms the basis of our study on the dynamic relationship between cryptocurrencies and traditional assets. We focus our attention on a select set of five cryptocurrencies, including Bitcoin (BTC), Ethereum (ETH), Ripple (XRP) and Tether (USDT), alongside three major traditional assets such as the S&P 500 Index, the Dow Jones Industrial Average (DJIA) and the price of crude oil (WTI). This selection of daily chronological data, covering a significant period from January 1, 2016 to December 12, 2023, was carried out to ensure adequate representativeness of temporal variations.

To study the dynamic relationship between cryptocurrencies and traditional assets, empirical analysis is stronger than theoretical literature. This is supported by a variety of studies.

The model therefore looks like this:

$$BTC = \alpha_0 + \beta_1\,ETH + \beta_2\,XRP + \beta_3\,USDT + \beta_4\,SP500 + \beta_5\,DJIA + \beta_6\,WTI + \varepsilon_i \qquad (1)$$

With;

BTC: Represents the independent variable and indicates the virtual currency Bitcoin,
ETH: Represents a dependent variable and indicates the virtual currencyEthereum,
XRP: Represents a dependent variable and indicates the virtual currency Ripple,
USDT: Represents a dependent variable and indicates the virtual currency Tether,
S&P500: Represents a dependent variable and indicates the stock market index S&P 500,

DJIA: Represents a dependent variable and indicates the stock market index Dow Jones Industrial Average,

WTI: Represents a dependent variable and indicatesthe price of crude oil,
β: Represents the estimated coefficients of the study variables.
α_0: Is a constant term, the ordinate at the origin of the regression line?
ε_i: The error term verifying the assumptions of the OLS method.

Autoregressive (AR) and moving (MA) models can be effectively combined to form a general and useful class of time series models, known as ARMA models.(Box, 2013).According to the correlogram of the residuals, our ARMA model is well represented by an order (p, q) equal to (2, 0).

In order to empirically test this structural regression model, equation 1 is transformed into a reduced form of the ARCH model as follows:

the associated ARCH model is characterized by an order p equal to 2, i.e. an ARCH (2) model. So, our ARCH (2) model is written in the following form:

$$\sigma_t^2 = \omega + \alpha_1\,\varepsilon_{t-1}^2 + \alpha_2\,\varepsilon_{t-2}^2 \quad (2)$$

With:

σ_t^2: The conditional variance at time t;
ω: The model constant;
α_i : The ARCH coefficients for the delays i;
ε_{t-i} : The residuals of past observations.

3. RESULTS AND DISCUSSIONS

3.1 Descriptive statistics

Descriptive statistics provides a comprehensive and accessible approach to data analysis by combining numerical and graphical methods. By combining these approaches, descriptive statistics provides a robust framework for exploring, analyzing, and effectively communicating the characteristics of datasets, regardless of the application domain. These charts provide an intuitive overview of the data, making it easier to interpret.

3.1.1 Graphical analysis

The chart above illustrates the daily price movement of cryptocurrencies and traditional assets from 2016 to the end of 2023. During this period, cryptocurrencies experienced significant fluctuations, notably Bitcoin (BTC) which reached an all-time high near $20,000 in December 2017, then fell in 2018 before experiencing significant increases in 2020 and 2021, surpassing $60,000 in May and November 2021. Ethereum (ETH) and XRP also saw notable swings.

In contrast, Tether (USDT) has maintained remarkable stability, with a current price of around $1.11, which sets it apart from other cryptocurrencies.

When it comes to traditional assets, the S&P 500 and the Dow Jones Industrial Average have seen steady growth with minor fluctuations during the mentioned period. In contrast, the price of crude oil (WTI) has been subject to significant fluctuations, mainly influenced by factors such as production, global demand and geopolitical tensions.

In short, all the series represented in the graph show an absence of stability over time, with the notable exception of Tether (USDT) among cryptocurrencies.
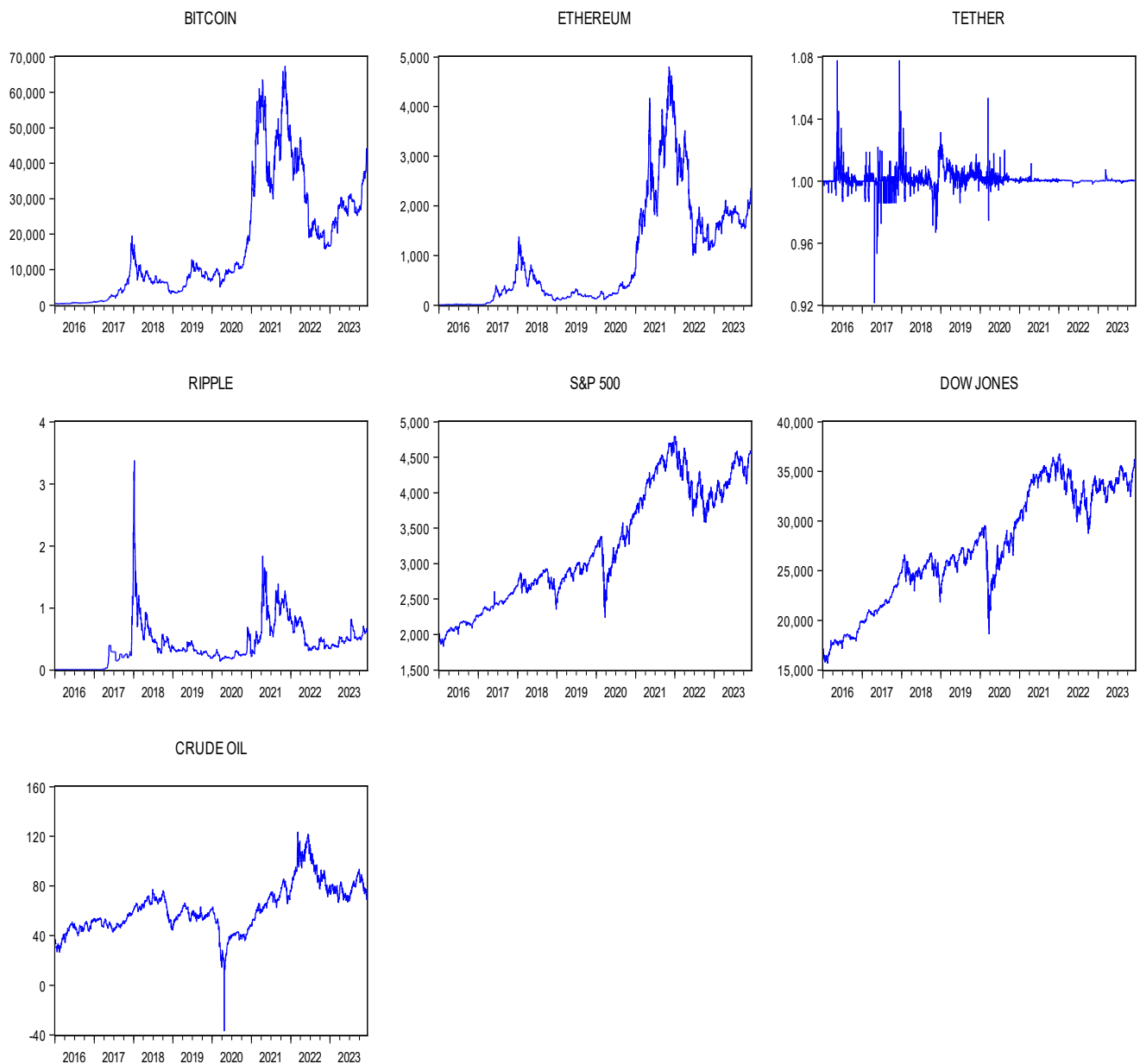
Figure 1. Historical evolution of the prices of cryptocurrencies and traditional assets
Source: Developed by the author

3.1.2 Digital analysis

The Table 1 below provides descriptive statistics for different cryptocurrencies (BTC, ETH, USDT, XRP) as well as some traditional assets (DJIA, S&P 500, WTI).

Table 1. Descriptive statistics

	BTC	ETH	USDT	XRP	DJIA	S&P500	WTI
Mean	16710.98	961.7673	1.001082	0.417025	27317.90	3249.449	61.87059
Median	9598.995	378.3050	1.000300	0.342685	26651.77	3002.735	59.21000
Maximum	67510.06	4805.950	1.077880	3.377810	36799.65	4796.560	123.6400
Minimum	357.5300	0.921000	0.921300	0.004500	15660.18	1829.080	-36.98000
Std. Dev.	16235.29	1094.861	0.006094	0.355134	5725.967	827.0814	19.03534
Skewness	1.076654	1.277704	1.003104	2.033012	-0.15524	0.199057	0.457248
Kurtosis	3.177121	3.876728	40.69028	11.62303	1.874156	1.680127	3.512146
Jarque-Bera	564.4525	882.5418	172255.7	10990.01	164.9218	229.8093	132.8385

Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Comments	2902	2902	2902	2902	2902	2902	2902

Source: Developed by the author

Table 1 presents the descriptive statistics for different variables, all based on a set of 2902 observations. The BTC series displays significant volatility, with a high standard deviation of 16235.29 and significant spikes in the price, suggesting a skewed distribution towards higher values. The ETH variable shows less volatility than BTC, but a slightly asymmetric distribution, with a standard deviation of 1094.861 and a positive skewness of 1.277704. USDT shows stability around parity with the dollar, but a distribution with heavier tails than normal, indicated by a high kurtosis of 40.69028. The XRP variable has a very low mean and a very skewed distribution with a high skewness of 2.033012. The DJIA and SP 500 show positive averages, with slightly skewed distributions. The WTI variable has a positive mean with an asymmetric distribution. Jarque-Bera tests show that not all series follow a normal distribution.

3.2 The correlation matrix between the variables

Table 2 indicates a more commonly used correlation test to assess multi-collinearity between two variables is the Pearson correlation coefficient.

Table 2. Correlation matrix results

	BTC	ETH	XRP	USDT	S&P500	DJIA	WTI
BTC	1						
ETH	0.938358	1					
XRP	0.669668	0.695801	1				
USDT	-0.064068	-0.080000	-0.001848	1			
S&P500	0.885523	0.869100	0.569280	-0.079256	1		
DJIA	0.850621	0.823838	0.602825	-0.058534	0.982941	1	
WTI	0.576151	0.656148	0.451389	-0.098584	0.693995	0.705942	1

Source: Developed by the author

The negative correlation of Tether (USDT) with all other variables suggests that the price movements of Tether are inverse compared to the other financial assets mentioned.

Cryptocurrencies have high positive correlations with each other, suggesting a tendency to move in the same direction.

There are high positive correlations between cryptocurrencies and stock indices, indicating some synchronization in their performance, likely influenced by macroeconomic factors or general market trends.

The positive correlations between oil (WTI) and cryptocurrencies could indicate a similarity in how these assets react to overall economic factors.

The strong positive correlation between S&P500 and DJIA suggests that they tend to move very similarly, often mirroring the overall performance of the US stock market.

3.3 Estimation methods and interpretation of results

3.3.1 Unit root test

The KPSS test depends on the calculated test statistic and the associated decision rule. If the test statistic is greater than the critical value (defined at a certain level of significance), we reject the null hypothesis in favor of the alternative hypothesis, indicating non-stationarity.

Table 3. KPSS unit root test results

Variable	BTC	ETH	XRP	USDT	S&P500	DJIA	WTI
LM-Stat	4.226	3,915	1.606	0.209***	6,277	6.172	3.168

Note: *** 1% (0.739).
Source: Developed by the author

This table indicates that all variables are not stationary, except the Tether series (USDT), since its LM test statistic value (0.209) is less than the critical value (0.739) at the 1% significance level.

3.3.2 Ordinary Least Squares Estimation

By considering the continuous nature of price variations of cryptocurrencies and traditional assets, OLS makes it possible to explicitly model the quantitative impact of one on the other. Additionally, OLS provides residual diagnostic tools, facilitating model validation and ensuring compliance with basic assumptions.

Some researchers have used the OLS method to estimate the parameters of their models,Rai and Kumari (2021) demonstrated the relevance of this technique in assessing the impact of global pandemic announcements on cryptocurrency returns and volatility. Moreover, Allen (2022) took a comprehensive approach using both parametric (OLS) and non-parametric methods (non-linear correlation measures, GMC, and non-parametric copula estimates) to estimate the parameters of their models and assess the relationships between cryptocurrencies and the S&P500 index. Table 4 below presentsthe estimate ofordinary least squares (OLS) method.

Table 4. OLS estimation results

Dependent variable: BTC				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
VS	-19569.28	14776.30	-1.324370	0.1855
ETH	10.37174	0.237888	43.59921	0.0000
XRP	1986.507	423.1789	4.694249	0.0000
USDT	9226.353	14754.32	0.625332	0.5318
DJIA	0.269704	0.112147	2.404927	0.0162
S&P500	5.237490	0.870815	6.014469	0.0000
WTI	-131.6685	6.847286	-19.22930	0.0000
R-squared	0.913442	Akaike info criterion		19.78530
F-statistic	5091.775	Hannan-Quinn critic.		19.79050
Prob(F-statistic)	0.000000	Durbin-Watson stat		0.019911

Source: Developed by the author

The results of Table 4 aboveof a multiple regression where the dependent variable (the variable predicted) is the price of Bitcoin (BTC) are as follows: This model suggests significant and positive relationships between the price of Bitcoin (BTC) and the prices of Ethereum (ETH), Ripple (XRP), Dow Jones (DJIA) and the S&P500 index. That is, it measures the proportion of the total variance of the dependent variable (BTC). However, the F-test statistic value is high (5,091.775) with very low probability (0.0000), indicating that

the model is overall statistically significant. The Durbin-Watson test presents a value very close to zero (0.019911), this suggests a possibility of autocorrelation of the residuals.

3.3.3 Autocorrelation test

The Breusch-Godfrey autocorrelation test, also called the Lagrange Multiplier (LM) test for serial auto-correlation, is a statistical method used to detect the presence of autocorrelation in the residuals of a regression model (Breusch, 1978). The LM statistic follows a chi-square distribution under the null hypothesis.

Null hypothesis (H0): There is no autocorrelation in the model residuals.

Table 5 below presents the Breusch-Godfrey autocorrelation test.

Table 5. Results of the Breusch-Godfrey autocorrelation test

Breusch-Godfrey Serial Correlation LM Test			
F-statistic	72978.95	Prob. F(2.2893)	0.0000
Obs*R-squared	2845.598	Prob. Chi-Square(2)	0.0000

Source: Developed by the author

The F statistic is extremely high (72978.95) and the associated probability (Prob. F (2, 2893)) is very close to zero (0.0000). This suggests that the model is overall significant and that it is unlikely that the coefficients are all equal to zero. Obs*R-squared (Observations multiplied by R-squared) is a measure of the extent of autocorrelation in the model residuals. In summary, the results strongly suggest the presence of autocorrelation in the model residuals. Therefore, it may be necessary to adjust the model to account for autocorrelation in the residuals.

3.3.4 Heteroskedasticity test

The heteroskedasticity test aims to determine whether the error variance of a regression model remains constant across all values of the independent variable. If the p-value associated with the test is below a significance threshold, generally 5%, we reject the null hypothesis of absence of heteroscedasticity, indicating that the variance of the errors is not constant. The most commonly used tests include the Breusch-Pagan test, which is widely recognized in the literature.

Table 6 below shows the Breusch-Pagan-Godfrey heteroskedasticity test.

Table 6. Results of the Breusch-Pagan-Godfrey Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	47.53968	Prob. F(6.2895)	0.0000
Obs*R-squared	260.2827	Prob. Chi-Square(6)	0.0000
Scaled explained SS	1862.552	Prob. Chi-Square(6)	0.0000

Source: Developed by the author

The Breusch-Pagan-Godfrey test confirms previous graphical observations by rejecting the null hypothesis of homoscedasticity (constancy of the variance of the residuals) in favor of the alternative hypothesis of heteroskedasticity. This means that the residuals exhibit an inconstant variation in their variance. Therefore, it is appropriate to explore and apply an ARCH or GARCH model to better model the conditional volatility of variables.

3.3.5 Estimation of the ARCH (Autoregressive Conditional Heteroskedasticity) model

The literature offers a considerable variety of ARCH model specifications that studied to detail the characteristics of financial markets. Various proposed ARCH processes are covered in several studies such as:Bera and Higgins (1993); Bollerslev el al. (1992); Gouriéroux (1997); Li et al. (2002).

3.3.5.1 Model result and interpretation

The results of Table 7 of estimation of the ARCH regression model (2) for the dependent variable "Bitcoin (BTC)" with different explanatory variables are as follows:

Table 7. Estimation results of the ARCH model (2)

Dependent Variable: BITCOIN				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
VS	-9687.396	1157.375	-8.370142	0.0000***
ETH	9.747150	0.016451	592.4982	0.0000***
USDT	1615.038	1157.711	1.395026	0.1630
XRP	538.1208	26.85593	20.03732	0.0000***
S&P500	6.307206	0.069199	91.14610	0.0000***
DJIA	-0.086242	0.009018	-9.563017	0.0000***
WTI	-73.51175	0.373221	-196.9657	0.0000***
Variance Equation				
VS	13978.53	2008.618	6.959276	0.0000***
RESID(-1)^2	0.796630	0.054397	14.64488	0.0000***
RESID(-2)^2	0.367130	0.034923	10.51249	0.0000***
R-squared	0.894381	Akaike info criterion		17.09054
Log likelihood	-24796.92	Schwarz criterion		17.11112
Durbin-Watson stat	0.013530	Hannan-Quinn critic.		17.09795

(***) Indicate respectively the significance of the coefficients at the 1% threshold.
Source: Developed by the author

The R-squared is high (0.894381), indicating that the model explains a large portion of the variance in the dependent variable. In other words, approximately 89.44% of the variance in Bitcoin's price is explained by the explanatory variables included in the model. Thus, the DW statistic is close to zero (0.013530). This indicates a strong positive autocorrelation in the residuals suggesting that the errors are not independent over time. The quality indicator of the AIC model is 17.09054.

The coefficient of the constant is significant at the 95% confidence level, meaning that the model has a statistically significant fit. A negative value of -9687.396 indicates that when all independent variables are equal to zero, the estimated price of Bitcoin is negative.

The cryptocurrencies Ethereum (ETH) and Ripple (XRP) have a positive and statistically significant relationship with Bitcoin. A one-unit increase in the price of Ethereum is associated with an increase of approximately 9.75 units in the price of Bitcoin, while a one-unit increase in the price of Ripple is associated with an increase of approximately 538.12 units in the price of Bitcoin. This suggests a positive impact of the price action of Ethereum and Ripple on the price of Bitcoin.

Regarding the stablecoin Tether (USDT), although the coefficient is high, the high p-value (0.1630) indicates that its effect is not statistically significant at the 5% level. However, considering the coefficient alone, there appears to be a potentially positive impact of Tether on Bitcoin.

For DJIA and WTI, the estimation shows a negative and statistically significant relationship with Bitcoin. An increase of one unit in the price of the Dow Jones is associated with a decrease of approximately 0.086 units in the price of Bitcoin, while an increase of one unit in the price of crude oil is associated with a decrease of approximately 73.51 units in the price of Bitcoin. This indicates a negative impact of Dow Jones and crude oil prices on Bitcoin.

In contrast, for the S&P500, a one-unit increase in the S&P500 index is associated with an increase of approximately 6.31 units in the price of Bitcoin. This suggests a positive impact of the S&P500 on Bitcoin, implying a possible correlation between the general stock market (represented by the S&P500) and the price of Bitcoin.

In summary, the results suggest that cryptocurrencies, notably Ethereum (ETH) and Ripple (XRP), appear to exert a positive influence on the price of Bitcoin. This trend could indicate a positive correlation between the developments of these cryptocurrencies and the behavior of the Bitcoin market. Conversely, the stablecoin Tether (USDT) presents a neutral relationship despite their coefficient being positive. Whereas, some traditional assets, such as the Dow Jones Industrial Average (DJIA) and the price of crude oil (WTI), appear to be associated with a negative impact on the price of Bitcoin. This observation suggests that variations in Tether and some traditional assets may be linked to downward fluctuations in the Bitcoin market. Furthermore, the S&P500 index shows a positive relationship with the price of Bitcoin, suggesting that movements in the overall market can positively influence the price of Bitcoin.

3.3.5.2 Discussions and implications

The empirical results of this study reveal complex and interconnected dynamics between cryptocurrencies including Bitcoin (BTC), Ethereum (ETH), Ripple (XRP), stablecoin Tether (USDT) and conventional assets such as stock indices (S&P500, DJIA), the price of crude oil (WTI). There is a strong positive correlation between cryptocurrencies including BTC, ETH and XRP, which has major economic implications.

In addition, the high correlations between cryptocurrencies and stock indices (the S&P500 index) highlight a possible convergence of behavior between traditional markets and cryptocurrencies. This synchronization could arise from common macroeconomic factors (which influence the general investment climate) or from a general shift in market sentiment. For investors, this means they need to consider overall market dynamics when evaluating the performance of cryptocurrencies.

The conclusions obtained reinforce the validity of our fourth hypothesis, affirming a significant relationship between Bitcoin and the stock index (S&P500). Our results are consistent with the conclusions of other previous research, notably those of Wang et al. (2022) And Elsayed et al. (2022). This convergence reinforces the robustness of our findings and suggests consistency in the positive relationship between cryptocurrencies and traditional assets, as highlighted by previous research.

Changes in certain traditional assets may be associated with downward fluctuations in the Bitcoin market. In particular, the complexity of the relationships between cryptocurrencies and traditional assets, illustrated by the negative impact of Crude Oil and the Dow Jones on Bitcoin, underlines the interconnection of markets. Investors must take these interactions into account to anticipate market movements. Our findings support the validity of our fifth hypothesis, which posits a mixed relationship between Bitcoin and traditional assets. These results are consistent with the conclusions of pre-existing studies, such as those stated by Doumenis et al. (2021) And Tufan et al. (2022).

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study highlights the growing importance of cryptocurrencies as diversification assets in investment portfolios. Investors are encouraged to reassess their approach to these assets, considering their impact on overall portfolio stability and performance. Proactive risk management and a thorough understanding of the interactions between cryptocurrencies and traditional markets are essential for informed investment decisions.

The empirical results highlight the relevance of the selected data sample, covering a significant period and revealing complex interactions between digital and traditional assets, as well as the price of crude oil. Using the ARCH model helped capture temporal variations in volatility, providing crucial information for adjusting investment strategies.

These results suggest that cryptocurrencies can play a significant role in investment portfolios. Investors are encouraged to reconsider the place of these assets in their strategies, carefully evaluating their impact on stability and overall performance.

In considering avenues for future research, it would be interesting to explore how the growing adoption of cryptocurrencies influences investors' decision-making patterns, portfolio management strategies, and attitudes toward traditional assets.

ACKNOWLEDGMENTS

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Economic Impacts of the COVID-19 Pandemic on Workers' Incomes: Evidence from Arab Countries

SARAH A. IBRAHIM[1], SUZAN ABDEL-RAHMAN[1], MOHAMED R. ABONAZEL[2] (Corresponding author), AWADELKARIM ELAMIN ALTAHIR AHMED[3] and EHAB EBRAHIM MOHAMED EBRAHIM[4]

[1]Assistant Professor, Department of Biostatistics and Demography, Faculty of Graduate Studies for Statistical Research, Cairo University, Giza, Egypt
[2]Professor, Department of Applied Statistics and Econometrics, Faculty of Graduate Studies for Statistical Research, Cairo University, Giza, Egypt. email: mabonazel@cu.edu.eg
[3]Assistant Professor, Department of Economics, College of Business, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh, Saudi Arabia.
[4]Assistant Professor, Department of Economics, Faculty of Commerce, Kafrelsheikh University, Kafrelsheikh, Egypt,

ARTICLE INFO

ABSTRACT

The COVID-19-induced economic downturn has increased unemployment and income losses in many countries. Arab countries have suffered negative impacts of the COVID-19 pandemic. This study assessed the extent to which COVID-19 has impacted workers' incomes in five Arab countries (Egypt, Jordan, Sudan, Morocco, and Tunisia), based on the COVID-19 MENA Monitor Household Survey. The study estimated the main drivers of income changes during the pandemic using the random effect ordinal logistic model. Workers who maintained the same working hours before the pandemic experienced positive income changes in Egypt, Tunisia, and Jordan. Regular work increased the odds of experiencing positive income changes in Tunisia and Jordan. Workers in the food and accommodation sector were the most exposed to negative changes in income in Egypt and Tunisia. Blue-collar workers showed a higher chance of experiencing income reduction in Morocco. Social insurance and teleworking were not significant drivers of income changes in most surveyed countries. The pandemic crisis reveals the need to strengthen social protection systems in Arab countries and protect vulnerable workers in such future crises.

INTRODUCTION

COVID-19 is a public health crisis of international concern. All countries have taken the necessary measures to confront the spread of the pandemic by closing schools and universities, suspending flights and gatherings, and reduced working days. Similar pre-cautionary measures and policy responses to COVID-19 have been applied in Arab countries to prevent the virus spread (Krafft et al., 2021a) The unprecedented measures taken to contain the COVID-19 outbreak have caused severe economic losses. These adverse economic implications hit Arab countries at both macro and micro levels (Eldeep and Zaki,

2022). The economic situation of workers in Arab countries has deteriorated due to these movement restrictions and labour market distributions. The livelihoods of vulnerable groups, including informal workers and daily wage earners, have been hit hard (Krafft et al., 2022). Assessing the extent to which COVID-19 has impacted workers' incomes is an urgent matter in assessing the government's responses and designing policies more compatible with the repercussions of the pandemic.

COVID-19 has a distinctive impact on the distribution of jobs and earnings compared to previous recessions. Women-dominated industries were more likely to be severely affected during the pandemic than the previous downturns in which male-dominated industries faltered. Lockdown and social distancing measures related to the pandemic have affected sectors that require personal interaction. Females are overrepresented in these lockdown sectors, such as home services, childcare homes, and customer services (Alon et al, 2020). However, women's incomes are not necessarily more affected than men's during the pandemic. Adams-Prassl et al. (2020) demonstrated that the gender gap in the probability of losing income was insignificant. Moreover, some industries dominated by women continued to work during the pandemic. Women working in educational activities were able to maintain their jobs using distance learning techniques. Meanwhile, some sectors in which men are concentrated, such as construction, manufacturing, and other industries, have been suspended (Hupkau and Petrongolo, 2020).

The unemployment rate has increased substantially in Arab countries since the onset of the pandemic (Krafft et al., 2021b). According to rapid labour force surveys conducted by Economic Re-search Forum (ERF), the unemployment shares within the surveyed population increased by 29% in Morocco and 33% in Tunisia since the onset of the COVID pandemic. Highly educated individuals were the most affected by increasing unemployment rates in Morocco; secondary educated workers saw a 70% increase in the unemployment rate. In contrast, workers with secondary education in Tunisia were less affected compared to those with or less than basic education. The unemployment rate increased dramatically among male workers, and informal workers in both countries (International Labour Organization, 2021a,b). In Egypt, the COVID-19-induced increase in economic inactivity (4%) was higher than that of unemployment (3). 16% of unemployed respondents before the COVID-19 outbreak became in-active and dropped out of the labour force. Females were more likely to fall into economic inactivity while males were more likely to be unemployed; the unemployment rate has doubled among males. Moreover, the share of females in employment dropped by 10% versus 8% for males (International Labour Organization, 2021c). Employment losses were more concentrated among informal wage workers, less-educated workers, rural residents, wage workers for the private sector, and farmers. While unemployment losses less impacted employees in the public sector and business owners (Blundell et al., 2020).

Several studies have demonstrated that demographic characteristics highly predicted the probability of income changes. Adams-Prassl et al. (2020); Blundell et al. (2020) and Montenovo et al. (2020) found younger workers have suffered more from job losses and reduced income during the pandemic outbreak. At the same time, Piyapromdee and Spittal (2020) indicated that the employment outcomes of younger and elderly workers are more likely to be disrupted than middle-aged workers. Education has served as a protection tool against negative outcomes induced by the pandemic such as job losses and income falls (Blundell et al., 2020). High-educated workers are more likely to maintain their incomes during the pandemic, in contrast to less-educated workers who have faced significant disruption in labour market outcomes (Piyapromdee and Spittal2020). Marital status also contributes to creating differences in income between males and females. Married working women are likely to leave work due to the current circumstances of closing schools and increasing household chores, unlike unmarried females who may continue working even considering the Coronavirus crisis. The closure of kindergartens, schools, and nursing homes has increased domestic work. Shifting to online learning has doubled the responsibilities of women (Blundell et al., 2020).

During the pandemic outbreak, most available studies in Arab countries investigated labour market disruptions. In a policy brief, Krafft et al. (2022) explored the changes in house-hold incomes, participation and employment rates in Arab countries and found that poor households more experiencing income losses than households in other income quintiles. There are similar policy briefs prepared by Krafft et al. (2021a,b,c) examining the impact of COVID-19 on small and medium enterprises, vulnerable workers, small entrepreneurs, and farmers in Arab labour market. Eldeep and Zaki (2022) studied the impact of the pandemic on the Egyptian economy using a computable general equilibrium model, assessed changes

in supply and demand aspects, identified the COVID-19-induced short and long-term effects on the economy and analyzed the impact of the government's response on economic sectors. Eldeep and Zaki (2021) indicated that the Egyptian economy is negatively affected as its sources of foreign currency declined substantially. Still, these are short-term effects and will minimize in the long run. Ramadan (2022) measured determinants of the decline in household income in Jordan and indicated that workers in hard-hit sectors, informal workers, youth, women, and poor households are more likely to experience income reductions. Some studies addressed the implications of a pandemic on employment outcomes from a gender perspective and found that COVID-19 has directly ex-acerbated some of the pre-existing inequalities between males and females (Abdel-Rahman et al., 2023a,b; Barsoum and Majbour, 2021; ElBehairy et al., 2022). Although extensive research has been studied negative labour market outcomes, no single study exists which highlights the various changes induced in workers' wages the study aims to fill the knowledge gap regarding income changes in Arab countries and investigate the effects of COVID-19 on workers' incomes using data from a five-country survey in the Middle East and North Africa (MENA).

1. MATERIALS AND METHODS

The Economic Research Forum (ERF) conducted rapid labour force surveys to monitor the economic changes caused by COVID-19 in the labour market. The survey was carried out using a phone based on a random digit dialing approach. The survey included mobile phone owners between the ages of 18 and 64. Moreover, Data was collected through a series of panel surveys in five Arab countries. ERF Survey estimates pre-COVID labour characteristics (February 2020) and the evolution of labour outcomes during the pandemic outbreak. The questionnaire covers the household's demographic and socio-economic characteristics, such as labour market outcomes, education status, food security, incomes, social safety nets, social distancing and mental health, attitudes toward risks, and coping strategies. Besides, it includes specific modules for individuals, workers, farmers, women, and business owners. The questionnaire includes demographic and household characteristics, labour market status, education, food security, incomes, social safety nets, attitudes towards risks and social distancing, coping strategies, and mental health. It includes a core module, an individual module, a worker module, a farmer module, a household enterprise module, a women module, and a tracking module. The data were compiled for Morocco, Tunisia, Egypt, Sudan, and Jordan from the year 2020 to the year 2021. Table A1 provides the description, abbreviation and encoding of the main variables used in the study.

The data included four rounds for each cross-sectional unit (individual), with a total of 34,219 observations. The first wave in each country is called the base wave, and the rest of the rounds are called the panel wave. Table A2 summarizes the number of times that each respondent was met through the four rounds in the five waves. Moreover, Table A3 presents the number of observations related to the maximum number of rounds according to the country name. It is evident from the tables that we will lose lots of information if we keep only the same number of rounds in each country to ensure the panel balance. Hence, we chose to use all the available observations and use unbalanced panels, but we excluded the respondents with only one wave. Moreover, we included wage workers for the Government/public sector or those in the private sector who responded to the employment section in the questionnaire.

The study adopted the random effect ordinal logistic model (proportional odds model) to explore the main drivers of wage changes during the pandemic. The random effect ordinal logistic model was firstly developed by McCullagh (1980), and updated to encompass the random effect by Tutz and Hennevogl (1996). The model equation can be expressed as follows:

$$Y_{it}^* = X_{it}'\beta + v_i + \varepsilon_{it}, \qquad i = 1, \dots, n; \ t = 1, \dots, T \tag{1}$$

where Y_{it}^* is the latent response variable, X_{it} denotes the vector of the explanatory variables. The error can be divided into two terms, the ε_{it} (The idiosyncratic error) are distributed as logistic with mean zero and variance $\pi^2/3$ and are independent of v_i (the individual effect). i is the respondent and t is the wave number, and the observed ordered response variable y_{it} can be generated from the latent continuous response, such that:

$$y_{it} = \begin{cases} 1 & if \; y_{it}^* \leq \theta_1 \\ 2 & if \; \theta_2 < y_{it}^* \leq \theta_3 \\ \vdots & \qquad \vdots \\ 5 & if \; \theta_4 < y_{it}^* \end{cases} \qquad (2)$$

where y_{it} has K (five) number of categories, $Y \in \{1,..,K\}$, θs are the cutoff points, $-\infty = \theta_0 < \theta_1 < \cdots < \theta_K = \infty$.

$$Y = k \Leftrightarrow \theta_{k-1} < Y^* \leq \theta_k \qquad (3)$$

The cumulative model derived from (3) is written as

$$P(Y \leq r|x) = F(\theta_r + x'\beta), \; r = 1, ..., K-1 \qquad (4)$$

where θ_r and β are the parameters, and F is the logistic function ($F(Z) = 1/1 + \exp(-Z)$).

The previous equation can be extended in case of random effect (unobserved heterogeneity) as follows:

$$P(Y_{it} \leq r \,|\, x_{it}, v_i) = F(\theta_r + x'\beta + v_i), \; r = 1, ..., K-1 \qquad (5)$$

where v_i is the individual effect. The thresholds will be shifted by the individual effect in the case of the random effect model. The analysis was performed separately for each country, as the number of waves differed and the social, economic, and political context couldn't be generalized for the five countries.

Estimating the model using fixed effect yields an incidental parameter problem as N → +∞ for fixed T. It's better to use the random effect model (the individual parameter is assumed to be a random variable with a certain distribution). It is commonly used in the case of the ordinal logistic model or generalized linear models in general (Croissant and Millo, 2018).

The ordered response variable is y_{it} is the change in the wage, it takes values from one to five; where one is "Decreased by more than 25% ", two is "decreased by 1%-25%", three is "stayed the same", four is "Increased by 1-25%, five is "increased by more than 25% ". The explanatory variables consist of the individual characteristics that are not changing through waves, which include gender, age, educational level, place of residence, and marital status. Additionally, the analysis will include work characteristics covariates such as the main job in February 2020, type of industry, occupation, job stability, social insurance, regularity, and working in an establishment or not. Moreover, the model encompasses variables related to work arrangements such as changes in working hours or delays in wages, and finally, the status of establishment, lay-off or suspension, work with or without payment, and can or can't work from home.

2. RESULTS

2.1 Characteristics of workers in Arab countries

COVID-19 has disrupted labour market conditions. Around three-quarters of the workers in Egypt and Sudan had their work permanently closed because of the pandemic. While in Tunisia and Morocco, more than 60% of the workers continue working with the same business hours through the available waves. Most sample wage workers didn't mention lay-off without payment through the available waves in the five countries (70% -90%). Moreover, more than 90% of the wage workers in the five countries didn't mention permanent lay-off (Figure A1 and Figure A2). In the five countries except for Egypt, most sample members didn't experience a change in business hours (60%-90%), with a slight increase in the recent waves. However, in Egypt, 63% of the wage workers in the first wave experienced a decrease in the working hours by more than 25%, but the percentage predominance in the second and the fourth waves went to "the same working hours" (Figure A3). In the four countries except for Egypt, most of the workers didn't experience a change in their wages (more than 80%). However, half of the Egyptian workers in the first wave experienced a decrease in their wages by more than 25% (Figure A4). Around 75% of Egyptian workers experienced a delay in wages in the two waves.

Similarly, in the first wave, the Moroccans, Sudanese, Tunisian, and Jordanian workers (97%, 88%, 68%, and 86%) experienced wage delays, with a slight decrease in the percentage in the upcoming waves

(Figure A5). Additionally, more than 75% of the wage workers in the five countries mentioned their inability to work from home (see Figure A6). The wage workers who mentioned the inability to work from home said that the main reason was the inability to do a job off work. Another reason that was dominant among Moroccan workers was "Not allowed to work from home", specifically in the first wave.

Negative labour market outcomes have been experienced across all educational levels. Less educated workers were the most affected: 30.68 % of them lost their jobs temporarily, and 25.02 % experienced a decrease in their hourly wages. In general, workers engaged in irregular work are the most exposed to income drops across different educational levels in Arab countries. However, less-educated workers engaged in regular work are most likely to lose a higher proportion of their incomes in Jordan. As the education level increases, the proportion decrease in income declines. Workers with basic and secondary education are the most affected in Morocco, while irregular workers generally incur high rates of income attrition across educational levels in Tunisia. The proportion decrease in income is somewhat similar among workers across different educational levels in Egypt without marked differences between regular and irregular workers (As indicated in Figure A7).

Less-educated, uninsured, private sector workers are the most affected by reduced working hours and incomes. As indicated in Figure 1, Figure 2, Figure 3, 25% of less-educated workers saw their hourly wages drop during the pandemic period compared to 12% of highly educated workers; the same is true for 26% of uninsured workers versus 12% of insured workers and 23% of private sector workers versus 7% of public sector workers. Also, the proportion of workers who have experienced a decrease in working hours varies according to worker characteristics: Wage workers with less than basic education or secondary education suffered marked reductions in their working hours more than others. For example, 29% of uninsured workers and 27% of private sector workers had reduced working hours compared with 21% of insured workers and public sector workers.
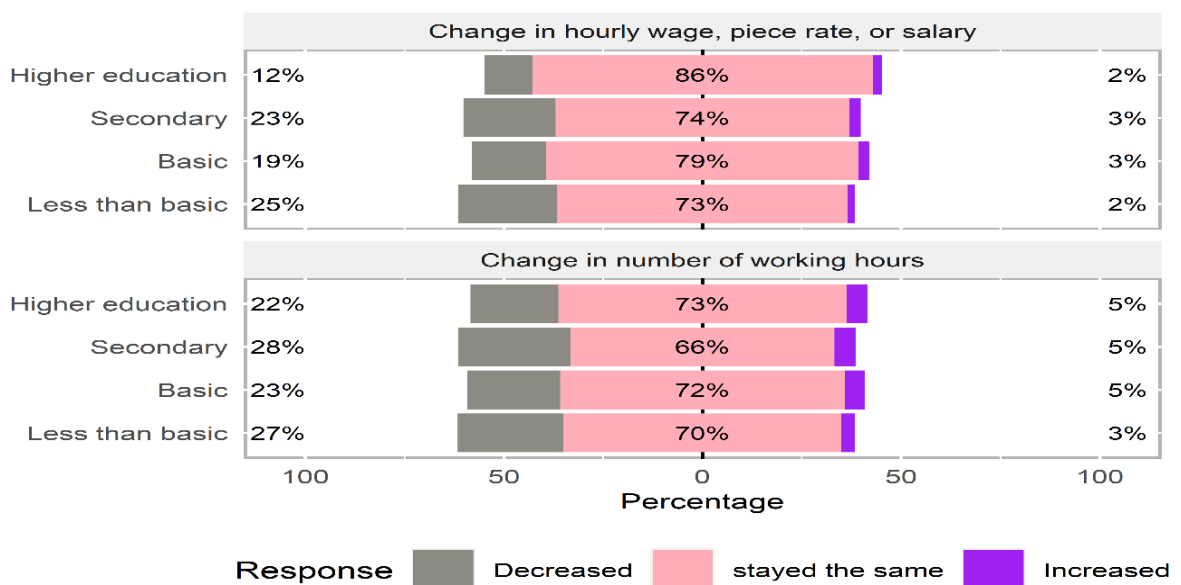
Figure 1. Changes in wages and working hours by education level
Source: own
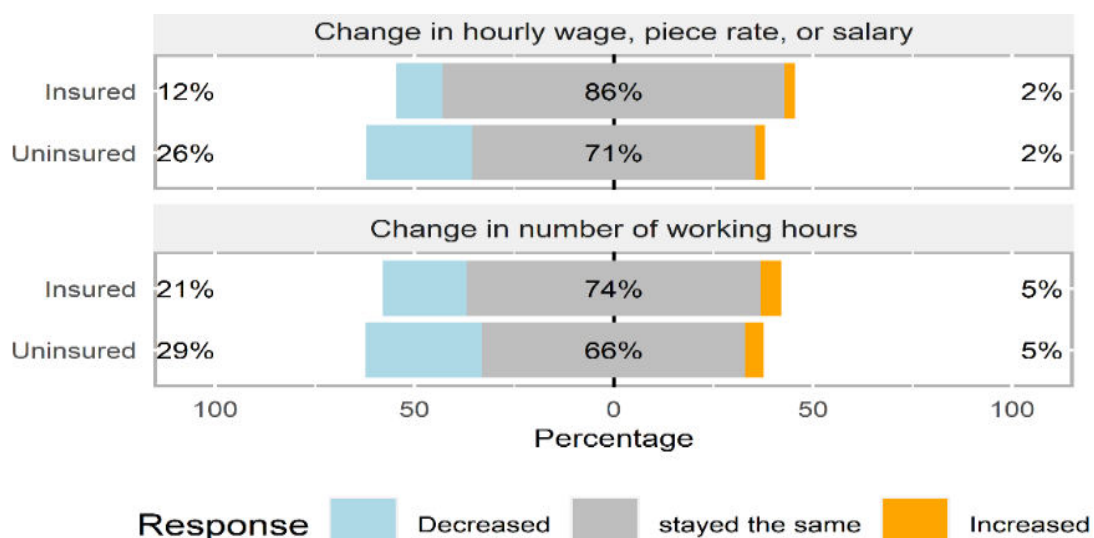
Figure 2. Changes in wages and working hours by social insurance
Source: own
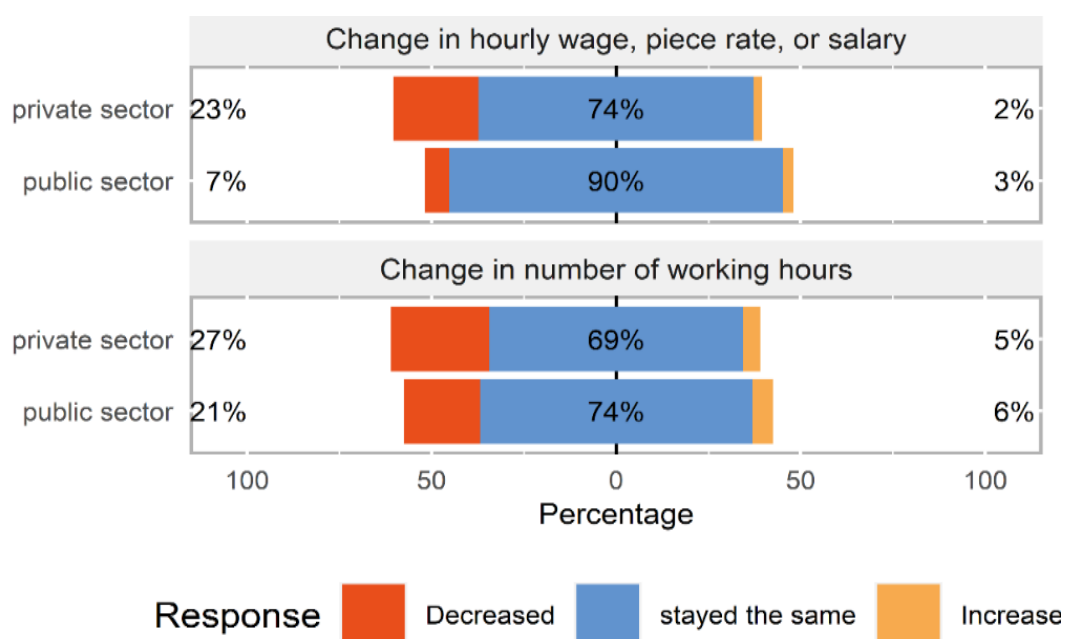
Figure 3. Changes in wages and working hours by sector
Source: own

On average, the number of working hours has changed for more than 27.6 % of workers in the surveyed countries; a quarter of workers had to work fewer hours than usual due to restrictions related to COVID-19, while 3.7 % had a 25% increase in the working hours after the COVID outbreak. Workers who experienced the largest decrease in working hours also suffered the largest decline in hourly wages. It turns out that the workers whose working hours decreased by more than 25% have endured a decrease in income by more than 25%. While the workers who kept the same number of working hours, their incomes did not change, as shown in

Figure **4.**
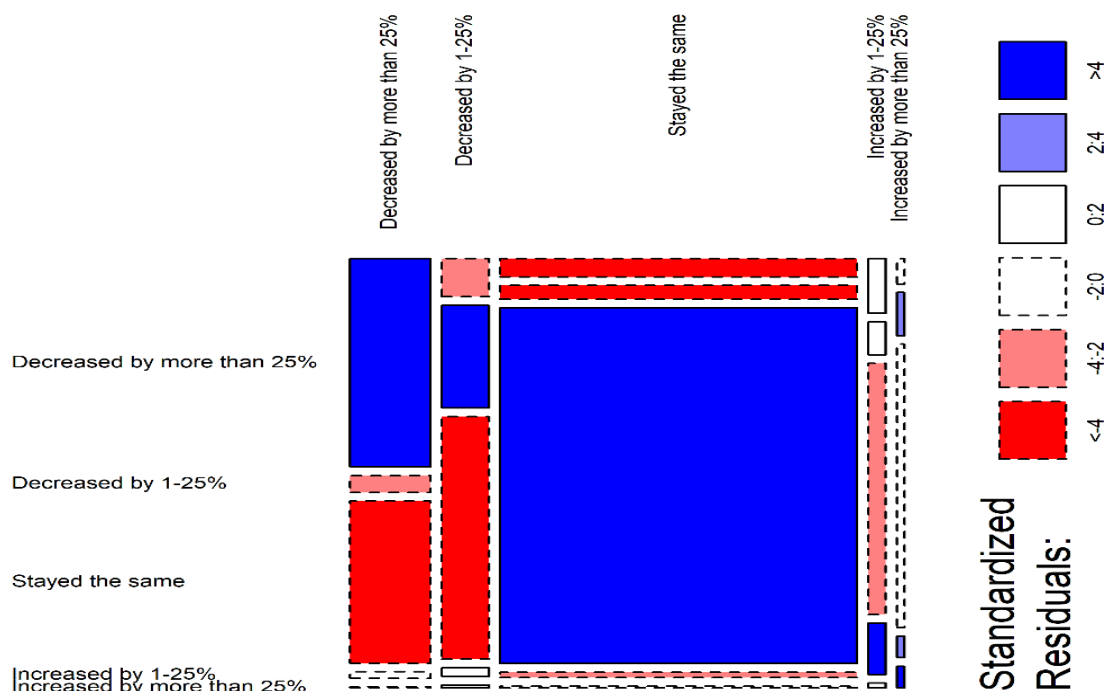
Figure 4. Mosaic plot for the relationship between changes in the hourly wage and working hours
Note: Both variables have the same categories. The surface of each category reflects the relative magnitude of its value. The blue surface reflects that the observed value is higher than expected, while the red reflects the opposite. The standardized residuals help to interpret the association between variables. The chi-square test indicated that they are significantly associated at a p-value less than 0.001.
Source: own

Investigating income changes across economic activities indicates that income drops have disproportionately impacted them. Workers in "Agriculture, fishing or mining" and "Construction or utilities", and "accommodation and food services" are the most affected by wage reductions compared to other activities. In contrast, workers in education and health services are less impacted by wage reductions. This result is highly expected for workers in educational activities who could shift to online and home-based work and for workers in the health sector due to the increasing pressure on the medical staff during the crisis. Moreover, health services have the largest portion of wage workers who witnessed an increase in their working hours during the COVID-19 pandemic. We also found that reporting changes in working hours varied significantly across economic activities. Although all the workers in the different activities suffer losses in their working hours, workers in "financial activities or real estate" are most likely to have reduced working hours. While workers in the health sector saw their working hours increase more than workers in other activities.

2.1 Determinants of income changes during the COVID-19 outbreak

We have conducted the Likelihood Ratio Test (LR) and the Wald test to determine the model's best fit. The LR test examines the significant difference between nested models, especially when adding the background characteristics of the respondents (Most of the demographic characteristics were insignificant except for educational level in Tunisia). However, the Wald test examines the full model and the model with restricted parameters to zero. The Wald test results were significant in the case of Egypt (P-Value<0.01), Morocco was significant (P-Value<0.1), Jordan significant (P-Value<0.01), Sudan was insignificant, and Tunisia was significant with (P-Value<0.01). The Likelihood ratio test was used to determine the variables in the model and whether there is a significant difference in the likelihood score of the nested models (better fit). The best model was stated in the paper.

The most important assumption that should be detected in the case of an ordered logistic model is the proportional odds assumption (the parallel regression assumption). This assumption states that the relationship between the different pairs of categories for the response variable is the same (only one set

of coefficients). The brant (1990) test was conducted to test the proportional odds assumption in the chosen model with the best fit with the null hypothesis (no difference in the coefficients between models), and the null hypothesis was accepted. Additionally, multicollinearity using a variance decomposition matrix was detected. The condition indices for the variables in the model are less than ten, indicating no multicollinearity in the variables under consideration, and we kept the chosen variables in the model.

Some questions were only available in one wave in Egypt and Sudan, such as work stability, social insurance, work in the establishment, and business status. The question related to the ability to work from home was available in one wave in Sudan. Accordingly, the former questions were not added to the model analysis. Additionally, we deleted some questions to avoid the multicollinearity problem. In Egypt and Sudan, we excluded permanent lay-offs and worked in the establishment. In Jordan, we excluded economic activity, permanent lay-off, lay-off without payment, work in the establishment, and occupation. In Morocco, we excluded permanent lay-off, lay-off without payment, work in establishment and economic activity. Finally, in Tunisia, we excluded permanent lay-offs and worked in the establishment.

2.1.1 Determinants of Covid-induced income changes in Egypt

Table 1 displays the proportional odds ratios1 for the determinants of Covid-induced income changes in Egypt. The odds of having an increase in wage change among respondents who didn't mention a wage delay is 0.22 the odds of being in higher levels of the wage for respondents who experienced a wage delay during the pandemic (p-value<0.05). Working in the education sector increases the odds of being beyond any category of wage change by eight times the odds of being in the food and accommodation sector. The odds of having any higher level of wage change among those who were working in agriculture and fishing (relative to stable and lower wage levels) were three times higher as compared with respondents who were working in the food and accommodation sector (OR = 3.356; 95%CI = 1.026, 10.98) with p-value <0.05. Similarly, the odds of having a higher level of positive wage change among health sector workers and other services workers (versus stable and lower wage levels) were (five and six, respectively) times higher than those who were working in the food and accommodation sector (with p-value<0.1). The other sector's types did not significantly affect the wage change. Regarding the occupation sector in February, the clerks/service workers showed a lower chance of being beyond any wage level (comparable with lower levels) than the chance for blue-collar, skilled agricultural, or production and transport (OR=0.6, p-value <0.1). Similarly, the chance of technicians/associate professionals is lower than the chance of the blue collars (OR=0.5, p-value <0.05).

The respondents who didn't experience a lay-off without payment had odds of being in increased levels of wage change two times higher than the odds in case of experiencing a lay-off, with a p-value<0.0.05. However, the change in working hours did not appear to significantly affect the wage change during the pandemic except for the category of being the same working hours. It showed that the odds of being beyond any high-wage category were four times higher than in the reference category (increased by 1-25%). As provided in Table 1, the variance of the individual effect is 0.05, and the likelihood ratio test that compares the model with individual effect and the model without individual effect didn't show a significant difference. The insignificance of the likelihood ratio test means we don't have evidence that the individual effect can explain any extra variation in the ordinal dependent variable. Thus, the insignificance can be due to the small number of respondents.

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[1] The odds of being beyond category k=logit p(Y>k) $=\frac{p(Y>k)}{p(Y\leq k)}$

2.1.1 Determinants of Covid-induced income changes in Egypt

Table 1. Factors affecting wage change using random effect ordered logistic model in Egypt

Wage Change	OR.	St. Err.	t-value	p-value	[95% Conf Interval]	
Wage Delay						
Not mentioned	.218***	.057	-5.87	0	.131	362
Economic activity						
Education	7.865***	5.77	2.81	.005	1.867	13.128
Transportation and storage	1.186	.556	0.36	.716	.474	2.971
Agriculture, fishing	2.777*	1.66	1.71	.087	.861	8.959
Construction or utilities	1.065	.458	0.15	.883	.459	2.475
Financial activity	.91	.605	-0.14	.888	.247	3.352
Health	4.701**	3.242	2.24	.025	1.217	18.166
Information and communication	1.534	1.5	0.44	.662	.225	10.434
Manufacturing	1.795	.866	1.21	.225	.697	4.62
Other services	5.617**	4.799	2.02	.043	1.052	29.979
Retail or Wholesale	1.157	.552	0.31	.76	.454	2.947
Occupation						
Clerks/service workers	.6*	.179	-1.71	.087	.335	1.077
Manager/professional	.586	.257	-1.22	.223	.248	1.385
Technicians/associate professionals	.462**	.179	-1.99	.047	.216	.989
Lay-off without payment						
Not Mentioned	2.266***	.589	3.15	.002	1.361	3.772
Work from home						
Yes	1.156	.345	0.49	.627	.644	2.075
Changing Hours						
Decreased by 1-25%	.802	.422	-0.42	.675	.286	2.249
Decreased by more than 25%	.74	.407	-0.55	.584	.252	2.172
Increased by more than 25%	.74	.568	-0.39	.694	.164	3.332
Stayed the same	3.608***	1.762	2.63	.009	1.386	9.394
Sigma-2 U	.054	.418				
LR test vs. ologit model: chibar2(01) = 0.02 Prob >= chibar2 = 0.4478 No. of obs=651						

Note: *** p<.01, ** p<.05, * p<.1. Reference Categories: (Changing hours: Increased 1-25%, Wage Delay: Mentioned, Occupation Type in February: Blue Collars, Sector type Feb: Accommodation and food services, Layout without payment: Mentioned, Work_Home: No)
Source: Authors collected and processed from R-software V. 4.4.2

2.1.2 Determinants of Covid-induced income changes in Jordan

Table 2 indicates the results of the proportional odds model. The model results showed a significant result in wage delay. The odds of being beyond any category of wage change in case of not having a wage delay was 0.2 the odds in case of mentioning a wage delay (p-value <0.01). The working stability was significant, and the odds of being in higher categories of wages (comparable to lower categories) were three times the odds in the irregular jobs. Social insurance, and the ability to work from home, didn't show a significant result. The changing hours showed a significant result in the category that stayed the same; the odds of being in higher categories of wage if the working hours stayed the same is four times the odds in case of the increased working hours (1-25%). The likelihood ratio test that compares the random effect model with the proportional odds model without random effect appeared to be significant (P-Value <0. 01), and the variance of the individual effect is 1.48.

Table 2. Factors affecting wage change using random effect ordered logistic model in Jordan

Wage Change	OR	St.Err.	t-value	p-value	[95% Conf Interval]	
Wage delay						
Not mentioned	.235***	.087	-3.93	0	.114	.484
Work Stability						
Regular	2.922***	1.012	3.10	.002	1.482	5.761
Social Insurance						
Yes	1.035	.359	0.10	.921	.524	2.042
Work from home						
Yes	1.043	.377	0.12	.907	.514	2.118
Changing Hours						
Decreased by 1-25%	.692	.417	-0.61	.542	.212	2.257
Decreased by more than 25%	.544	.347	-0.96	.339	.156	1.897
Increased by more than 25%	2.43	2.39	0.90	.367	.353	16.707
Stayed the same	4.217***	2.11	2.88	.004	1.581	11.245
Sigma-2 U	1.483	1.182				
LR test vs. ologit model: chibar2(01) = 2.63 Prob >= chibar2 = 0.0525 No. of obs=788						
*** p<.01, ** p<.05, * p<.1						

Note: Reference Categories:(Wage delay: Mentioned, Work stability: Irregular, Social insurance: No, Working from home: No, Changing hours: increased by 1-25%)
Source: Authors collected and processed from R-software V. 4.4.2

2.1.3 Determinants of Covid-induced income changes in Sudan

Table **3** shows that the wage delay was significant; the odds of being beyond any category of wage change in case of not mentioning the wage delay is 0.2 the odds in the reference category. Besides, the model shows a significant result in the case of not mentioning a lay-off without payment; in this case, the odds of being in higher wage categories were seven times the odds in the case of mentioning a lay-off without payment. The model doesn't show any significant results for the changing hours, the sector type, and the occupation type. The variance of the individual effect is 0.46, but the likelihood ratio test was insignificant in comparing the models with random and without random effect (P-Value = 0.4326). Accordingly, there is no evidence of the individual effect on the variation of the dependent variable.

Table 3. Factors affecting wage change using random effect ordered logistic model in Sudan

Wage Change	OR	St.Err.	t-value	p-value	[95% Conf Interval]	
Wage Delay						
Not mentioned	.109*	.141	-1.71	.088	.009	1.391
Economic activity						
Transportation, storage	.652	.809	-0.34	.73	.057	7.415
Construction or utilities	1.051	1.599	0.03	.974	.053	20.721
Manufacturing, retail	.423	.479	-0.76	.448	.046	3.892
Occupation						
Clerks/service workers	1.186	1.713	0.12	.906	.07	20.13
Manager/ professional	.934	1.341	-0.05	.962	.056	15.587
Technicians/associate professionals	7.384	15.141	0.98	.329	.133	41.776
Lay-off without payment						
Not Mentioned	7.227**	6.666	2.14	.032	1.185	44.072
Changing Hours						

Stayed the same	1.802	1.584	0.67	.503	.321	10.098
Sigma-2 U	.468	2.674				
LR test vs. ologit model: chibar2(01) = 0.03			Prob >= chibar2 = 0.4326 No of obs=142			

Note: *** p<.01, ** p<.05, * p<.1. Reference Categories:(Wage delay: Mentioned, Sector type: Education, accommodation and food services, Layoff without payment: Mentioned, changing hours: Changed, Occupation Type in February: Blue Collars). The observations were small in each category of the occupation sector, the following categories were combined: (1) Education, accommodation and food services, (2) Transportation, storage, agriculture, fishing or mining, (3) Construction or utilities, financial activities or real estate, health, and information and communication, (4) manufacturing, retail or wholesale, and other services. Moreover, we added the categories of the change in the working hours together (increase or decrease) in one category, and the second category stayed the same.
Source: Authors collected and processed from R-software V. 4.4.2

2.1.4 Determinants of Covid-induced income changes in Morocco

Table **4** shows the odds of being in higher categories of wage change (versus lower categories) relative to the odds of the reference category. The wage delay variable was significant; it indicates that if there was no wage delay, the odds of being in high categories of wage were lower than the odds of the high categories in case of having a wage delay by 96%. The odds of high wages were 12 times higher in the clerks' categories than in the blue-collar category, and the rest of the categories didn't show any significance. The business status category (open with the same business hours) was significant, indicating that the odds of positive change in wages were 14 times the same odd in the reference category (chose to reduce the business hours). The variables such as the ability to work from home, social insurance, changing hours, and work stability didn't show any significance, and the variance of the individual effect was 1.16. The last row in the Table shows the number of observations (245). The likelihood ratio test result showed that the model with individual and without individual effect didn't show any significant difference, and the variables were enough to explain the variation in the dependent variable.

Table 4. Factors affecting wage change using random effect ordered logistic model in Morocco.

Wage change	OR	St.Err.	t-value	p-value	[95% Conf Interval]	
Wage Delay						
Not mentioned	.034***	.034	-3.41	.001	.005	.238
Occupation						
Clerks/service workers	12.327**	13.744	2.25	.024	1.386	19.621
Manager/professional	1.802	2.633	0.40	.687	.103	31.599
Technicians/ associate professionals	2.496	2.095	1.09	.276	.482	12.929
Work from home						
Yes	2.784	3.128	0.91	.362	.308	25.167
Work stability						
Regular	2.375	1.631	1.26	.208	.618	9.128
Social insurance						
Yes	3.27	2.674	1.45	.147	.659	16.242
Changing Hours						
Stayed the same	1.253	1.005	0.28	.779	.26	6.037
Business Status						
open but reduction in hours government mandate	6.003	7.36	1.46	.144	.543	66.384
open with the same business hours	13.95**	16.439	2.24	.025	1.385	14.486
Other	6.466	9.072	1.33	.183	.413	10.124
Sigma-2 U	1.162	2.089				
LR test vs. ologit model: chibar2(01) = 0.60			Prob >= chibar2 = 0.2197 Number of obs=245			

Note: *** p<.01, ** p<.05, * p<.1. some categories of business status were combined because of a very small number of observations in some categories. Reference Categories:(Business Status: Chose to reduce the number of business hours, Social Insurance: No, changing hours: Changed, Work Stability: Irregular, Wage Delay: Mentioned, Occupation Type in February: Blue Collars).

2.1.5 Determinants of Covid-induced income changes in Tunisia

The background characteristics didn't show any significant difference when using the likelihood ratio test except for Tunisia; we added only the education because it was significant. Table 5 shows the odds of being in higher categories of wage change (versus lower categories) compared to the odds of the reference category. The category (less than basic education) was significant; the odds of being in high wages (comparable to lower wages) for workers with less than basic education was 44% lower than the same odds of basic education (P-value<0.1). The wage delay variable was significant; it indicates that if the wage delay was not mentioned, the odds of being in high categories of wage are lower than the odds of the high categories in case of a wage delay by 49%.

Regarding the effect of the sector type in February, the odds of high wages were around (3, 4, and 6) times higher in the categories of education and health, agriculture, and other services, respectively, than the odds in the accommodation and food services category. The rest of the categories didn't show any significance. If there was no lay-off without payment, the odds of being in positive change in wage were two times the odds of having a lay-off without payment. The business status category (open with the same business hours) was significant, indicating that the odds of positive change in wages were two times the same odd in the reference category (chose to reduce the business hours). Regular work status increases the odds of being in higher categories of wage change by 2.5 the odds of being in an irregular job. As for the working hours, if they were the same, the odds of being high wages were four times the odds in case of increasing working hours from 1-25%. The variables such as the ability to work from home, social insurance, and occupation type didn't show any significance, and the variance of the individual effect was 1.2. The last row in the Table shows the number of observations (1519). The likelihood ratio test result showed that the model with individual and without individual effect showed a significant difference, and the individual effect should be added to explain the variation in the dependent variable.

Table 5. Factors affecting wage change using random effect ordered logistic model in Tunisia

Wage Change	OR	St.Err.	t-value	p-value	[95% Conf Interval]	
Education						
Less than basic	.561*	.173	-1.88	.061	.306	1.027
Secondary	.833	.242	-0.63	.529	.472	1.471
Higher education	1.455	.562	0.97	.331	.683	3.101
Wage delay						
Not mentioned	.517***	.105	-3.24	.001	.347	.771
Work from Home						
Yes	.768	.246	-0.82	.41	.411	1.438
Economic activity						
Education	2.558*	1.341	1.79	.073	.916	7.147
Transportation and storage	1.638	.746	1.08	.278	.671	3.997
Agriculture, fishing, or mining	3.852***	1.852	2.80	.005	1.501	9.886
Construction or utilities	2.641**	1.142	2.25	.025	1.132	6.165
Financial activities or real estate	2.933	2.138	1.48	.14	.703	12.243
Health	3.358*	2.281	1.78	.075	.887	12.717
Information and communication	1.209	.829	0.28	.782	.315	4.638
Manufacturing	1.404	.556	0.86	.391	.646	3.049
Other services	5.988***	3.142	3.41	.001	2.141	16.747
Retail or Wholesale	1.341	.604	0.65	.515	.554	3.241
Occupation						
Clerks/service workers	1.112	.387	0.30	.761	.562	2.198
Manager/professional	1.019	.364	0.05	.959	.506	2.051
Technicians/ associate professionals	1.02	.342	0.06	.954	.528	1.969
Lay-off without Payment						

Not Mentioned	2.105***	.455	3.45	.001	1.379	3.215
Business Status						
open but reduction in hours_government mandate	.998	.335	-0.01	.995	.516	1.928
open with the same business hours	2.015**	.649	2.18	.029	1.073	3.787
Chose to temporarily close due to challenges	2.044	1.211	1.21	.228	.64	6.527
Don't know	.628	.374	-0.78	.435	.195	2.02
Temporarily closed due to government	1.841	1.055	1.06	.287	.599	5.663
Temporarily or permanently unrelated to the COVID-19	1.163	.6	0.29	.769	.423	3.196
Work Stability						
Regular	2.478***	.555	4.05	0	1.597	3.845
Social Insurance						
Yes	1.413	.317	1.54	.123	.91	2.192
Changing Hours						
Decreased by 1-25%	.562	.224	-1.44	.148	.257	1.228
Decreased by more than 25%	.778	.338	-0.58	.562	.332	1.821
Increased by more than 25%	1.122	.707	0.18	.855	.327	3.857
Stayed the same	3.836***	1.42	3.63	0	1.857	7.924
Sigma-2 U	1.192	.474				
LR test vs. ologit model: chibar2(01) = 12.38			Prob >= chibar2 = 0.0002		Number of obs=1519	

Note: *** p<0.01, ** p<0.05, * p<0.1. We combined two categories of business status due to small observations (permanently closed due to COVID19 outbreak and do not know) were combined because of a very small number of observations in some categories. Reference Categories: (Educ: Basic, Business Status: Chose to reduce the number of business hours, Social Insurance: No, changing hours: Increased 1-25%, Work Stability: Irregular, Wage Delay: Mentioned, Occupation Type in February: Blue Collars, Sector type Feb: Accommodation and food services, Layout without payment: Mentioned).
Source: Authors collected and processed from R-software V. 4.4.2

3. DISCUSSION

Work arrangements during the pandemic induced income changes. Workers who report delayed wages are likely among those who experienced increased incomes during the pandemic in Egypt, Jordan, Sudan, Morocco, and Tunisia. Experiencing a decrease in working hours and permanent lay-off contributed significantly to negative income changes. In Egypt, Jordan and Tunisia, the odds of being in categories of positive wage changes are higher for workers whose working hours stayed the same during the pandemic. Moreover, workers in the business, which is still open with the same working hours, are more experience with positive changes in wages in Tunisia. Permanently laid-off workers were also vulnerable to negative changes in incomes in Egypt, Tunisia, and Sudan. Work stability protected workers against income reductions in Jordan.

COVID-19 hit certain industries with its lockdown measures (International Labour Organization, 2020). Business characteristics such as its activity and size could explain differences across wage groups (Cajner et al., 2020). Workers in the food and accommodation sector experienced negative income changes, in contrast to workers in the education and health sectors, who were more likely to experience income increases in Egypt and Tunisia. Workers in the health sector were expected to be less affected due to the intense pressure on health facilities during the pandemic outbreak and those working in educational activities due to the transition to online teaching during the pandemic.

The impact of COVID-19 on wage workers varied according to work characteristics. Wage workers in the private sector, those working irregularly without social insurance and outside establishments were the most affected by the pandemic; they mentioned higher incidence rates of layoffs, decrease in incomes, or delays in wage payments. However, the effect of work characteristics differed across countries. Blue-collar, skilled agricultural, or production and transport showed a higher chance of experiencing income reduction in Egypt and Morocco. Engaging in regular work was negatively corrected with the experience of wage

reduction in Tunisia. While work stability, social insurance, economic activity, and occupation were not significant drivers of income changes in Jordan and Sudan.

Other studies found that sociodemographic characteristics significantly correlated with income changes during the pandemic. Younger workers were more likely to lose jobs and suffer income reduction during the COVID-19 outbreak, see Adams-Prassl et al. (2020), Blundell et al. (2020), and Montenovo et al. (2020). High-educated workers were more likely to maintain their incomes during the pandemic, in contrast to less-educated workers who have faced significant disruption in labour market outcomes. Piyapromdee and Spittal (2020) found that less-educated workers faced inadequate and inflexible working conditions, inability to work from home (location inflexibility), low demand for their industries, high lay-off rates, and low wages. In comparison, Adams-Prassl et al. (2020) found that younger workers and those with a university degree were more likely to suffer a drop in their incomes. Studies have also shown that females face high rates of unemployment and have reached their peak during the pandemic (Mamgain, 2021) and were more likely to experience a decrease in their incomes (Cajner et al., 2020; Adams-Prassl et al. (2020). However, the sociodemographic characteristics didn't show any significant difference in explaining income changes in Arab countries.

Working from home is one of the most notable features of the pandemic. Working from home was more concentrated among highly educated, high-paid workers (Blundell et al., 2020). Mongey et al. (2020) found that workers in jobs that cannot be completed from home or require physical proximity are more economically vulnerable, low-wage, low-education workers. There are notable differences in the inability to work from home across occupations and industries. A large proportion of jobs in developed countries can be done completely at home without a significant drop in earnings (Montenovo et al., 2020; Dingel and Neiman, 2020, Mongey and Weinberg, 2020). Workers in occupations related to information work and management were allowed to work remotely from home and other professions that could be performed remotely. Conversely, the largest share of jobs in lower-income economies cannot be performed at home (Dingel and Neiman, 2020). Our study found that the worker's ability to work from home didn't shape their income changes during the pandemic.

Although most Arab countries have unemployment insurance systems, they target limited groups of workers. Developing unemployment protection systems that ensure workers against unemployment and negative income changes prepares countries to face such crises. Expanding the scope of emergency social protection measures to protect financially vulnerable workers, especially workers in the affected sectors who experience permanent job loss and working hours reduction, represents a significant opportunity to develop a more comprehensive social protection system.

CONCLUSIONS

Introducing empirical findings that quantify the extent to of COVID-19 has impacted on the workers' economic status and signifies the key factors responsible for income changes is a useful tool for recovery efforts and designing policy responses. Work arrangements during the crisis have captured the emerging changes in workers' incomes. Workers who lost their jobs or worked fewer hours have experienced a substantial drop in their incomes. The economic effects of the pandemic have disproportionately affected workers across different countries. Work stability explained the differences in income changes between Jordanian workers partially. Food and accommodation workers suffered larger income declines than workers in other industries in Egypt and Tunisia. Blue-collar, skilled agricultural or production and transport showed a higher chance of experiencing income reduction than other workers in Egypt and Morocco. Regular work status increases the odds of experiencing positive income changes in Tunisia. It is imperative to expand the existing social protection systems in Arab counties to support those vulnerable workers.

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APPENDIX

Table A1. Variables' descriptions and categories

Main categories	Variable description	Categories
Background characteristics	Sex	1= Male 2= Female
	Age (in years)	Age (in five-year age groups)
	Highest level of education completed	1= Less than basic 2= Basic 3= Secondary 4= Higher education
	Marital status	1= Never Married 2= Currently Married 3= Widowed/divorced
	Place of residence	1= urban 2= rural
Work type	The main job/activity as of the end of February 2020	1= Farmer (owns a farm/self-employed on a farm) 2= Business owner/self-employed (but not a farmer) 3= Unpaid family worker on a farm 4= Unpaid family worker (but not a farmer) 5= Wage worker for Government / public sector 6= Wage Worker for a private sector /NGO 7= Unemployed and looking for work 8= Housewife 9= Full Time Student 10= Retired 11= Other, not employed and not looking for work (e.g. taking care of family members)
	The main job/activity in the past month	1= Farmer (owns a farm/self-employed on a farm) 2= Business owner/self-employed (but not a farmer) 3= Unpaid family worker on a farm 4= Unpaid family worker (but not a farmer)

		5= Wage worker for Government / public sector 6= Wage Worker for a private sector /NGO 7= Unemployed and looking for work 8= Housewife 9= Full Time Student 10= Retired 11= Other, not employed and not looking for work (e.g. taking care of family members).
	Economic activity (Feb. 2020)	Categorical 1= Agriculture, fishing or mining 2= Manufacturing 3= construction or utilities 4= Retail or Wholesale 5= Transportation and storage 6= Accommodation and food services 7= Information and communication 8= Financial activities or real estate 9= Education 10= Health 11= Other services
	Economic activity (Last Month)	Categorical 1= Agriculture, fishing or mining 2= Manufacturing 3= construction or utilities 4= Retail or Wholesale 5= Transportation and storage 6= Accommodation and food services 7= Information and communication 8= Financial activities or real estate 9= Education 10= Health 11= Other services
	Occupation (Feb. 2020)	1= Manager/professional 2= Technicians/associate professionals 3= Clerks/service workers 4= Blue collar, skilled agricultural, production and transport
	Occupation (Last Month)	1= Manager/professional 2= Technicians/associate professionals 3= Clerks/service workers 4= Blue collar, skilled agricultural, production and transport
Work characteristics	Employment stability (Feb. 2020)	1= Regular (permanent or temporary) 2= Irregular (casual, seasonal, or intermittent)
	Social insurance (Feb. 2020)	1 (Yes), 2 (No)
	Work inside establishment (Feb. 2020)	1 (Yes), 2 (No)

Work arrangements	Status of business worked for (Feb. 2020)	1= Temporarily closed due to government mandate related to the COVID-19 outbreak 2= Chose to temporarily close due to other challenges related to the COVID-19 outbreak 3= Temporarily or permanently closed due to factors unrelated to the COVID-19 outbreak 4= Permanently closed due to challenges related to the COVID-19 outbreak 5= open with the same business hours 6= open but reduction in business hours due to government mandate related to the COVID-19 outbreak 7= Business chose to reduce number of business hours 8= Do not know
	Past 60 days: temp. layoff/suspension (without pay)	0= Not mentioned 1= Mentioned
	Past 60 days: permanent layoff/suspension	0= Not mentioned 1= Mentioned
	Past 60 days: changed hours	1= Decreased by more than 25% 2= Decreased by 1-25% 3= Stay the same 4= Increased by 1-25% 5= Increased by more than 25%
	Past 60 days: delay in wage payment	0= Not mentioned 1= Mentioned
	Ability to work from home	1 (Yes), 2 (No)
	The reason for inability to work from home	1= Not allowed 2= Lack technology 3= Lack internet connection 4= Caregiving responsibilities 5= Not possible to do job off work site 6= Other (specify)
The dependent variable	Changed pay	1= Decreased by more than 25% 2= Decreased by 1-25% 3= Stay the same 4= Increased by 1-25% 5= Increased by more than 25%

Source: own

Table A2. The number of observations by waves and the total number of rounds

Observations by completed number of rounds					
Waves	1	2	3	4	Total
1	3773	590	261	1306	5930
2	2957	2384	1981	1306	8628
3	2677	1585	994	1306	6562
4	2726	2773	1720	1306	6562
5	2599	988	987		4574

Source: own

Table A3. The number of observations by country, waves, and the maximum number of rounds.

Country	Waves	Maximum number of rounds	Number of observations
Egypt	1,2,4	2	883
Sudan	3,5	2	452
Morocco	1,2,3,4	4	314
Tunisia	1,2,3,4	4	992
Jordan	2,4,5	3	982

Source: own
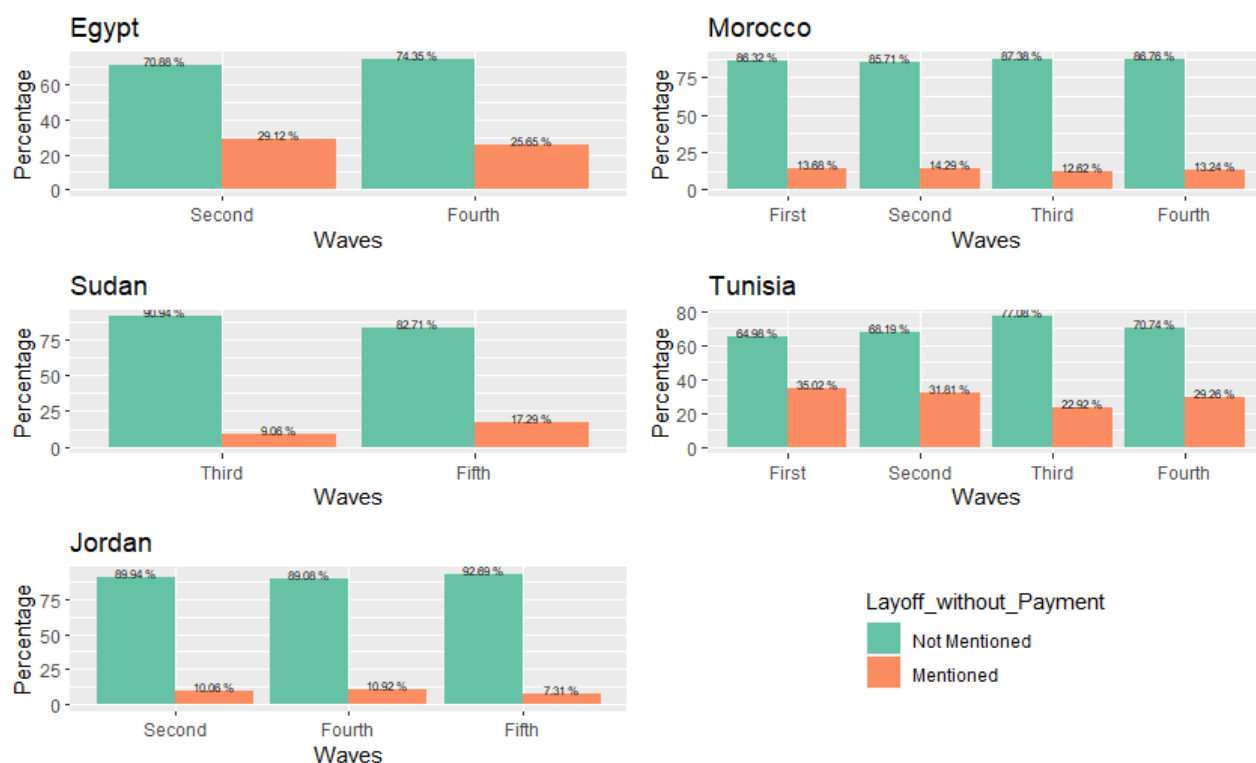
Figure A1. The distribution of the sample members according to the waves and the presence of the temporary layoff without payment in the five selected countries
Source: own
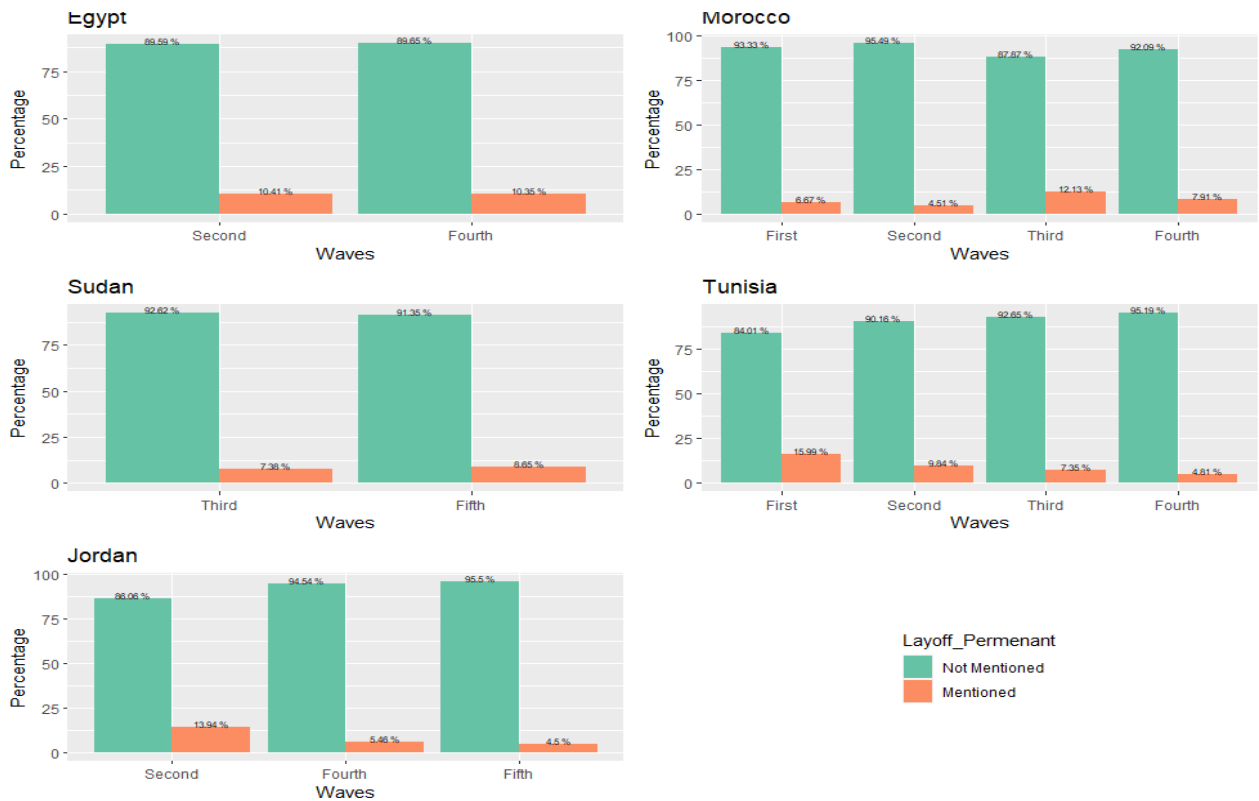
Figure A2. The distribution of the sample members according to the waves and the existence of permanent layoffs in the five selected countries
Source: own
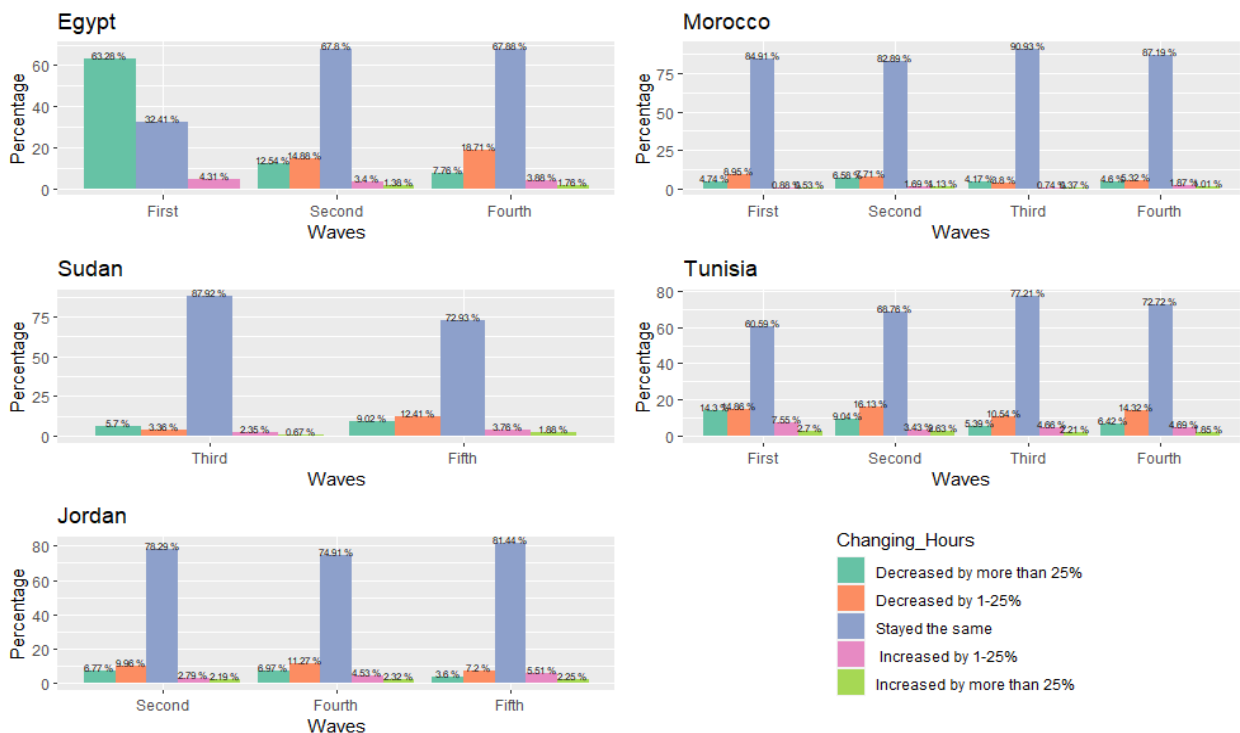
Figure A3. The distribution of the sample members according to the waves and the working hours during the pandemic in the five countries
Source: own
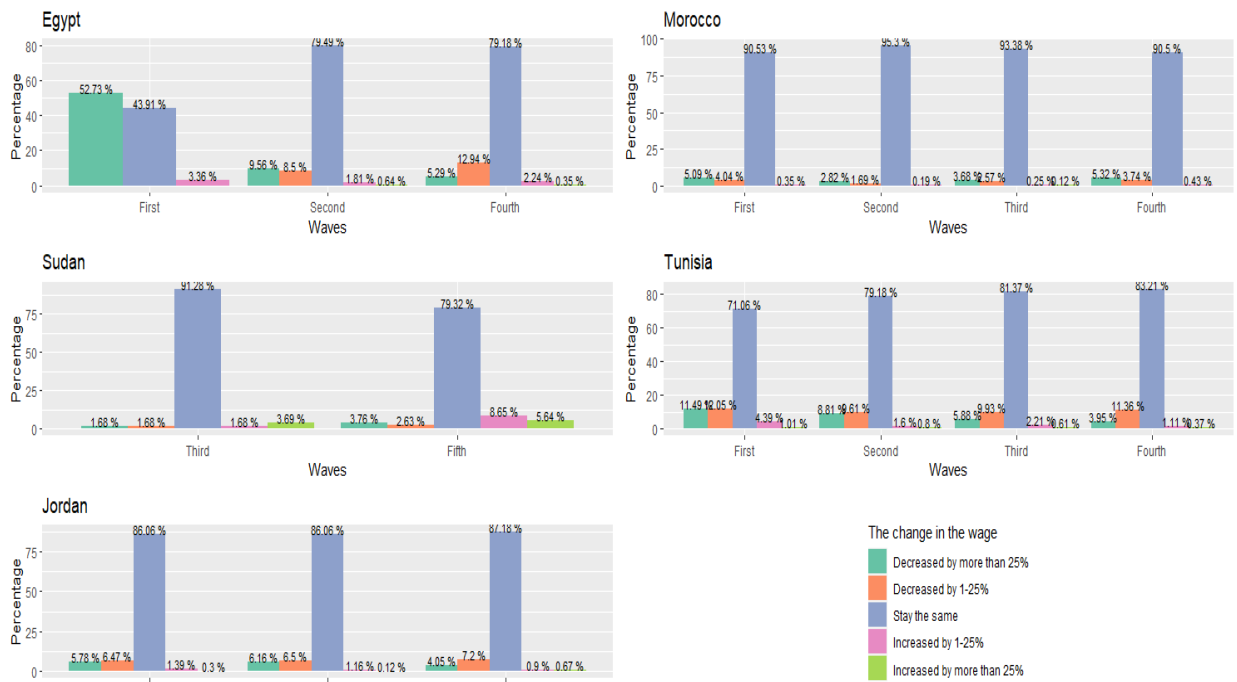
Figure A4. The distribution of the sample members according to waves and the percentage of the change in the wage in the five selected countries
Source: own

Figure A5. The distribution of the sample members according to the waves and the delay in wage during pandemic in the five selected countries
Source: own

Figure A6. The distribution of the sample members according to the waves and the ability to work from home in the selected countries
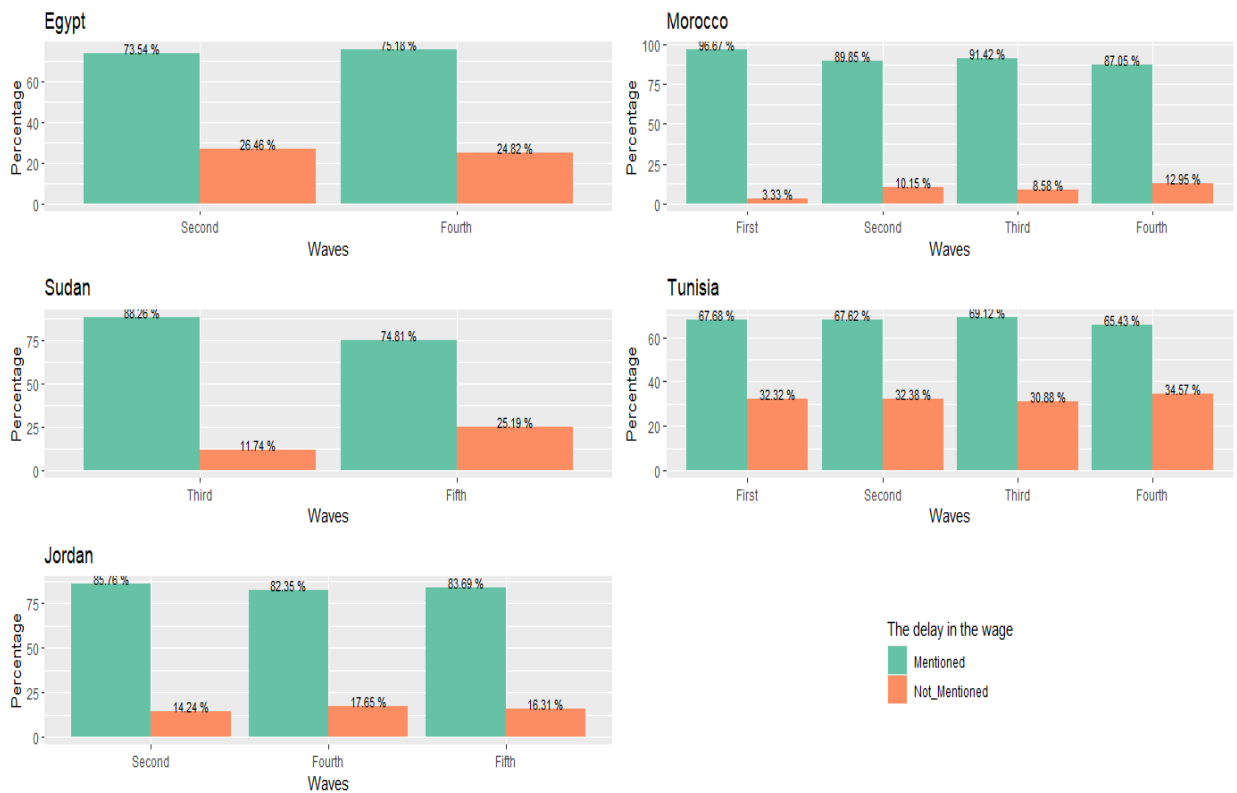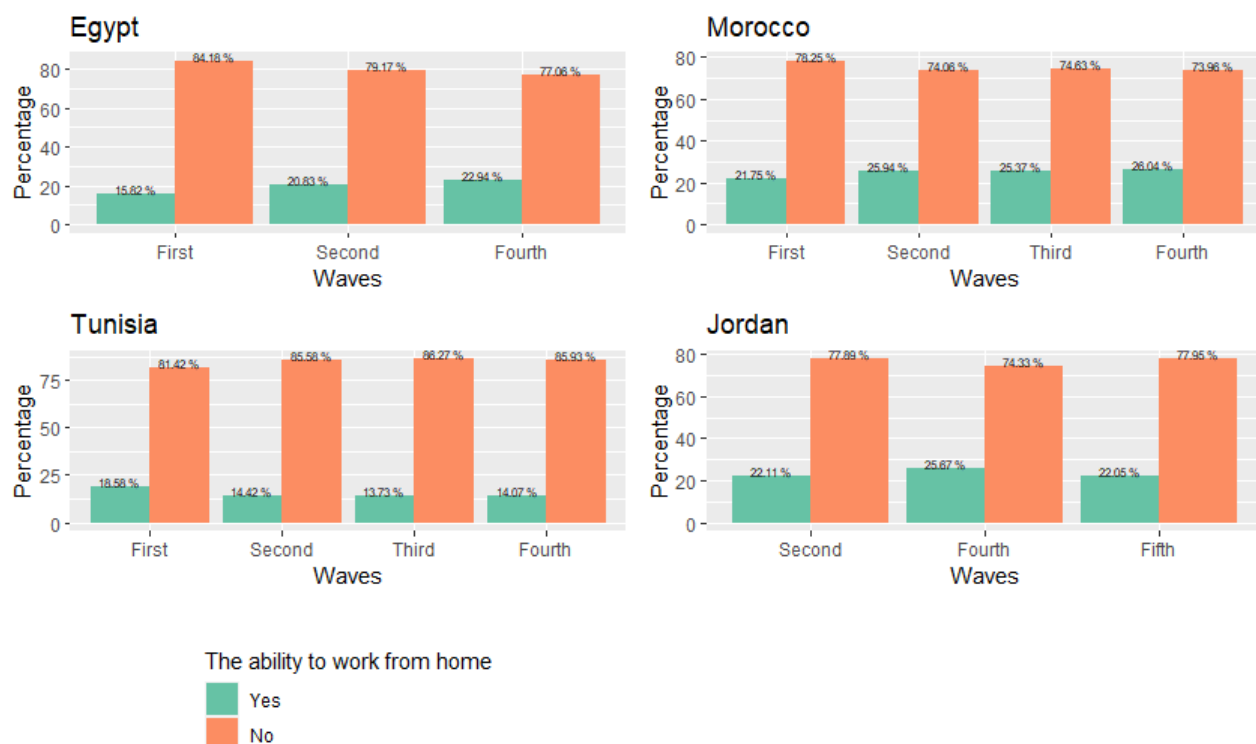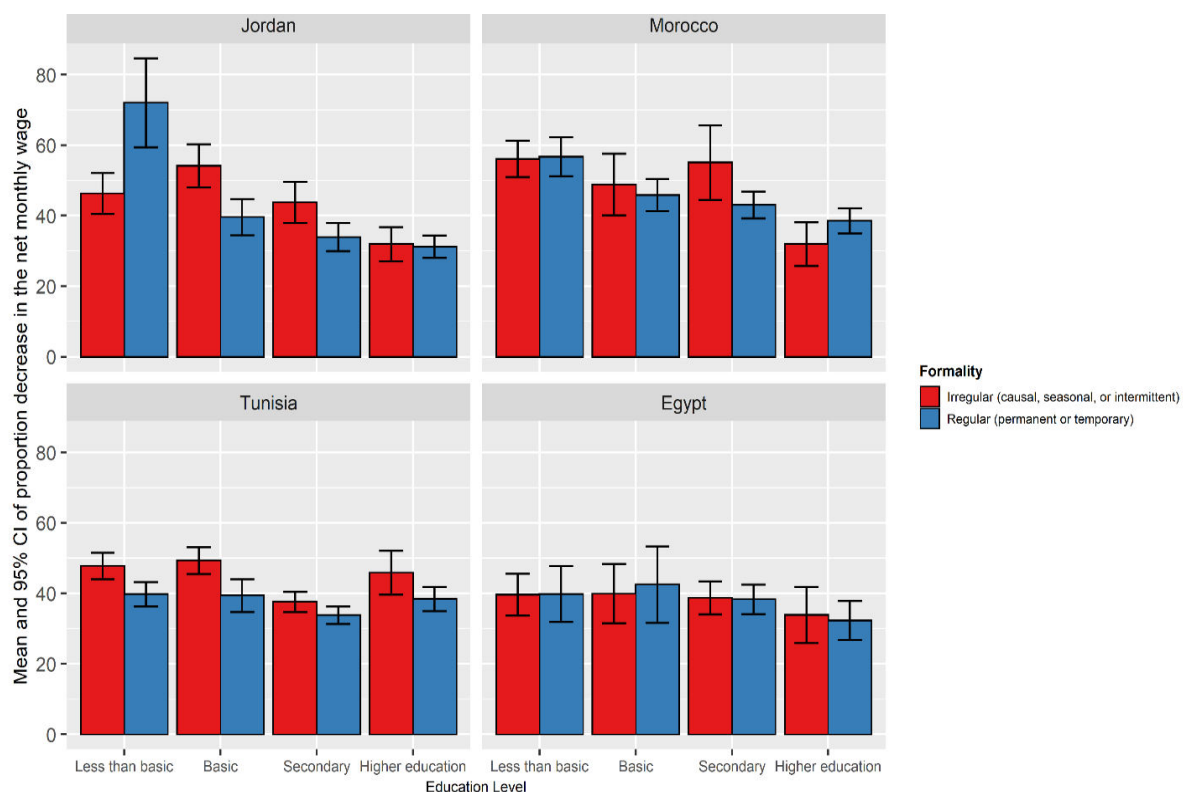Source: own

Figure A7. Mean and 95% of proportion decrease in the monthly wage by education level in Arab countries
Source: own

Foreign Experience in Building an Algorithmic Model for the Formation of Banking Ecosystems

ZAURE SULEIMENOVA[1], LYAZAT TALIMOVA[2] and NURILYA KUCHUKOVA[3] (Corresponding Author)

[1] PhD student, Karaganda University of Kazpotrebsoyuz, Karaganda, Kazakhstan, email: zaus_89@mail.ru, ORCID ID: https://orcid.org/0009-0004-4941-9440

[2] Doctor of Economic Sciences, Professor of the Department of «Finance», Karaganda University of Kazpotrebsoyuz, Karaganda, Kazakhstan, email: laztal@mail.ru, ORCID ID: https://orcid.org/0000-0002-7652-8333

[3] Doctor of Economic Science, Professor, Gumilyov Eurasian University named after I. umilyov, Astana, Kazakhstan, email: nkuchukova@mail.ru, ORCID ID: https://orcid.org/0000-0003-1704-7393

ARTICLE INFO

ABSTRACT

The article is devoted to the study of foreign experience in creating algorithmic models for the formation of banking ecosystems. The conceptual approaches and practical implementations used by the world's leading banks to integrate financial and non-financial services into a single digital platform are considered. Special attention is paid to the principles of ecosystem building, including the use of artificial intelligence, machine learning, and cloud technologies to improve customer engagement. The key advantages and challenges associated with the digital transformation of the banking sector, including data management, cybersecurity, and regulatory constraints, are discussed. The results of the study emphasize that algorithmic models of the formation of banking ecosystems contribute to increasing the competitiveness and sustainability of financial institutions, opening up new opportunities for business development and improving customer service. Reducing the share of factors such as payment calculations in explaining changes in equity allows us to consider them as auxiliary to forecasting operating expenses. The findings confirm the possibility of creating an adaptive model that redistributes priorities depending on changes in the external and internal conditions of banking activity. The recommendations are aimed at adapting best international practices in the context of national markets.

INTRODUCTION

In modern conditions of global digitalization, the banking sector is faced with the need to transform traditional business models. One of the key directions of such transformation is the creation of banking ecosystems — integrated platforms combining financial and non-financial services using modern technologies (Al-Omoush & Gomez-Olmedo, 2024). The ecosystem approach allows banks not only to strengthen their market positions, but also to expand the range of services offered, improving customer experience and generating new sources of income (Vinuela & Sapena, 2024).

The world's leading banks, such as JPMorgan Chase, HSBC, and DBS, are actively developing ecosystem models by implementing artificial intelligence, machine learning, and blockchain technologies to automate processes, improve decision-making accuracy, and provide personalized service. This approach allows not only to adapt to changes in the market environment, but also to set new standards in the financial sector.

The purpose of this study is to study foreign experience in building algorithmic models of banking ecosystems, to identify key factors of their success, as well as the possibilities of adapting these approaches in national conditions. The research focuses on the consideration of structural and technological solutions, as well as the analysis of the economic efficiency of the implementation of the ecosystem approach.

The relevance of the topic is due to the growing competition in the banking sector, where success is determined not only by the quality of services provided, but also by the ability to innovate, be flexible, and have a strategic vision. Consideration of foreign experience will allow us to identify best practices and develop recommendations for optimizing the processes of digital transformation of the banking sector.

The hypothesis of the study is that effective management of banking ecosystems directly depends on key drivers influencing changes in equity, such as fee income, corporate loans, interbank loans and settlements. Commission income and corporate loans have the most significant impact, which implies their priority use in algorithmic models to optimize resource allocation and increase the sustainability of banking ecosystems.

1. MATERIALS AND RESEARCH METHODS

The following methods were used to conduct this study:
- statistical analysis - conducting statistical tests and analyzing data to confirm the hypothesis of the study;

- correlation and regression analysis, used to assess the degree of influence of each variable on the change in equity. The calculation of regression coefficients (bi) allowed us to determine the directions and strength of the influence of factors.;
- a comparative analysis method that allowed us to evaluate the results of the study in the context of international experience and identify the features of the banking ecosystem of Kazakhstan;
- the method of standardized coefficients - the calculation of standardized coefficients (Ii) allowed us to determine the share of each factor in explaining changes in equity, which is critically important for the formation of an algorithmic model;
- economic and mathematical modeling - a linear regression model has been developed to build an algorithmic model of the formation of banking ecosystems. Standard formulas were used to assess the impact of factors on the key indicators of the banking system.;
- a systematic approach is a comprehensive consideration of all factors, their interrelationships and integration into an algorithmic model of the formation of banking ecosystems.

These methods ensure the reliability of the research results and make it possible to substantiate recommendations for improving the structure and management of banking ecosystems in the face of changes in the external and internal environment.

2. LITERATURE REVIEW

The financial ecosystem is developing in the context of digital transformation and integration of global trends, contributing to the creation of new opportunities for the banking sector, businesses and consumers. Considering the foreign experience of ecosystems created by large banks, it is necessary to note their features and key elements (Table 1).

Table 1. Comparison of ecosystems created by large banks

№	Bank	Feature	Key elements of the ecosystem	Ecosystem features

1	JPMorgan Chase (USA) [1]	JPMorgan Chase uses an ecosystem approach to integrate its financial products with various digital services. The focus is on platforms that provide convenience for private and corporate clients.	- payment platforms: Zelle (real-time transfers); - investment services: You Invest (online investment platform); - partner programs with technology companies such as Amazon.	- integration of artificial intelligence-based solutions to personalize recommendations; - great emphasis on cybersecurity and customer data protection.
2	DBS Bank (Singapore) [2]	DBS Bank has been recognized as one of the world's leading digital banks due to its strategy of building a fully integrated ecosystem.	- financial management platforms for business (DBS BusinessClass); - virtual banks and mobile applications such as Digibank; - integration with non-banking services, including platforms for travel and e-commerce	- using machine learning to analyze customer behavior; - emphasis on minimizing human interaction through full digitalization.
3	Santander (Spain) [3]	Santander has successfully integrated banking services with various technology platforms, focusing on the development of small and medium-sized businesses.	Openbank: one of the largest digital platforms in Europe; - Small business lending platforms (Santander InnoVentures); - integration with blockchain systems such as Ripple for cross-border payments.	- support for startups and fintech companies through the venture division; - innovative platforms for servicing small and medium-sized enterprises.
4	HSBC (United Kingdom	HSBC is focused on creating a global ecosystem that supports operations in different regions and sectors of the economy.	- platforms for international business: HSBCnet; - integration of asset management and insurance services; - innovations in the field of green finance and sustainable development	- using cloud technologies to unify services; - support for ESG (environmental, social and corporate governance) within the ecosystem
5	of Great Britain) [4]	ICICI Bank actively uses fintech solutions to build an ecosystem focused on digital transformation.	- mobile applications for retail customers such as iMobile; - digital business lending platform – InstaBIZ; - partnerships with Indian startups and fintech companies	- localization of products to meet the specific needs of regional markets; - fast scaling through digital solutions
6	ICICI Bank (India) [5]	BBVA integrates cutting-edge technologies, focusing on financial inclusion and digital platforms	- Open Banking platform for developers; - digital solutions for lending to small businesses and individuals; - focus on mobile payments through the BBVA Wallet app	- active use of the API to connect external developers; - participation in startup incubators and accelerators

Source: Compiled by the author based on the sources

Large banks such as JPMorgan Chase, DBS Bank, and Santander use different approaches to build ecosystems. The main differences are in the level of digitalization, integration with non-banking services, and targeting specific customer segments. The experience of these banks shows that an ecosystem approach helps to increase competitiveness and customer retention.

Each of the major banks demonstrates a unique approach to building an ecosystem. JPMorgan Chase and Santander are focused on corporate clients, DBS Bank and BBVA focus on digital platforms and mobile solutions, and HSBC and ICICI Bank focus on globalization and localization of their ecosystems, respectively. Such diverse experiences can serve as a basis for developing an optimal ecosystem model that takes into account the specific needs of the region or the target audience.

The role of the digital economy in economic transformation is becoming more and more noticeable (Chen, W. et al., 2023) [7], (Tian et al., 2021) [8]. Financial products combining online standardization and regional customization can provide a more convenient payment method, a more efficient workflow, and

lower-cost credit products for consumers and service providers in the industry chain (Huang and Hao, 2021) [9]. Modern financial institutions and Internet companies are actively implementing advanced technologies such as big data, IoT, cloud computing, blockchain, and artificial intelligence into their operations. These innovative technologies are used to create new financial business models that include finance, payments, and investments. This combination of finance and digital technologies is called digital finance (Huang and Huang, 2018). It contributes to the improvement of risk management through the use of technological innovations [10]. Foreign authors Shen G., Lin G., Ouyang A. The influence of various factors on the credit policy of commercial banks is considered, and country differences in banking activities are identified [11]. The issues of credit policy transformation in the context of digital transformation have been studied in the work of Azzawi A., Fouad J. [12].

The integration of online standardization with regional customization of financial products helps create more convenient payment methods, improve workflows, and reduce the cost of credit products for consumers and service providers in various industries. Modern financial institutions and Internet companies are actively implementing advanced technologies that contribute to the creation of new financial business models covering finance, payments and investments. The combination of finance and digital technologies, known as digital finance, significantly improves risk management through the application of technological innovations. The digital transformation of the financial sector not only increases the efficiency and competitiveness of banking institutions, but also opens up new opportunities for the development and optimization of credit policy and digital business models, being an important factor for sustainable economic growth in the digital economy.

Over the past few years, the volume of data has grown exponentially, and it has attracted a lot of attention due to its impact on society (Barrett and Greene, 2023) [13], (Muniswamaiah et al., 2023) [14]. The ability to collect and store ever-growing amounts of data, made possible by technological progress and lower computing and storage costs, has opened up new business opportunities and changed the way companies operate (Chen et al., 2012) [15], (Mamonov and Triantoro, 2018) [16]. The targeted integration of new technologies requires the provision of opportunities for academia and industry to explore and experiment with such technologies. The banking sector is increasingly aware of the need to introduce robotic consulting. The introduction of this service can lead to an increase in the efficiency of banks, improve the quality of customer service, and strengthen the image of banks as innovative institutions. Robo-advisory uses data about customers, their behavior and preferences obtained by banks from various communication channels (Ozheshko., Piotrovsky D., 2024) [17].

Algorithmic trading supported by computer algorithms has become widespread (A. Azzutti, 2022) [18]. It is especially common in high-frequency trading (V. Manakhov, 2015) [19]. Artificial intelligence and machine learning play a crucial role in the development of complex algorithms capable of analyzing large datasets and identifying patterns beyond human capabilities. This achievement leads to increased trading efficiency and reduced risks (J. Prix, O. Loistl, M. Huetl, 2007) [20]. The analysis of foreign experience in building ecosystems by large banks demonstrates that vertical integration and digitalization are becoming key elements of the transformation of the financial sector. Banks such as JPMorgan Chase, DBS Bank, Santander, HSBC, ICICI Bank, and BBVA are successfully using digital technologies to create ecosystems that not only enhance their competitiveness, but also provide customers with more convenient and innovative financial services. These examples show that a successful ecosystem combines the following aspects:

A. Integration with digital technologies. The use of artificial intelligence, blockchain, big data, and cloud computing makes it possible to automate processes, improve risk management, and personalize customer service.

B. Customer orientation. Banks are implementing mobile applications, digital platforms, and innovative payment solutions, increasing the accessibility and convenience of financial services.

C. Flexibility and adaptability. An important factor in the success of the ecosystem is the bank's ability to adapt to changing market conditions and customer needs, which is especially important in the context of digital transformation.

D. Support for sustainable development. Banks such as HSBC focus on financing environmental and social initiatives, strengthening their reputation and meeting global trends.

3. THE MAIN PART

Digital transformation is stimulating the development of new business models in the banking sector (Figure 1).
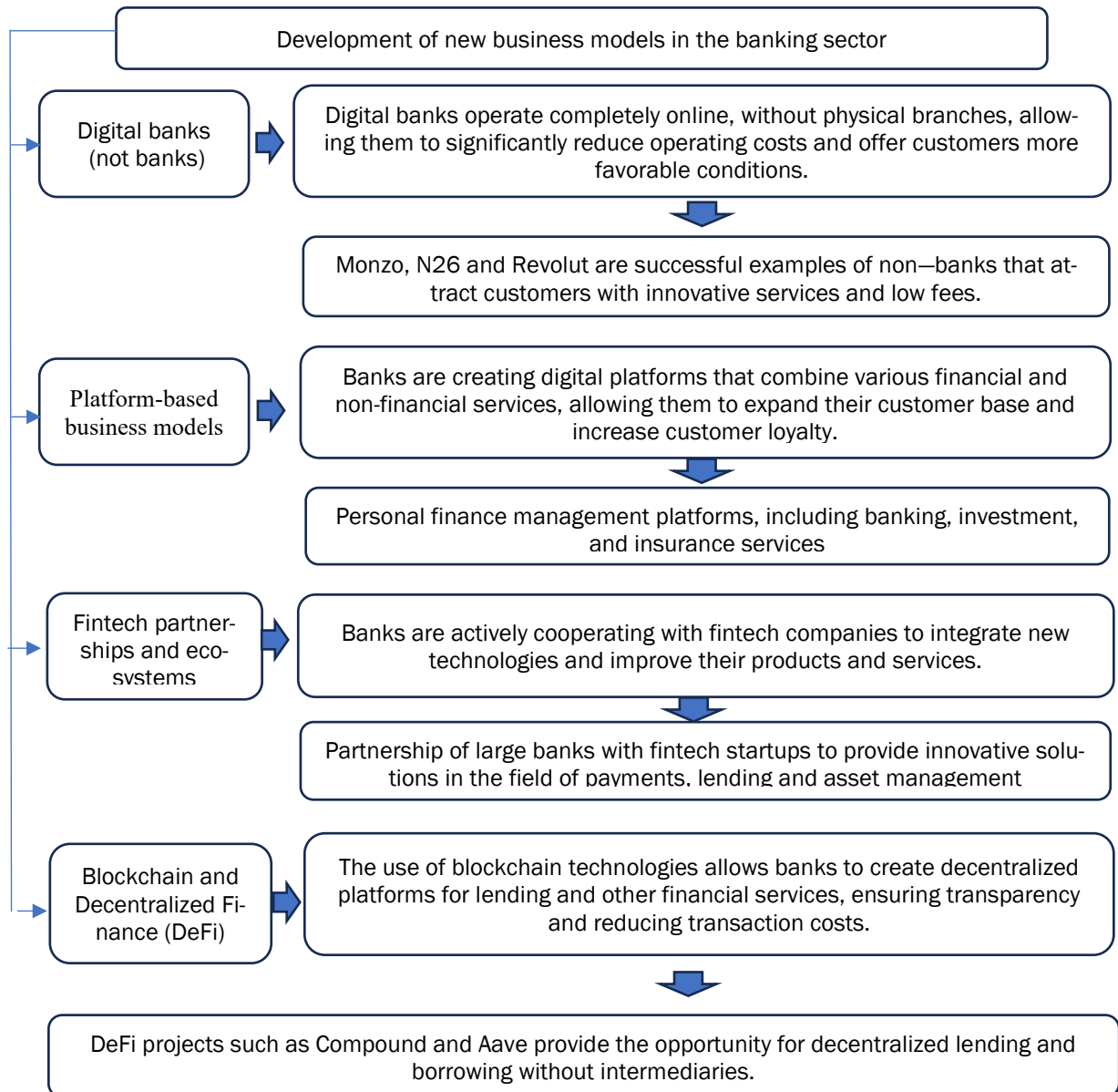
Figure 1. Development of new business models in the banking sector
Source: Compiled by the author

Currently, innovative IT solutions, API integrations with different systems, and mergers and acquisitions have become priority ways to expand banking ecosystems, providing the opportunity for a synergistic effect. For example, integrating financial services with online grocery orders or ticket bookings not only simplifies processes for users, but also expands the range of services available in a single application. This approach allows banks to diversify revenue, increase the number of transactions, and increase customer loyalty by offering comprehensive solutions for financial and day-to-day needs. At the moment, the financial system of the Republic of Kazakhstan is characterized by a bank-centric model. The main share of financial system assets is concentrated in the banking sector (Figure 2).

Figure 2 - Assets of the STB RK, trillion.tenge
Source: Compiled based on the source: https://ranking.kz/

Table 2. Deviation results

Year	Total	Growth towards the total, %	Absolute change (million)	Percentage change (%)
2010/07	11,8	99,2	-	-
2011/07	13,1	110,5	1,3	11,02
2012/07	13,3	101,9	0,2	1,53
2013/07	15,3	114,4	2,0	15,04
2014/07	17,4	113,9	2,1	13,73
2015/07	17,6	101,3	0,2	1,15
2016/07	25,4	144,2	7,8	44,32
2017/07	23,8	93,8	-1,6	-6,3
2018/07	24,3	101,9	0,5	2,1
2019/07	25,2	104	0,9	3,7
2020/07	29,1	115,3	3,9	15,5
2021/07	34,9	119,7	5,8	19,93
2022/07	40,3	115,7	5,4	15,47
2023/07	46,6	115,4	6,3	15,64
2024/07	56,8	122	10,2	21,89

Source: Compiled by the author on the basis of calculations performed

Nevertheless, at the end of 2024, there are still problems in Kazakhstan that hinder the effective formation and development of STB financial ecosystems in the context of digital transformation.:

- The financial ecosystem is not fully integrated with other sectors of the economy, limiting the synergetic effects. For example, insurance products and the stock market are poorly developed due to lack of public confidence and weak investor engagement.
- High transaction costs, as Banks face high costs for the implementation of innovative technologies. Despite efforts to digitalize, technologies such as artificial intelligence, blockchain, and big data are slowly being implemented. This is due to the lack of comprehensive strategies and underfunding of pilot projects. This problem reduces the competitiveness of Kazakhstani banks at the international level.

- Poor financial literacy of the population, as a significant part of bank customers are not ready to use complex digital products due to lack of knowledge, limiting the scale of implementation of digital services.
- Cyber threats and insufficient data security. With the growth of digitalization, the risks of data leaks and cyber attacks are increasing. Kazakh banks are facing the need for significant investments in cybersecurity, complicating the process of transition to a digital ecosystem.
- Unresolved issues of interoperability. The systems of different banks often do not integrate with each other, creating inconvenience for customers and reducing the overall efficiency of the financial ecosystem.
- Regional disparities in the availability of financial services. In rural areas, digital infrastructure is underdeveloped, limiting access to banking services, exacerbating economic inequality and reducing financial inclusion.
- Insufficient support for small and medium-sized businesses (SMEs). Financial products for SMEs remain complex and expensive, and the process of obtaining them requires significant time and administrative costs, hindering the development of entrepreneurship.

The relationship between the monthly indicators of second-tier banks (STBs) of the Republic of Kazakhstan, which affect equity, and the construction of an algorithmic model for the formation of banking ecosystems can be considered through the following aspects (Table 3) [22].

Table 3. Monthly indicators of STBs of the Republic of Kazakhstan affecting equity in 2022

Period	Authorized capital, thousand tenge	Accrued commission income, thousand tenge	Loans to corporate clients, trillion tenge	Bank loans, trillion tenge	Loans provided to other banks, thousands of tenge	Settlements on payments, thousands of tenge
01.01.2022	1767347094	16568734	5,2	14,5	86458387	11497151
01.02.2022	1767347094	16835752	5,1	14,4	88366537	10955760
01.03.2022	1750458102	17469498	5,3	14,8	73848728	15799828
01.04.2022	1752863842	18397040	5,3	15	66403796	22934531
01.05.2022	1750226139	18724939	5,4	15,8	70192554	22558176
01.06.2022	1745901139	19192049	5,2	15	68525475	24627716
01.07.2022	1725827458	19546668	5,2	15,9	71692775	23270452
01.08.2022	1725827458	19925481	5,3	16	75632755	23097012
01.09.2022	1725827458	19850453	5,4	16,4	83280685	28842947
01.10.2022	1460948987	20750081	5,5	16,9	84229884	20606168
01.11.2022	1483948986	21259433	5,7	17	87418526	29092417
01.12.2022	1483948986	21383991	5,8	17,8	99287385	20766651

Source: Compiled based on the source: Official resource. – Access mode: https://www.nationalbank .kz

Let's consider the factors affecting the equity of the STB RK using correlation and regression analysis. The monthly statistical data used for the analysis for 2022 are presented in Table 4.

For each pair of variables, use the Pearson correlation formula:

$$r = \frac{n\Sigma([xy] - \Sigma x \Sigma y}{\sqrt{[\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

where:
x and y - are variables (for example, accrued commission income and bank loans),
n - is the number of observations (12 months).

Table 4. The result of the factor analysis

	y	X1	X2	X3	X4	X5
y		-0,79721561	-0,86119	-0,847727	-0,60390251	-0,31431
X1			0,79501	0,9413545	0,276756082	0,755555
X2				0,8935774	0,551051953	0,460638
X3					0,488086052	0,593232
X4						-0,22449

Source: Compiled by the author on the basis of calculations performed

We interpret the data obtained:

A) Y (dependent variable):

- has a strong negative correlation with $X1$ (-0.797), $X2$(-0.861) and $X3$(-0.848)
- moderate negative association with $X4$(-0.604)
- weak negative correlation with $X5$(-0.314)
The main influence on Y is exerted by $X1, X2, X3$, since their correlation coefficients are close to -1.

B) X1 (independent variable):

- strong positive correlation with $X2$(0.795) and $X3$(0.941)
- weak positive correlation with $X4$(0.277) and $X5$(0.756)
$X1$ is closely associated with $X2$ and $X3$, indicating a possible multicollinearity.

C) $X2$ (independent variable):

- strong positive correlation with $X3$(0.894) and moderate correlation with $X4$(0.551) and $X5$(0.461);
$X2$ is also strongly related to $X3$, which confirms the relationship between the variables.

D) X3 (independent variable):

- moderate correlation with $X4$(0.488) and $X5$(0.593)

The effect of X to Y 3 strong, but his relationship with $X4$ $X5$ and weaker, which indicates a more personalized effect.

E) X4 (independent variable):

- weak positive association with $X5$(-0.224)
$X4$ has minimal effect on other variables.

F) X5 (independent variable):

- practically does not correlate with other variables, especially with $X4$.

4. ANALYSIS RESULT

A. Significant variables:

- the main influence on Y is exerted by $X1, X2, X3$, which is evident from the strong negative correlation. The bank can focus on the development of digital services (for example, payment automation, the introduction of AI in customer support), increasing customer loyalty and strengthening the ecosystem.

B. Multicollinearity:

- there is a high positive correlation (>0.8) between $X1, X2$, and $X3$, indicating the need to check and possibly exclude one of these variables to eliminate multicollinearity in the regression model.

C. Weak influence:

- $X4$ and $X5$ have a weak effect on the dependent variable Y and on other independent variables. They can be considered as additional factors.

The author also calculated the Influence Concentration Index, calculated for the share of each variable in explaining the changes. Y:

A. Calculate the sum of the products $bi \cdot \sigma i$:

$\sum$ = − 0.8767+(−0.7749) + (−0.7208) + (−0.7248) + (−0.3140) = −3.4112

B. We calculate Ii (%) for each variable:

$$Ii = (bi \cdot \sigma i) / \sum (bi \cdot \sigma i) *100\%$$

where:
bi is the regression coefficient;
σi is the standard deviation of the variable.

Calculations of the proportions of each variable in explaining the changes are presented in Table 5.

Table 5. Calculations of the proportions of each variable in explaining the changes Y

Variable	bi	σi	bi · σi	Ii (%)
X1	-0.797	1,1	-0,8767	25,:9
X2	-0.861	0,9	-0,7749	22,72
X3	-0.848	0,85	-0,7208	21,13
X4	-0.604	1,2	-0,7248	21,25
X5	-0.314	1,0	-0,3140	9,21
Total			-3,4112	100%

Source. Compiled by the author on the basis of calculations performed

Variables $X1$ (25.69%) and $X2$ (22.72%) contribute the largest share in explaining the changes in Y. The variable $X5$ has the smallest share (9.21%).

The results of the factor analysis, which includes the calculation of fractions of Ii, provide an understanding of the degree of influence of various factors on the change in the target indicator. In the context of building an algorithmic model for the formation of banking ecosystems, such data allows us to identify key drivers that must be taken into account in the model to ensure the effectiveness of the ecosystem. The main conclusions and their relation to modeling are presented in table 6.

Table 6. Main conclusions and their relation to modeling

№	Indicator	Variables	Necessary actions
1	Key drivers of changes (X1, X2)	Variables $X1$ (accrued commission income) and $X2$ (loans to corporate clients) have the most significant impact on changes in Y (equity) - 25.69% and 22.72%, respectively.	This indicates the need to integrate these indicators into the decision-making algorithm, such as loan portfolio management, service pricing, and setting conditions for corporate clients.
2	Average level of influence (X3, X4)	The variables $X3$ (bank loans) and $X4$ (loans to other banks) also significantly affect the target - 21.13% and 21.25%, respectively.	They reflect the interrelationships between banks within the ecosystem and should be taken into account in the model to optimize interbank transactions and the distribution of financial flows.
3	Lower importance of the variable (X5)	The variable $X5$ (payment calculations) has the least impact (9.21%). This indicates that this factor plays a lesser role in the changes. Y	For an algorithmic model, this factor can be useful for secondary functions such as forecasting operating costs.

Source: Compiled by the author

Integration into the algorithmic model will contribute to:

A. Optimization of asset management:

- variables $X1$ and $X2$ can be used to build an asset allocation algorithm between retail and corporate customer segments, allowing banks to increase the profitability and sustainability of the ecosystem.

B. Algorithms of interbank interaction:

- data on $X3$ and $X4$ should be embedded in the model to predict the volume of credit resources and loans within the ecosystem, allowing minimizing financial risks.

C. Consideration of all factors:

- The calculation of Ii allows you to take into account the relative contribution of each variable to the overall result. This is important for building an algorithm that adaptively redistributes priorities depending on changes in external and internal conditions.

The results of calculating the shares of influence (Ii) form the basis for building an algorithmic model of the formation of banking ecosystems. The model will take into account key drivers such as fee income and corporate loans, as well as lesser factors to ensure sustainability and adaptability. This approach allows banks to build efficient ecosystems that optimize resources and enhance competitive advantages.

Kazakhstan's approach to the development of digital financial services sets a high bar in terms of speed and economic efficiency. It is expected that all segments of the fintech market in Kazakhstan will continue to demonstrate a double-digit average annual growth rate (CAGR) in the period from 2022 to 2027, taking into account the development of the financial ecosystem. Based on the fintech segments in Kazakhstan in the 2x2 matrix, their potential, attractiveness and the relative size of the market, such a financial ecosystem was formed (Figure 3).
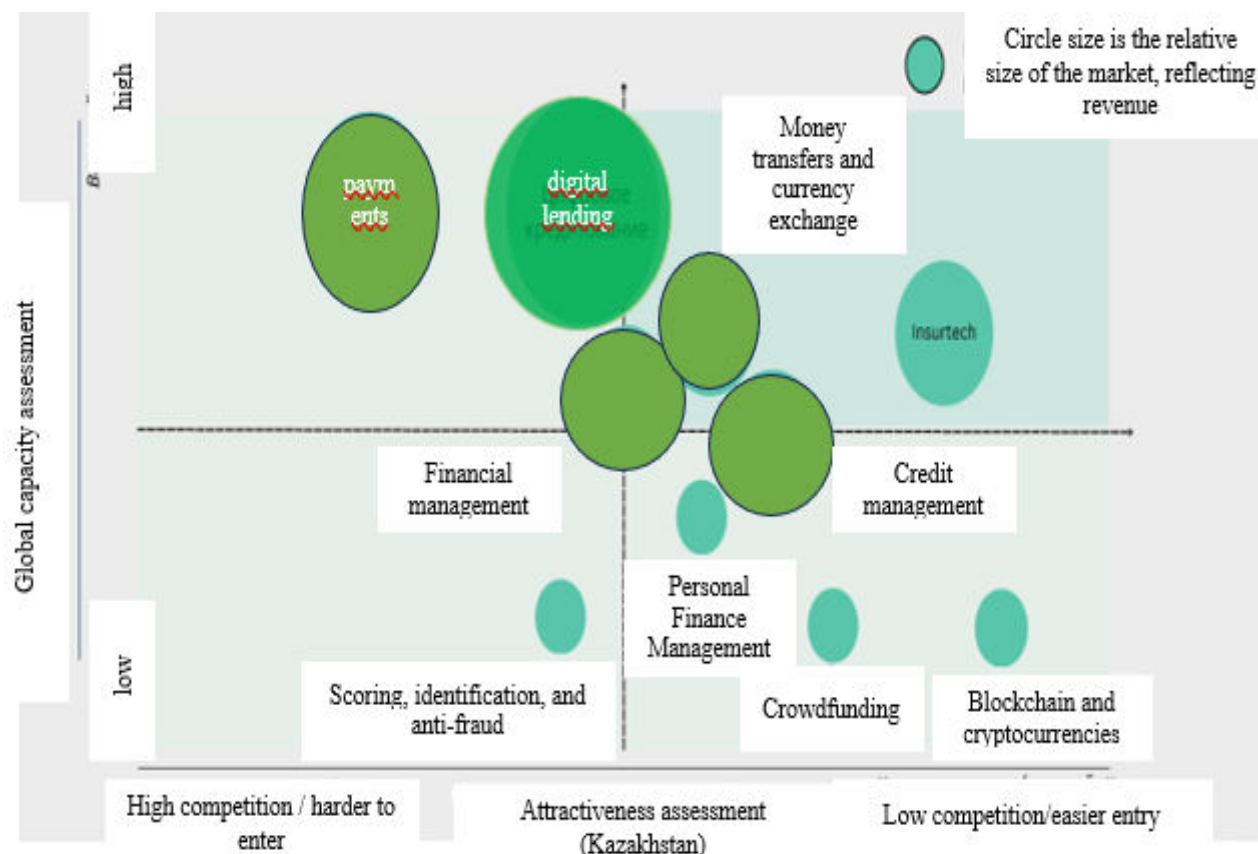
Figure 3. Development of the financial ecosystem
Source: Compiled from the source: Fintech market of Kazakhstan 2024.

Open Banking is fundamentally changing the global financial industry by making it possible to securely exchange customer financial data between banks, non-bank financial institutions, and third-party financial service providers. The advantages and value of open banking solutions became apparent after successful implementation examples in the UK, EU, USA, Brazil and Asian countries – Singapore, Hong Kong, Japan, etc. Today, the volume of transactions in the world within the framework of Open Banking is estimated at $ 57 billion [24]. The pilot project in Kazakhstan took place with the participation of second-tier banks: Bank RBK JSC, Altyn Bank JSC, Home Credit Bank JSC, Bank CenterCredit JSC, Otbasy Bank JSC. By 2027, this volume is expected to grow to $330 billion, and the number of operations will increase from 102 billion to 508 billion units.

Modern economic development is unthinkable without a systematic renewal of fixed assets, including banking, contributing to the introduction of technological innovations in business processes [25]. The formation of a stable capital market and a stable banking system is a prerequisite, after which economic growth will be significantly positive. The banking sector of the Republic of Kazakhstan has a significant amount of capital and liquidity to operate and provide all types of banking services.

Technological innovations play a key role in the development of banking ecosystems and have a significant impact on the equity of second-tier banks in the Republic of Kazakhstan. The relationship between these factors can be considered through several main aspects (Table 7).

Table 7. The relationship between technological innovations as a factor in the development of banking ecosystems in STB activities and factors affecting equity

№	The factor	This feature	Opportunity
1	Increased revenue and profitability	allows banks to optimize operations, reduce costs and improve the quality of customer service	They allow banks to optimize operations, reduce costs and improve the quality of customer service	it leads to an increase in income and, consequently, profitability, having a positive effect on equity
		. Mobile banking applications, online loans and investment platforms	mobile banking applications, online loans and investment platforms	- contribute to the creation of new products and services; - attracts new customers and retains existing ones, increasing the bank's revenues and strengthening its capital
2	Reducing risks and improving asset management	use advanced analytical tools and risk management systems	using advanced analytical tools and risk management systems	- allows banks to better assess the creditworthiness of borrowers; - predict market changes; - make informed decisions; - reduces the risks of non-repayment and losses, strengthening the financial stability of the bank and its equity
		. Modern technologies ensure a high level of data protection and fraud prevention	Modern technologies provide a high level of data protection and fraud prevention	minimizes operational risks and protects the bank's assets
3	Optimization of operational processes and cost reduction	. The introduction of robotic processes and automation of routine tasks reduce the need for human resources and reduce operating costs.	The introduction of robotic processes and automation of routine tasks reduce the need for human resources and reduce operational costs	allows banks to direct the released funds to increase their own capital
		Using cloud solutions reduces infrastructure and IT support costs	Using cloud solutions reduces infrastructure and IT support costs	contributes to the increase of capital reserves
4	Improving customer experience and loyalty	technological innovations allow banks to better understand the needs of their customers and offer personalized services	Technological innovations allow banks to better understand the needs of their customers and offer personalized services	increases the level of satisfaction and loyalty
		the development of mobile and online banking makes banking services more accessible	The development of mobile and online banking makes banking services more accessible	attracts more customers and increases the volume of operations, contributing to the growth of equity
5	Regulatory compliance and improved reporting	modern technologies help banks meet strict regulatory requirements and reporting standards	Modern technologies help banks meet strict regulatory requirements and reporting standards.	reduces the risks of fines and sanctions. Stable and transparent activities strengthen investor confidence and contribute to capital growth.

Source: Compiled by the author

Changes in the banking industry directly affect business and commerce, as evidenced by the profit indicators of the STB RK. This year, both all major market players and all banks in the Republic of Kazakhstan have made profits, and not a single financial institution has shown losses (Figure 4) [26].
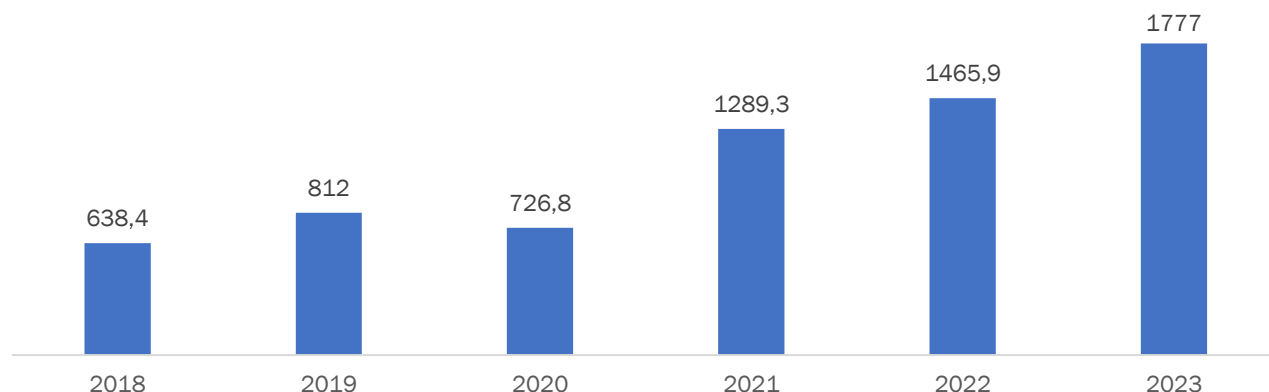
Figure 4. Profit of the STB RK, billion tenge
Source: Compiled on the basis of the source: Profit of the STB RK: which banks are leading, which are lagging behind. – [Electronic resource] – Access mode: https://ranking.kz/rankings/banking-and-finance-rankings/pribyl-bvu-rk-kakie-banki-lidiruyut-kakie-otstayut.html

The introduction of digital technologies in the banking sector of the Republic of Kazakhstan contributes to a significant improvement in credit policy and profitability of second-tier banks by optimizing processes, reducing operating costs and improving risk management. The introduction of digital technologies allows banks to:

−   improve credit risk management through big data analysis;
−   reduce operating costs through automation and process optimization;
−   to offer clients more convenient and affordable financial products and services;
−   increase the level of safety and reliability of operations.

In an era when cyber threats are becoming more sophisticated, the role of artificial intelligence in fraud detection and risk management is indispensable. Artificial intelligence algorithms can analyze transaction patterns in real time, spotting suspicious activity and reducing the risk of fraud.

CONCLUSION

Financial ecosystems created by large banks demonstrate significant potential in the context of global digitalization and growing consumer demands. Based on the experience of leading global banks such as JPMorgan Chase, DBS Bank, Santander, HSBC, ICICI Bank, and BBVA, key areas of ecosystem development can be identified: integration of digital technologies, customer orientation, support for innovation and sustainable development. These ecosystems are not just tools for increasing banks' competitiveness, but also platforms for implementing advanced financial solutions that improve the availability and quality of services. The use of technologies such as artificial intelligence, big data, and blockchain has enabled banks to automate processes, minimize risks, and provide personalized services to both private and corporate clients.

In relation to Kazakhstan, the development of banking ecosystems requires the adaptation of global experience to local conditions, including:

−   Development of digital platforms for small and medium-sized businesses;
−   Support of environmental initiatives through sustainable financing;
−   implementation of robotic consulting and algorithmic trading to improve the efficiency of operations.

Thus, the ecosystem approach allows banks not only to strengthen their market positions, but also to contribute to economic development by improving access to financial services and contributing to the country's integration into global economic processes. The experience of the world's leading banks can serve as a guideline for building an optimal ecosystem model in Kazakhstan, taking into account the strategic goals of digital transformation and the development of innovative potential.

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The impact of environmental and social factors on Hilton's economic value

STELA KOLESÁROVÁ[1], ERIKA KORMANÍKOVÁ[2], ANNA ŠENKOVÁ[3] and KRISTÍNA ŠAMBRONSKÁ[4]

[1]Assistant Professor, Faculty of Management and Business, University of Prešov, Slovakia; email: stela.kolesarova@unipo.sk
[2]Internal doctoral student, Faculty of Management and Business, University of Prešov, Slovakia; email: erika.kormani-kova@smail.unipo.sk
[3]Associate Professor, Faculty of Management and Business, University of Prešov, Slovakia; email: anna.senkova@unipo.sk
[4]Associate Professor, Faculty of Management and Business, University of Prešov, Slovakia; email: kristina.sambron-ska@unipo.sk

ARTICLE INFO

ABSTRACT

An ESG report is a strategic tool that assesses a company's sustainability by reflecting the environmental, social and governance factors that directly impact its value. The number of companies in the tourism sector publishing ESG reports is currently increasing, as there is a demonstrable link between sustainability performance and a positive impact on market value and competitiveness. ESG reports not only inform investors and the market about sustainable activities but also support effective risk management and increase long-term share value. This study analyses the impact of key ESG indicators on Hilton's market value over the past five years. Using Pearson's correlation analysis, water consumption indicators were identified as the most significant factors affecting the company's value. The findings reveal which ESG factors directly or indirectly impact Hilton's value, providing valuable information for optimizing ESG strategies and increasing the company's market value.

INTRODUCTION

Nowadays, an increasing number of companies in the tourism industry are focusing on transparently assessing their sustainability through Environmental, Social and Governance (ESG) reports, which reflect the environmental, social and governance aspects of their activities (Lee & Lee, 2019; Leung et al., 2020). These reports serve as strategic tools, helping investors, managers and other stakeholders to better understand the impact of businesses on the environment, society and governance structures. These reports are economically significant because they increase investor confidence, reduce information asymmetry and optimize capital flows, leading to lower capital costs and a higher market value for the company (Yang et al., 2021; Aakash et al., 2021).

In the tourism industry, where natural resource consumption is high, the emphasis on ESG is particularly important. Hotel chains such as Hilton, which regularly publish ESG reports, demonstrate that effectively monitoring and improving environmental and social indicators can have a positive effect on financial performance and competitiveness (Chevers & Spencer, 2019; De Langhe et al., 2016). Research confirms that there is a significant relationship between environmental factors, such as water consumption and emissions, and company value. For example, effective water management significantly impacts Hilton's perception and evaluation by the market. Conversely, indicators such as waste production have little or no impact on value. This study aims to analyze the relationship between selected environmental, social and governance (ESG) management indicators and Hilton's market value over the past five years. The Pearson correlation statistical method will be used to identify and quantify these relationships, with a focus on key environmental, social and governance indicators, including emissions, water consumption, energy use and supplier diversity. The results will provide valuable insights into the extent to which environmental and social factors can affect company value. This has important practical implications for strategists, investors and policymakers in the hospitality and tourism industry.

In summary, properly implemented and monitored ESG strategies have the potential to enhance a company's environmental and social responsibility and increase its market value. This is an important step towards a more sustainable and responsible future for the tourism industry.

1. LITERATURE REVIEW

An ESG report is a document published by companies that details the environmental, social and governance (ESG) impacts of their activities. It enables recipients and users to better understand a company's environmental and social impacts and to evaluate the risks and opportunities it faces. From an economic perspective, an ESG report is a tool for increasing investor confidence and reducing information asymmetries, which can lead to better capital allocation, a lower cost of capital, and a higher market value for the company. It is also a key factor in investors' and financial institutions' assessment of corporate competitiveness and long-term sustainability. As a communication tool, it plays an important role in convincing skeptical observers that a company's activities are genuine (PwC, 2025). As a significant report on steps towards achieving sustainability, ESG is linked to the three basic pillars of sustainability (E – environmental impact, S – social impact, and G – corporate governance) (Fig. 1). These pillars have direct economic consequences, including influencing share value, profitability, the cost of capital, and the company's long-term financial stability.

Figure 1. Key elements of ESG
Source: www.dbs.com.hk

The concept of ESG (Environmental, Social, and Governance) is experiencing exponential growth, with investors increasingly focused on the positive societal impact of companies. These investors evaluate companies based on their contributions to various social and environmental causes. More and more, ESG factors are becoming integral to investment analyses and the overall decision-making process.

The ESG framework can be divided into three key categories (Atkins, 2020):

1. Environmental (E): This category encompasses elements such as carbon footprint, greenhouse gas emissions, waste management, and water usage. It emphasizes the importance of protecting the environment, conserving natural resources, and promoting sustainable consumption.

2. Social (S): The social aspect focuses on issues such as equal pay, human rights, community relations, privacy and data protection, and the treatment of social justice issues. It underscores the necessity for companies to foster equitable and responsible practices within society.

3. Governance (G): The governance category pertains to the management of the environmental and social factors mentioned previously. It involves examining the composition and structure of corporate boards, the establishment of sustainability strategies, political contributions, and lobbying activities. Additionally, it addresses concerns related to corruption and other complex governance challenges.

Overall, ESG considerations are increasingly shaping investor behavior and corporate practices, driving companies toward greater accountability and positive societal impact.

The ESG concept was developed based on the theory of corporate social responsibility. Although it was initially developed by investors demanding the evaluation of responsible corporate behaviour and the prediction of future financial results based on non-financial information, the term is now widely used as a synonym for sustainability. ESG activities are intended not only to contribute to climate change mitigation by guiding the European Union towards green transformation and ultimately achieving climate neutrality by 2050, but also to support the transition to a fair and prosperous society with a modern, competitive economy (Vitálošová & Bíziková, 2023). Sustainability reports are becoming increasingly important as investors and other stakeholders are calling on companies to disclose more information about their sustainability activities and environmental, social and governance strategies. The increased focus on companies' sustainability activities is also gaining importance alongside the increasing legislation that has now entered into force or is in the process of being prepared (PwC, 2025). The most important legislative documents in this area include:

- Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020, which establishes a framework to facilitate sustainable investment (EU Taxonomy Regulation, effective from July 2020).
- Corporate Sustainability Reporting Directive (CSRD, effective from January 2023).
- Corporate Sustainability Due Diligence Directive (CSDD, proposal).
- Regulation of the European Parliament and of the Council of the EU establishing a framework for the setting of eco-design requirements for sustainable products (proposal).

In addition, companies can attract new potential investors by reporting sustainable activities through ESG reporting, as investors can rely on ESG data when assessing long-term risks. At the same time, publishing these reports contributes to greater transparency for investors when making decisions. ESG reporting can also provide a competitive advantage, helping to build trust among employees, customers, and stakeholders. Furthermore, ESG promotes responsible business practices by aligning with corporate social responsibility (CSR), which is considered a precursor to ESG (Legendre, Ding & Back, 2024).

As ESG reporting is not tied to a specific business area, company size or other factors, this type of activity monitoring can be used by companies in the tourism industry. Special emphasis is placed on monitoring environmental and social impacts within the framework of ESG for companies operating in the tourism sector, due to their intensive use and waste of natural resources (e.g. water and food) (Legendre, Ding & Back, 2024). In practice, several hotel companies (e.g. Hilton) are currently publishing ESG reports. According to a study by Chung, Nguyen and Nguyen (2024), ESG can increase hotel efficiency. Shin, Song

and Kang (2024) share a similar view on ESG, having confirmed in their research the mutual influence of ESG factors and the financial performance of hospitality facilities, particularly in conditions of interest rate changes.

ESG is not only a way of presenting a hotel's activities, but also an issue for internal and external stakeholders. According to Li, Stamolampros and Zhao (2025), hotel employees' perception of ESG practices has gradually increased over the years. At the same time, perception of ESG practices is higher among current employees (compared to former employees) and among managers (compared to non-managers) and increases with length of service in the organization. Perception of ESG practices is also related to higher job satisfaction and lower employee turnover, with length of service and level of position moderating these relationships (Li, Stamolampros & Zhao, 2025; Zheng, Gao & Thomas, 2025). From the perspective of external stakeholders (e.g. hotel customers), perception of ESG is as important as that of employees. According to Park and Shin (2024), customers' subjective knowledge of ESG influences their intention to visit a given facility. These findings also highlight the importance of marketing strategies that increase customer awareness and education about ESG practices (Choi & Choi, 2024).

Despite the significant advantages of ESG reporting, it is important to note that measuring environmental, social and governance aspects in the tourism and hospitality industry is still in its infancy, particularly in developing countries (Lin et al., 2024). The absence of the necessary measurements often causes companies in the tourism and hospitality sector to neglect ESG. This puts tourism companies, especially those in developing countries, at a significant disadvantage. According to a study by Xue et al., (2024), there is a positive relationship between ESG performance and company market value. For this reason, this study evaluates the connections between selected ESG report indicators and Hilton's value over the past 5 years. Hilton is one of the world's largest hotel companies, and recognizes they have a critical responsibility to protect communities and our planet, so the destinations where they operate can remain vibrant and resilient for generations of travelers to come.

Hilton is committed to continuously improving its ESG strategy, ensuring it aligns with the latest climate change insights and best practices. In 2022, they unveiled their new strategic ESG framework to guide them on their future journey to achieving their 2030 goals. Based on their previous commitments, the new framework also incorporates more ambitious ESG goals.

Environmental: environmental ambition in the form of updated, more ambitious emissions targets validated by the Science Based Targets Initiative (SBTi) will lead to a net zero future.

Social: expanded commitments to team members and communities enable Hilton to act with purpose and create opportunities.

Governance: Hilton is committed to maintaining a robust governance structure to help the company achieve its goals while upholding integrity and transparency. In 2020, Hilton undertook a robust evaluation, inviting company leadership, owners and developers, NGOs and community organizations, hotel guests, investors and suppliers to assess which aspects of ESG are most important to prioritize over the next three to five years. The results of the assessment are being used to ensure that Hilton's ESG programs not only remain aligned with long-term business strategies across departments and geographic regions but ultimately will have a positive impact on responsible tourism (HILTON, 2024).

2. METHODOLOGY AND RESEARCH METHODS

This study aims to examine the impact of selected ESG report indicators on Hilton's market value over the past five years. We focus on the impact of the following indicators:

1. Total Location-Based Emissions: Managed and Franchised,
2. Total Market-Based Emissions: Managed and Franchised,
3. Total Energy Consumption,
4. Total Water Consumption,
5. Total Waste Generated,

6. Volunteering,
7. Supplier Diversity.

These indicators represent key environmental, social and governance factors that can significantly impact the company's value in the eyes of investors and the market. It is important to evaluate their impact to understand how environmental and social initiatives are integrated into the corporate strategy, and what effect they have on the company's financial performance.

Based on the above, our research question is as follows: Is there a statistically significant relationship between the selected ESG report indicators and Hilton's market value? We have formulated the following research hypotheses:

- H0: There is no statistically significant relationship between the selected ESG indicators and Hilton's market value.
- H1: There is a statistically significant relationship between the selected ESG indicators and the market value of Hilton.

We used Pearson's correlation coefficient to perform a correlation analysis to determine the connections between the selected indicators and the market value of Hilton. The selected indicators were tested at a significance level of $\alpha = 0.05$ to assess whether the correlations were statistically significant. The statistical analyses were performed using the R program, which provides reliable tools for processing data and interpreting results. These results will improve our understanding of the relationship between environmental and social factors and Hilton's value, which could help investors, managers, and policymakers develop sustainability strategies and evaluate companies in the hospitality industry.

3. EMPIRICAL RESULTS

This section provides an in-depth analysis of Hilton's ESG reporting from 2019 to 2023. This time period is included because the statistical data required for the 2024 ESG report is not currently available, meaning the analysis is limited to data from previous years. Analyzing this period enables us to track trends and changes in environmental, social, and governance indicators over five years, while also considering the impact of global events, such as the 2019–2020 pandemic, on the way Hilton monitors and reports its environmental impacts.

Table 1 shows the outputs of the section of the report focusing on the environmental impact of the Hilton hotel company. The environmental impact area includes four main output categories that focus on monitoring carbon emissions, energy consumption, waste management and water consumption. These categories are essential for evaluating the company's environmental sustainability and its environmental impact.

Specifically, the following indicators are monitored and evaluated within these categories:

- **Carbon emissions:** including location-based and market-based emissions, distinguishing between emissions from managed and franchised hotels.
- **Energy consumption:** the total amount of energy consumed across all Hilton operations, reflecting the environmental burden associated with operating the hotels.
- **Waste management:** the amount of waste produced and how it is sorted and recycled, as well as the overall efficiency of waste management, which impacts reducing the environmental burden.
- **Water consumption:** the total amount of water used in operations, with emphasis on efficient use and minimizing waste.

This data provides a comprehensive overview of Hilton's environmental performance during the review period, highlighting areas where the company has improved or where it needs to enhance its environmental efforts. Analyzing this data is important for both assessing the current situation and planning future improvements and strategic sustainability initiatives.

Table 1. Hilton Hotel Company environmental performance table

Environmental impact indicator	2019	2020	2021	2022	2023
ENERGY AND CARBON					
Direct emissions					
Emissions (MT CO_2e)	476.036	329.57	415.034	446.084	489.016
Emissions intensity (MT CO_2e/m^2)	0.0199	0.0132	0.0151	0.0157	0.0164
Indirect emissions					
Location-based emissions (MT CO_2e)	1 949.324	1 419.705	1 778.303	1 922.844	2 095.366
Location-based emissions intensity (MT CO_2e/m^2)	0.0815	0.0569	0.0646	0.0678	0.0701
Market-based emissions (MT CO_2e)	1 931.834	1 388.664	1 762.174	1 904.610	2 081.095
Market-based emissions intensity (MT CO_2e/m^2)	0.0808	0.0557	0.0641	0.0672	0.0697
Emissions					
Franchise emissions (MT CO_2e)	3 884.715	3 189.909	4 087.530	4 020.579	4 202.841
Franchise emissions intensity (MT CO_2e/m^2)	0.0971	0.0749	0.0785	0.0742	0.0737
Emissions from business travel (MT CO_2e)	26.754	6.449	7.616	17.095	22.578
Emissions from waste (MT CO_2e)	117.772	59.986	73.000	86.883	96.013
Emissions from waste intensity (MT CO_2e/m^2)	0.0049	0.0024	0.0027	0.0031	0.0032
Total Location-Based Emissions: Managed and Franchised					
Location-based emissions (MT CO_2e)	6 314.510	4 39.185	6 280.868	6 389.506	6 787.223
Location-based emissions intensity (MT CO_2e/m^2)	0.0988	0.0732	0.0789	0.0774	0.0781
Total Market-Based Emissions: Managed and Franchised					
Market-based emissions (MT CO_2e)	6 292.556	4 908.143	6 264.739	6 371.272	6 772.953
Market-based emissions intensity (MT CO_2e/m^2)	0.0985	0.0727	0.0787	0.0772	0.0779
ENERGY					
Energy Consumption (MWh)					
Managed	6 828.225	4 956.217	6 164.255	6 800.671	7 440.224
Franchised	11 838.738	10 015.986	12 900.585	13 127.543	13 409.049

Σ	18 666.964	14 972.203	19 064.840	19 928.215	20 849.273
Energy Use Intensity (MWh/m²)					
Managed	0.2856	0.1987	0.2241	0.2398	0.2490
Franchised	0.2960	0.2353	0.2479	0.2423	0.2352
Σ	0.2921	0.2218	0.2396	0.2412	0.2399
WATER					
Water Consumption (megaliters)					
Managed	14.026	9.672	12.287	13.766	16.01
Franchised	23.327	16.788	22.435	25.196	27.504
Σ	37.353	26.46	34.722	38.962	43.514
Water Consumption Intensity (liters/m²)					
Managed	586	388	447	485	536
Franchised	583	394	431	462	482
Σ	858	392	436	472	501
Water Withdrawals (megaliters)					
Managed	53.103	38.687	49.147	55.065	64.039
Franchised	93.309	67.154	89.74	100.784	110.016
Σ	149.412	105.841	138.887	155.849	174.056
Water Withdrawals Intensity (liters/m²)					
Managed	2.346	1.551	1.787	1.942	2.144
Franchised	2.333	1.578	1.724	1.86	1.93
Σ	2.338	1.568	1.746	1.888	2.003
WASTE					
Total Waste Generated (MT)					
Managed	192.23	96.609	114.226	143.678	167.956
Franchised	332.103	212.321	239.453	271.113	286.225
Σ	524.334	308.929	353.679	414.791	454.181
Total Waste Intensity (MT/m²)					
Managed	0.0080	0.0039	0.0042	0.0051	0.0056
Franchised	0.0083	0.0050	0.0046	0.0050	0.0050
Σ	0.0082	0.0046	0.0044	0.0050	0.0052
Landfilled Waste Generated (MT)					
Managed	125.289	63.815	77.659	92.429	102.142
Franchised	281.772	188.956	217.948	249.702	265.63
Σ	407.061	252.772	295.607	342.131	367.772
Landfilled Waste Intensity (MT/m²)					
Managed	0.0052	0.0026	0.0028	0.0033	0.0034
Franchised	0.0070	0.0044	0.0042	0.0046	0.0047
Σ	0.0064	0.0037	0.0037	0.0041	0.0042
Waste Diverted from Landfill (MT)					
Managed	66.941	32.794	36.566	51.249	65.814
Franchised	50.332	23.364	21.505	21.412	20.595
Σ	117.273	56.158	58.072	72.661	86.409
Waste Diversion Intensity (MT/m²)					
Managed	0.0028	0.0013	0.0013	0.0018	0.0022
Franchised	0.0013	0.0005	0.0004	0.0004	0.0004
Σ	0.0018	0.0008	0.0007	0.0009	0.0010
Waste Diversion Rate (%)					
Managed	34.8	33.9	32.0	35.7	39.2
Franchised	15.2	11.0	9.0	7.9	7.2
Σ	22.4	18.2	16.4	17.5	19.0

Source: own processing according to Hilton 2022 Environmental, Social and Governance Report

As shown in Table 1, Hilton carries out detailed and systematic monitoring of its activities to assess their environmental impact. This monitoring involves the evaluation of 54 different indicators, providing a comprehensive view of the company's environmental performance. Focusing on indicators related to carbon emissions, we observe a significant decrease in both direct and indirect emissions, as well as their

intensity, particularly in 2020. This decrease is likely due to the impact of the 2020–22 global pandemic, during which many Hilton hotels were forced to close due to measures aimed at preventing the spread of the virus. These temporary operational restrictions led to a significant reduction in environmental impact, as evident from the emissions data.

However, after 2020, emissions (including location- and market-based emissions) began to gradually increase. This is related to the recovery of tourism and the resumption of hotel activities, reflected in increased service and operating capacity utilization. Similar trends were observed in energy and water consumption, which began to increase again after a period of decline, reflecting a return to normal operations and higher levels of activity at Hilton.

Significant variations in waste generation were observed over the period under review. In 2019, waste generation reached its highest level, most likely due to the high level of operational activity prior to the pandemic. During the pandemic, waste generation decreased by almost half due to restrictions and the temporary closure of operations. However, compared to 2019, we see a further decrease in waste generation in 2023, confirming positive trends in environmental efficiency and sustainability.

Another interesting indicator is the landfill rate, which has steadily increased since 2019. This indicator, known as the Waste Diversion Rate, has increased every year, reaching 39.2% in 2023. Higher values of this indicator suggest that waste is being diverted more efficiently from landfills towards recycling, composting, and other forms of treatment. This is a positive step towards minimizing Hilton's environmental impact.

Based on these data, we can confidently state that, during the monitored period, Hilton significantly improved its environmental performance, particularly regarding minimizing waste and reducing its intensity. These results confirm that the company is actively implementing measures to improve its environmental impact, moving towards more sustainable operations while gradually reducing its negative environmental impact and increasing the rate at which waste is recycled and diverted from landfills.

Hilton also publishes a detailed overview of social impact indicators in its ESG report, demonstrating its commitment to transparency and sustainability regarding the social aspects of its business. This overview includes two main groups of indicators designed to assess the company's impact on communities and its management.

The first group of indicators focuses on social aspects related to the communities in which Hilton operates. These include support for local communities, investment in community projects, initiatives to support local entrepreneurship and programmers aimed at reducing social inequalities. These indicators measure the extent to which the company contributes to the development and support of the communities in which it operates and the impact this has on improving the quality of life of residents.

The second group focuses on internal social aspects, such as diversity and inclusion in management structures, working conditions, employee satisfaction, health and safety in the workplace, and measures to promote equal opportunities. These indicators reflect Hilton's commitment to creating an inclusive and equitable work environment where diversity is encouraged, and where employees are motivated and protected.

Table 2 below presents the individual indicators in both groups, alongside their values for the review period and a brief commentary on the trends or significance of these indicators. In this way, Hilton transparently presents its social impact, setting the standard for sustainable development around social responsibility within its industry. This section of the report therefore provides stakeholders with a comprehensive view of how the company contributes to sustainable societal development and the actions it takes to promote social justice and inclusion.

Table 2. The output of the Hilton Hotel Company in terms of social impact

Social impact indicator	2019	2020	2021	2022	2023
Communities					

Volunteering (number of hours)	549.887	184.425	197.824	344.958	377.27
Refugee Support	10.883	11.725	26.335	78.588	29.92
Conduct					
Supplier Diversity	3.476	2.7	2.508	2.438	2.248
Human Rights (%)					
Managed	78	71	54	98	99
Franchised	-	-	-	70	92
Σ	-	-	-	-	-

Source: own processing according to Hilton 2022 Environmental, Social and Governance Report

Examining Hilton's social impact indicators, as shown in Table 2, reveals that their number is significantly lower than that of environmental waste indicators. The company only tracks five key social impact indicators overall, and the available data shows that some of these have incomplete or insufficiently updated information. This suggests possible challenges in collecting and processing social data, or in prioritizing individual areas by the company.

The first indicator, which falls under the social impact category, is the number of volunteer hours worked by Hilton employees. Table 2 shows that the number of volunteer hours worked has changed significantly over the years. In 2019, the number of hours worked reached its highest value, indicating a strong commitment to community activities among employees even before the start of the pandemic. There was a significant decline in 2020, likely due to global measures and restrictions on movement, as well as the closure of many operations, which limited volunteer opportunities.

The number of volunteer hours did not reach pre-pandemic levels by 2023, suggesting that Hilton may still be facing challenges in supporting community activities, or that the intensity of volunteer work has not yet fully recovered.

Another interesting indicator is refugee support, where the highest numbers were recorded in 2022. This may reflect an increase in Hilton's social activities and initiatives around refugee assistance and integration, in line with global initiatives to support vulnerable groups during and after the pandemic.

We also consider other aspects of social impact, such as supply chain diversity, which reached its highest level in 2019. This may reflect Hilton's commitment to fair and inclusive business practices and its promotion of diversity and equality in supplier relationships. A decline in this indicator in subsequent years could suggest changes to the supplier structure or difficulties in maintaining diversity within the supply chain. While fewer and less comprehensive than environmental indicators, social impact indicators provide valuable information about Hilton's activities in supporting communities, employees, and vulnerable groups. Tracking these indicators enables us to gain a better understanding of the company's contributions to social justice and societal development.

As evidenced by research such as Xue et al. (2024), ESG performance can have a significant positive impact on a company's market value. Table 3 below therefore provides an overview of Hilton's market value from 2019 to 2025. These figures, which are in billions or trillions of USD, provide a basis for further analysis and assessment of the company's financial stability and attractiveness in line with its ESG performance.

Please note that the figures for 2024 and 2025 are for informational purposes only, as official ESG data for these years is not currently available. These preliminary figures illustrate possible developments and trends in the company's market value in relation to expected improvements or changes in ESG performance.

This data can be used as part of the analysis to identify the relationship between ESG performance and market value, bearing in mind that actual values will only be available once the relevant reports are published. It is also important to monitor how and whether changes in ESG indicators are reflected in the company's valuation in financial markets, and to consider what factors may affect this relationship, such as global economic conditions, industry trends, and regulatory changes.

Overall, Table 3 provides valuable insight into Hilton's market value development in the context of ESG performance, serving as a basis for deeper interpretation to help investors, analysts, and other stakeholders better understand the long-term impact of environmental, social, and governance factors on the company's value.

Table 3. Hilton Hotel Company value over the last 6 years

Market value of Hilton (in trillions USD)	2019	2020	2021	2022	2023	2024	2025
	30.94	30.86	43.47	34.17	46.69	60.93	55.18

Source: own processing according to Global ranking 2025

As can be seen from Table 3, despite the significant economic and market challenges caused by the effects of the pandemic, Hilton's market value remained almost at the same level as in 2019. This indicates the company's resilience to adverse circumstances and its ability to maintain its market value during a global crisis.

However, there was a clear increase in Hilton's market value in 2021, rising by $12.61 trillion. This may be due to market recovery following the most difficult periods of the pandemic, as well as positive trends in the hospitality and tourism industry. This increase reflects investors' confidence in the company's future potential and its ability to adapt to changing market conditions.

However, the most striking and interesting trend is that Hilton's market value increased by an impressive $14.24 trillion in 2024 compared to 2023. This substantial growth can be attributed to various factors, including strategic investments, portfolio expansion, enhanced ESG performance and favorable economic forecasts.

Notably, Hilton's market value in 2024 reached its highest level in the last six years, indicating that the company is poised for continued growth and market value expansion. This also confirms that despite temporary challenges such as the pandemic, Hilton has the ability to grow and strengthen its position in the global hospitality and tourism market.

Overall, the analysis shows that Hilton's market value is highly dynamic, being significantly influenced by current industry trends, the economic environment and the company's internal strategies. This is crucial information for investors, managers, and other stakeholders, as it shows how the company adapts to changing conditions and its potential for growth in the coming years.

As this study aims to verify the existence and strength of the relationship between Hilton's market value and selected ESG report indicators, it is necessary to analyze the statistical indicators that characterize these relationships in more detail. Therefore, Table 4 below focuses on the p-values for individual indicators, which are used to test the statistical significance of these relationships.

P-values provide information on the extent to which the observed connection between market value and a particular indicator is statistically significant. P-values below the 0.05 threshold (usually around 0.01) indicate that the relationship is statistically significant and unlikely to be the result of chance.

Conversely, higher p-values indicate that it is not possible to confirm the existence of a statistically significant relationship between the monitored variables with certainty.

Table 4 therefore presents the p-values for individual ESG report indicators, such as environmental, social and governance (ESG). These values will enable us to evaluate the most significant impact of each aspect on Hilton's value and the extent to which these impacts can be considered statistically significant.

The results of this analysis are important from both a theoretical and a practical perspective, as they provide investors, managers and policymakers with valuable information on which ESG aspects have the greatest potential to impact a company's value. Rigorous interpretation of these results will improve our understanding of how to integrate ESG factors into strategic decision-making and how these factors can contribute to Hilton's long-term sustainability and growth.

Table 4. Correlations between selected ESG indicators and Hilton's market value

Indicator	Total Location-Based Emissions	Total-Market Based Emissions	Total Energy Consumption	Total Water Consumption	Total waste Generated	Volunteering	Supplier Diversity
p-value	0.2678	0.2659	0.2392	0.1673	0.988	0.7482	0.2075
r	0.6167	0.6187	0.6458	0.7233	- 0.0094	-0.1991	-0.6789

Source: own processing

As can be seen from Table 4, a statistically significant relationship with the market value of Hilton was confirmed for all the indicators examined. This means that the p-value of each variable analyzed is lower than the established significance level α (usually 0.05), enabling us to confidently state that there is a statistically significant relationship between these indicators and the company's value. These results therefore suggest that the company's performance in ESG areas significantly impacts its overall market value.

It can therefore be concluded that ESG (environmental, social and governance) aspects do indeed affect the value of Hilton, with some indicators having a more significant impact than others. The strongest relationship, based on intensity, is observed for the 'Total Water Consumption' indicator, with a correlation coefficient of 0.7233. This indicates a strong positive correlation between the amount of water consumed by the company and its market value: higher water consumption is associated with higher company value. Conversely, the weakest correlation is observed between waste production and market value, with a correlation coefficient of only -0.0094. This near-zero value suggests that waste production does not significantly impact Hilton's value over a given period.

At the same time, we can conclude that the number of emissions produced, location-based emissions, energy consumption and water consumption are directly related to Hilton's market value. This is confirmed by the positive correlation coefficients of these variables. This suggests that improving environmental performance in these areas is associated with a positive perception of the company and its value in the market. Conversely, aspects such as waste production, volunteer hours and supplier diversity affect market value indirectly, suggesting their impact may be mediated by other factors or indicators.

These results provide valuable insight into the direct or indirect impact of selected ESG indicators on Hilton's market value. They also provide an important basis for managers, investors and policymakers to consider when making strategic decisions and creating sustainable business strategies. Furthermore, this knowledge can facilitate further research into the impact of ESG factors on company value in the hospitality and tourism industry.

This study therefore aims to verify how selected ESG report indicators have affected Hilton's market value over the past 5 years. In our analysis, we employed Pearson's correlation coefficient to quantitatively

express the relationship between monitored variables and company value, providing valuable insights into the strength and direction of these relationships.

CONCLUSION

This study aimed to examine how selected ESG indicators from the report affect Hilton's market value between 2019 and 2023. This timeframe was chosen to capture the impact of various internal and external factors, including the effects of the pandemic, on Hilton's environmental, social, and governance practices. Based on the obtained data and correlation analysis using Pearson's correlation coefficient, we can conclude that Hilton is making significant progress in monitoring and reducing its environmental impact. The results show that Hilton is effectively assessing and managing its carbon emissions, energy consumption and waste and water management. They also demonstrate the company's ability to adapt to external factors such as the pandemic. Although this global crisis temporarily affected its operations, the company was able to reduce its negative environmental impacts, demonstrating its resilience and ability to implement sustainable measures even in challenging times. A notable finding is the sustained decrease in emissions and waste intensity after 2020, clearly indicating the company's growing commitment to environmental sustainability. In 2023, Hilton made significant improvements in all monitored environmental indicators, with the most notable progress being in waste minimization. For instance, the increase in the Waste Diversion Rate to 39.2% demonstrates effective waste management measures and improvements in recycling and composting. These results demonstrate the company's commitment to implementing sustainable practices and efficient resource management, which directly impacts its environmental performance and reputation in the market positively.

In the area of social impacts, despite the relatively small number of monitored indicators, it is evident that Hilton faces certain challenges regarding social responsibility and commitments. For instance, there are fluctuations in volunteering, with the highest performance recorded in 2022, possibly due to various initiatives, programmers or changes in the organizational structure. These findings highlight the need to continuously increase employee engagement and develop social projects that can contribute to a more positive public and investor perception of the company.

Analyzing the correlation between ESG indicators and Hilton's market value reveals the significant impact of environmental performance on the company's value. The highest correlation was recorded with the water consumption indicator, suggesting that effectively managing and reducing water consumption are key factors in how the company is perceived and valued in the market. Conversely, waste production appeared to have the least significant impact, potentially due to various factors including how waste is managed and how it is perceived by investors and the public.

In conclusion, effective ESG strategies can significantly improve a company's environmental and social responsibility and positively affect its market value. These findings have important practical and theoretical implications, as they provide evidence that companies emphasizing sustainability and responsibility can achieve better economic results and become more attractive to investors. They also pave the way for further research into ESG investments, their impact on companies' financial performance, and the importance of integrating them into strategic decisions in various sectors of the economy.

ACKNOWLEDGMENT

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Cost-effectiveness of introducing artificial intelligence tools into verbal evidence processes

SALTANAT KAPYSHEVA[1], ASKHAT ORAKBAYEV[2], LARISSA KUSSAINOVA[3], EVGENIY SHULGIN[4], SVETLANA VOROBYEVA[5] (Corresponding author) and YERGALI MA-BIYEV[6]

[1]Associate Professor, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan, email: karipovaainur@mail.ru, ORCID ID: https://orcid.org/0000-0003-4376-9074
[2]Senior Lecturer, Alikhan Bokeikhan University, Astana, Kazakhstan, email: askhat333orakbaev@gmail.com, ORCID ID: https://orcid.org/0000-0001-7363-3835
[3]Professor, Karaganda Buketov University, Karaganda, Kazakhstan, email: klarisa_777@mail.ru, ORCID ID: https://orcid.org/0000-0002-8208-6623
[4]Associate Professor, Karaganda Academy of the Ministry of Internal Affairs of the Republic of Kazakhstan, Karaganda, Kazakhstan, email: shulgin_e@internet.ru, ORCID ID: https://orcid.org/0009-0003-1471-7600
[5]Associate Professor, Karaganda Buketov University, Karaganda, Kazakhstan, email: sve-vor@mail.ru, ORCID ID: https://orcid.org/0000-0002-6159-5859
[6]Researcher, IT by Design, Astana, Kazakhstan, email: zhanna.shugaipova@mail.ru, ORCID ID: https://orcid.org/0009-0008-8949-9958

ARTICLE INFO

ABSTRACT

The relevance of this study stems from the need to improve the economic efficiency of law enforcement agencies in the context of the digital transformation of public administration. The transition to electronic pre-trial proceedings and the growing volume of verbal information processed make it necessary to implement artificial intelligence tools that can reduce the labor intensity of procedural procedures, optimize the use of human and budgetary resources, and increase the productivity of investigative units. The aim of the study is to assess the economic efficiency of implementing artificial intelligence tools in verbal procedural procedures based on an analysis of the dynamics and regional structure of pre-trial investigations in the Republic of Kazakhstan. The study utilized statistical and economic-mathematical analysis methods, including the calculation of absolute and relative dynamics indicators (Δ, %Δ, CAGR), structural shares of regions, and a model for assessing the savings in investigator work time. Based on data for 2019–2025, a steady decline in the overall number of pre-trial investigations was established, with the electronic format dominating from 2022. A regional analysis revealed a concentration of procedural workload in cities of national significance and industrially developed regions, where the implementation of AI provides the greatest economic benefit. Calculations show that the automation of verbal procedural procedures frees up a significant amount of investigator time, equivalent to a significant reduction in the need for additional human resources. The obtained results confirm that the implementation of artificial intelligence tools in verbal procedural procedures is economically feasible and contributes to the optimization of public spending, increased productivity, and the rationalization of procedural workload. The need for a

differentiated regional approach to the implementation of AI solutions, taking into account the scale and dynamics of pre-trial investigations, is substantiated. The results of the study can be used in the development of programs for the digitalization of the law enforcement system and subsequent cost-benefit analysis and return on investment calculations.

INTRODUCTION

In the context of the digital transformation of the economy and public administration, the implementation of artificial intelligence (AI) tools is becoming a key factor in improving the efficiency of public and law enforcement processes. This trend is particularly significant in criminal proceedings, which traditionally remain highly labor-intensive, time-consuming, and place significant burdens on budgets and human resources.

Verbal procedural procedures (questioning, interviews, confrontations, recording and analysis of testimony) are among the most resource-intensive elements of procedural activity, as they require significant time, the participation of qualified specialists, and the subsequent analytical processing of large amounts of textual information. With the growing volume of criminal cases and the increasing complexity of the evidence base, there is an objective need to find technological solutions that can increase productivity, reduce costs, and ensure a more efficient use of public resources. Despite the rapid development of AI technologies (speech recognition, automatic transcription, text analysis, and detection of logical contradictions), their economic efficiency in the context of verbal procedural procedures remains understudied, especially in developing economies and resource-constrained government systems.

The aim of this study is to assess the economic efficiency of implementing artificial intelligence tools in verbal procedural procedures in terms of cost optimization, increased productivity, and improved evidentiary processing in the criminal justice system.

The practical significance of this study lies in the potential use of the obtained results:
- in justifying the feasibility of budget investments in the digitalization of law enforcement agencies;
- in developing economic and organizational models for implementing AI in procedural activities;
- for developing key performance indicators (KPIs) for digital solutions in law enforcement;
- in the activities of government agencies when planning digital reforms and optimizing administrative costs;
- in educational and scientific-practical programs related to the digital economy, public administration, and law.

The results of the study can be used in the preparation of strategic documents, digitalization programs, and methodological recommendations for law enforcement and judicial authorities.

1. RESEARCH METHODS

The methodological basis of the study was developed taking into account the interdisciplinary nature of the work and combines economic, statistical, analytical, and modeling methods aimed at assessing the cost-effectiveness of implementing artificial intelligence tools in verbal procedural procedures of pre-trial proceedings.

1. Analysis of Official Statistical Data

The empirical basis of the study was official statistical data from the Legal Statistics and Special Records Portal of the Republic of Kazakhstan, reflecting the dynamics of initiated pre-trial investigations, their regional structure, and the degree of transition to electronic formats for the period 2019–2025. The use of official sources ensured the reliability and comparability of the analyzed indicators.

2. Descriptive Statistical Methods

The first stage utilized descriptive statistical methods, including the analysis of absolute and relative indicators, the construction of time series, and the calculation of the structural shares of regions in the national volume of pre-trial investigations. This stage allowed us to identify general trends in digitalization and regional differentiation of the procedural workload.

3. Dynamic Analysis and Calculation of Change Rates

To assess the intensity of change, dynamic analysis methods were used, including the calculation of:
- Absolute changes in indicators (Δ);
- Relative changes (%Δ);
- Compound Annual Growth Rate (CAGR).

The use of these indicators allowed us to characterize the rate of transformation of pre-trial proceedings and assess the sustainability of the identified trends in the medium term.

4. Structural Analysis and Regional Typology

To identify territorial disparities and priority areas for AI implementation, a structural analysis of the distribution of pre-trial investigations by region was conducted. Additionally, cluster analysis (hierarchical clustering using Ward's method) was used to group regions by level of procedural burden (high, medium, and low). This allowed us to develop a typology of regions and justify a differentiated approach to digitalization.

5. Economic and Mathematical Modeling of Time Savings

A key element of the study was the development of a model for assessing the savings in investigator work time when implementing artificial intelligence tools in verbal procedural procedures. Time savings were calculated as a function of:
- the volume of pre-trial investigations in the region;
- the share of electronic formats;
- the average intensity of verbal procedures;
- the reduction in labor costs per procedure due to AI.

The resulting values were interpreted as full-time equivalents (FTE), allowing for an assessment of the impact of digitalization in terms of freed-up human resources.

6. Methods of Economic Evaluation of Effectiveness (CBA and ROI)

To interpret the results from an economic perspective, elements of cost-benefit analysis and return on investment calculations were used. The economic impact was determined through the monetization of freed-up work time using a range of costs per hour of investigator labor, which ensured the flexibility of scenario analysis.

7. Scenario and Comparative Analysis

The study utilized a scenario approach (conservative, baseline, and optimistic) to assess the sensitivity of the results to changes in key model parameters (procedure intensity, share of electronic format, and time savings). A comparative analysis of the results by region identified areas of maximum and minimum economic benefit from AI implementation.

2. RESEARCH BACKGROUND

According to Brandao, P. R. (2025) In recent years, artificial intelligence (AI) has become a transformative force in various sectors of modern society, changing the economic landscape, social interactions and ethical aspects. This article examines the multifaceted impact of AI, analyzing its impact on employment, privacy, and decision-making processes. Organizations around the world are using these AI capabilities to increase productivity. Seventy-four percent of companies using AI claim that it has given them a competitive advantage. Many companies have started using AI to automate administrative and engineering design tasks. For example, legal AI algorithms can find relevant legal cases, draw up contracts based on templates, and analyze the language for problems.

AI has the potential to bring about fundamental changes in humanity. For example, many decisions in a person's life can already be delegated to technology. As AI systems improve, these systems can perform more complex tasks. The risk is that much of human judgment can be transferred to AI agents, forcing people to follow the guidance of smart agents without question. Independent human judgment allows you to reflect values, contexts, and long-term perspectives. At the same time, AI systems tend to focus on short-term goals, often overlooking secondary effects such as spirals and backlash (Velarde, 2019).

Understanding the political implications of algorithmic governance also helps to assess the political structures involved. AI and related technologies can have unintended consequences for organizational, institutional, social, and economic aspects of governance. Relying solely on the technical design of AI for management can also lead to immediate negative political consequences. To ensure that AI does not exacerbate existing political tensions or create new ones, it must meet clearly defined, legally established political goals. The high-dimensional input state space supports the modeling of complex systems. However, in such decision-making conditions, poor AI specification can lead to negative management consequences. These systems can also harm political representation (Sætra, 2020).

The development and implementation of artificial intelligence (AI) in the field of verbal evidence confirms the pronounced multidisciplinary and interdisciplinary nature of modern research, covering legal, technological, managerial and economic aspects. A significant body of literature is devoted to the use of automatic speech recognition (ASR) and natural language processing (NLP) technologies for recording and analyzing oral evidentiary information in law enforcement. So, the research of Harrington L. (2023) demonstrate that the use of ASR in transcribing investigative interviews can significantly reduce the complexity of documentation, however, the quality of automatic transcription significantly depends on the recording conditions, speech characteristics and the context of the interrogation. In the same context, Stoykova R., Porter K., Beka T. (2023) it is emphasized that the legal admissibility and procedural reliability of such decisions require regulatory regulation and built-in quality control mechanisms, which is especially important in the context of the implementation of the provisions of the AI Act and similar initiatives in the law enforcement sphere.

A separate area of research focuses on the intellectual analysis of the content of verbal evidence. Using NLP methods, an automated assessment of the characteristics of witness testimony becomes possible, including the degree of confidence of eyewitnesses and the features of linguistic expression, which expands the analytical capabilities of pre-trial proceedings (Greenspan et al., 2024). In related papers, Sola-Sales (2023) showed that linguistic styles and speech patterns can be used to identify signs of unreliability or distortion of memories, which is important for assessing the evidentiary value of oral testimony. At the same time, the authors emphasize that such tools should be considered as auxiliary, rather than replacing the procedural discretion of the investigator or the court.

The creation and continuous improvement of the information space is becoming one of the key factors of sustainable development. The development of digital solutions promotes organizational transformations, changes business paradigms and forms new models of service and interaction.

Han et al. (2024) considers new digital infrastructure as the cornerstone of the formation of an innovative environment. It facilitates the transition to green, low-carbon, and smart development in the context of the digital economy. Organizations providing information technology (IT) services play a crucial role in economic growth and job creation.

The transition to an electronic pre-trial format serves not only as a tool for increasing the transparency and manageability of processes, but also as a technological foundation for the further automation of analytical and documentary operations at the pre-trial stage. In particular, studies devoted to the use of electronic information technologies in the activities of internal affairs agencies during pre-trial proceedings note the need for the systematic development of electronic document management and digital accounting systems to improve the effectiveness of preliminary investigations and the quality of procedural decisions. A separate line of research examines the digitalization of judicial and law enforcement activities in Kazakhstan as an institutional reform that changes the organization of processes, reduces transaction costs, and creates the conditions for the subsequent implementation of intelligent technologies based on accumulated data.

The digitalization of criminal proceedings and the introduction of artificial intelligence (AI) tools into the activities of law enforcement agencies are considered in modern scientific literature as one of the key factors in increasing the efficiency of public administration and optimizing the use of public resources. With the growing volume of processed information and the increasing complexity of the evidence base, the automation of verbal procedural procedures, traditionally characterized by high labor intensity and significant time costs, is acquiring particular importance (Lohr, 2020).

In the regulatory framework of the Republic of Kazakhstan, the digital transformation of the law enforcement system is enshrined in strategic and programmatic documents, including the State Program "Digital Kazakhstan" and the Concept for the Development of Artificial Intelligence for 2024-2029. The Criminal Procedure Code of the Republic of Kazakhstan permits the use of electronic forms of recording and storing procedural materials, which creates the institutional preconditions for the implementation of intelligent digital tools at the pre-trial stage. The practical implementation of these provisions is reflected in the statistics of the legal statistics and special records portal, demonstrating a sustainable transition to an electronic format for pre-trial investigations. International studies emphasize that AI in the public sector has the greatest economic impact in processes involving the processing of large amounts of text and speech information, where automation can significantly reduce labor costs (Duan et al., 2019; Sun et al., 2019). In particular, automatic speech recognition (ASR) and natural language processing (NLP) technologies are considered a fundamental technological building block for optimizing the documentation, analysis, and structuring of verbal information.

A number of studies have explored the use of ASR and NLP in law enforcement and judicial processes. Researchers note that automated transcription of interviews, interrogations, and surveys can reduce the time required to prepare procedural documents, improve the completeness of testimony recording, and reduce the burden on employees performing routine operations (Leo et al., 2020).

From an economic point of view, the introduction of AI into verbal procedural procedures is interpreted through the prism of increasing labor productivity and reducing transaction costs. In the works devoted to the economics of digital technologies, it is emphasized that the main contribution of AI is not to replace a person, but to free up his working time to perform more complex analytical and managerial tasks. This approach is especially relevant for the law enforcement sphere, where a significant part of the investigator's working time is associated with the processing and analysis of textual information.

Bibliometric and review papers confirm that the greatest contribution of AI in the public sector is associated with increased efficiency of decision-making and analytical support for government activities (Di Vaio et al., 2022). The concept of "smart governance" emphasizes that the integration of AI, data analytics, and digital platforms increases the adaptability and transparency of public administration, including law enforcement (Jiang, 2021).

International organizations, including the OECD and the World Bank, recommend evaluating the effects of AI in public administration through indicators of saving time, increasing process throughput, and optimizing budget expenditures. In this regard, the transfer of released working time to full-time equivalent (FTE) is considered as a correct tool for the economic interpretation of the results of digitalization.

Kazakh research focuses on both legal and economic aspects of the digitalization of criminal proceedings. The authors emphasize that the transition to an electronic format of pre-trial proceedings contributes to increased transparency, manageability and procedural discipline, while creating conditions for the introduction of intelligent analytical tools. At the same time, it is noted that there is a need for an economic assessment of digital reforms, since the effect of technology implementation varies significantly depending on the regional workload and organizational maturity of departments.

At the same time, the literature highlights the risks and limitations of the use of AI in the law enforcement sphere related to requirements for data quality, transparency of algorithms, protection of the rights of participants in the process and error management (Sun, 2019), (Meijer, 2019). This indicates the need to include in economic calculations not only direct benefits, but also the costs of quality control, staff training and regulatory compliance.

The main challenge in the cost-effectiveness of implementing AI in verbal procedural procedures is the gap between technological readiness (electronic format, data, ASR/NLP tools) and the system's managerial and legal readiness. This means that the expected effect (time savings, increased productivity, cost reduction) often fails to translate into a sustainable ROI. This gap manifests itself in several bottlenecks:

1) The metric of "digitalization" replaces the metric of "efficiency."
The growth of the electronic format does not in itself guarantee savings: if investigators still spend time on manual proofreading, retyping, duplicating data across multiple systems, or correcting speech recognition errors, then AI becomes an "add-on" rather than a replacement for routine operations.

2) Data quality and the legal significance of the result.
AI transcription/summarization can introduce errors (noise, dialects, overlapping speech, legal terminology). If the verification procedure isn't integrated into the system, the following risks arise:

- either "overinsurance" (checking everything manually → the effect almost disappears);
- or "trust without control" (errors → procedural risks and challenging evidence).

3) Uneven regional workload and digital maturity.
Data shows that the workload is concentrated in a few regions. A universal implementation "the same everywhere" leads to overspending in regions with low workloads and underinvestment in areas where the effect is greatest.

4) The economic effect is not "monetized" in the management cycle.
Even if man-hours are freed up, the system often doesn't translate them into measurable results (reduced timeframes, improved quality, reduced overload). Without KPIs and process changes, savings remain "on paper." AI in verbal procedural procedures is economically feasible, but only if its implementation is interpreted not as "digital modernization" but as business process reengineering (BPR): regulations, role distribution, quality control, and outcome indicators are changed.

Thus, an analysis of scientific sources allows us to conclude that the economic efficiency of implementing artificial intelligence tools in verbal procedural procedures is determined by a combination of three factors: the presence of an electronic procedural framework, the technological maturity of ASR and NLP solutions, and a correct economic assessment of the effects through CBA and ROI models. This justifies the methodology chosen in this study, based on an analysis of the procedural workload, calculation of savings in investigator work time, and regional differentiation of the effects of digitalization.

3. ANALYSIS AND RESULTS

Let's consider the share of electronic formats and growth rates, which reflect the portion of procedural actions that are technologically feasible for AI application. In economic terms, this is:
- the upper limit of scalability of AI solutions;
- the actual volume of processes where savings in labor and transaction costs are possible.

In a paper-based document flow, the implementation of AI does not lead to a systemic economic effect. On the contrary, an increase in the share of electronic formats:
- expands the data set for automatic processing;
- reduces the marginal cost of processing one unit of information;
- creates conditions for the standardization of verbal procedures.

Consequently, the share of electronic formats is a key prerequisite for achieving economic benefits from AI, rather than a secondary technological indicator (Table 1).

Table 1. Share of electronic format and growth rates of pre-trial investigations in the Republic of Kazakhstan (2015–2025)

Year	Total, in thousands	In electronic format	Share of electronic format, %	Total Growth Rate (YoY)	Electronic Format Growth Rate (YoY)
2015	373	0	0	-	-
2016	345	0	0	-7,5	-
2017	298	0	0	-13,6	-
2018	274	13	4,7	-8,1	-
2019	231	44	19,0	-15,7	+238,5
2020	157	68	43,3	-32,0	+54,5
2021	149	114	76,5	5,1	+67,6
2022	149	149	100	0,0	+30,7
2023	133	133	100	-10,7	-10,7
2024	127	127	100	-4,5	-4,5
2025	116	116	100	-8,7	-8,7

Source: compiled by the authors

An analysis of the share and growth rate of the electronic format:
- enables prioritization of regions and departments for AI implementation;
- serves as an argument for differentiated digital policies rather than one-size-fits-all solutions;
- provides a basis for the phased implementation of AI depending on digital maturity.

1. The growth rate of the electronic format reflects the speed at which investments in digitalization begin to yield economic results. In the context of CBA and ROI:
- high growth rates indicate a rapid expansion of the base on which AI reduces costs;
- low growth rates increase the payback period and reduce the cumulative effect.

2. The sharp increase in the share of the electronic format in 2019–2021 indicates a scaling phase, in which:
- fixed implementation costs (training, software, infrastructure) begin to be spread across the growing volume of cases;
- the average cost of processing one verbal procedural action decreases. 3 The share of electronic formats and their growth are directly related to the economics of working time:
- the electronic format reduces the time it takes to record, transcribe, and analyze testimony;
- AI tools (speech-to-text, NLP analysis) enhance this effect not linearly, but exponentially as the volume of data grows.
Thus:
- with a low share of electronic formats, AI has a localized effect;

- with a share of >70–80%, AI becomes a systemic factor in increasing the productivity of investigative units. 4 CAGR (Compound Annual Growth Rate)
- Total CAGR (2015-2025)
$CAGR=(116 / 373)^{1/10} - 1 \approx -11.0\%$ per year
- Electronic Format CAGR (2018-2025)
$CAGR=(116 / 13)^{1/7} - 1 \approx +36.7\%$ per year

The total volume of initiated investigations is declining by approximately 11% per year, while the electronic format (as an infrastructural basis for AI) is growing by an average of 36–37% per year during the scaling period from 2018 to 2025.

3.1 Assessment of the economic efficiency of the implementation of artificial intelligence tools

Analyzing the share of electronic formats and their growth rates is crucial for assessing the economic efficiency of implementing artificial intelligence tools in verbal procedural procedures. The share of electronic formats reflects the actual scale of processes available for automation, while growth rates characterize the speed of cost transformation and the time it takes to achieve economic benefits. Collectively, these indicators form a methodological basis for accurately calculating CBA and ROI, and allow AI to be viewed not as a technological innovation, but as a factor in increasing labor productivity and optimizing public spending.

This transition is crucial for the economic evaluation of digitalization and the implementation of artificial intelligence tools in verbal procedural procedures, as the workload of law enforcement agencies, the crime structure, and the intensity of procedural actions vary significantly across regions. Consequently, identical digital solutions may demonstrate different economic returns depending on territorial conditions, the level of urbanization, the density of office work, and the staffing of investigative units. To substantiate the economic efficiency of digitalizing pre-trial proceedings and integrating artificial intelligence tools into verbal procedural procedures, an important stage of the analysis is comparing the volume of criminal cases investigated electronically with the number of cases referred to court. This comparison allows us to assess not only quantitative changes in procedural activity but also structural shifts in preliminary investigation mechanisms, reflecting the transformation of costs, labor intensity, and the effectiveness of procedural actions.

Table data for 2019–2024 document the dynamics of the transition to electronic investigations and allow us to determine the proportion of cases reaching the trial stage, which is fundamental for the economic interpretation of the implementation of digital and intelligent technologies. In the context of this study, this indicator is considered an indirect indicator of the effectiveness of pre-trial filtering and the quality of analytical processing of materials, including the use of automated tools for analyzing verbal information (Table 2).

Table 2. Pre-trial investigations in electronic format and the share of cases sent to court

Year	Criminal cases investigated (electronic format), units	Sent to court, units	Share of cases sent to court, %
2019	20309	5844	28,78
2020	68487	10391	15,17
2021	115811	13417	11,59
2022	164135	16443	10,02
2023	133000	12000	9,0
2024	127000	10800	8,5

Source: compiled by the authors

An analysis of the ratio of cases investigated to those referred to court provides an empirical basis for assessing the potential savings in labor and time resources achieved through digitalization and the use of AI in the pre-trial stage. A decrease in the proportion of cases referred to court, coupled with an increase

in the volume of electronic investigations, indicates a redistribution of the workload within the criminal justice system and creates the basis for calculating cost-benefit analysis (CBA) and return on investment (ROI) indicators for the implementation of AI solutions for the automation of verbal procedural procedures.

Regional differentiation allows for a transition from average national indicators to an analysis of the marginal effectiveness of AI implementation, identifying regions where the automation of verbal procedures provides the greatest reduction in labor and transaction costs. In economic terms, this means the ability to compare the volume of pre-trial investigations with potential savings in labor time and budgetary resources, as well as to assess the variability of CBA and ROI indicators across regions.

Regional analysis provides the basis for developing a differentiated digitalization model, where the priority for implementing AI tools is determined not by formal criteria, but by the actual procedural workload and digital maturity of regional divisions. This approach allows us to view artificial intelligence not as a universal technological solution, but as an optimization tool adapted to the economic conditions of specific regions, thereby improving the validity of management decisions and the efficiency of public resource allocation.

The grouping of regions by workload type (high/medium/low) is shown in Figure 1.
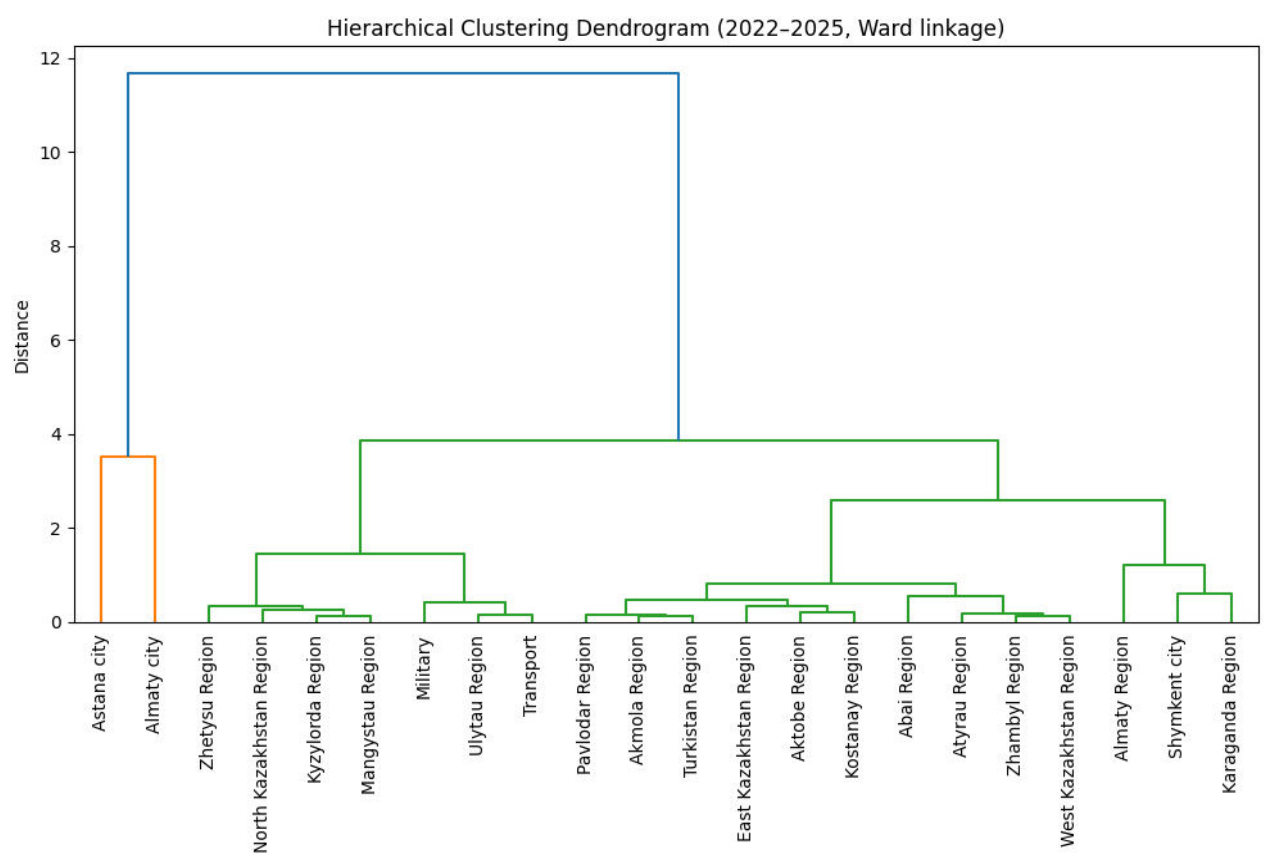
Figure 1. Grouping of regions by load type
Source: compiled by the authors based on calculations

The dendrogram provides insight into the following:

1) High Load:
- this is the number one priority for AI implementation (speech-to-text, automatic protocol, NLP analysis of testimony) because the caseload is highest, meaning greater scalability and faster time/cost savings;
- a high ROI is most likely here: fixed implementation costs (integration/training/licenses) are "spread" over a large caseload.

2) Medium Load:
- the optimal strategy is to scale standard solutions after the High Load pilot, but with adaptation to regional specifics (staffing, crime structure, seasonality);
- the economic effect is expected to be stable, but the ROI will depend on the intensity of verbal procedures (interrogations/questioning/confrontations) in a particular region and the degree of standardization of the processes.

3) Low-load:
- for these areas, lightweight solutions are more rational: a centralized transcription service, protocol templates, and targeted NLP analysis, rather than expensive, complex on-site implementations;
- economic logic: with small caseloads, the payback period is longer, so the emphasis is on minimizing CAPEX and using shared platforms/competence centers.

3.2 Modelling of economic effects of digitalization and the implementation of artificial intelligence tools

To fully assess the economic impact of digitalization and the implementation of artificial intelligence tools in verbal procedural procedures, analyzing the absolute volume of initiated pre-trial investigations alone is insufficient. Research into the structural and dynamic heterogeneity of regions, reflecting differences in procedural burden, the speed of transformation, and the contribution of individual administrative-territorial units to the national total, is essential.

The Δ indicator characterizes the absolute redistribution of pre-trial investigation volumes between regions, while %Δ and CAGR reflect the intensity of institutional and procedural changes, including the impact of digitalization and organizational reforms. The regional share indicator in 2025, in turn, captures the structural concentration of procedural activity, which is fundamental for prioritizing the implementation of AI solutions and assessing potential savings in labor and budgetary resources.

It should be noted that for regions formed as a result of administrative-territorial transformations after 2021, dynamic indicators for 2019–2025 were not calculated due to the lack of a comparable baseline value, ensuring the methodological correctness of the analysis and eliminating distortions in conclusions associated with formal structural breaks in statistical series. This expanded regional analysis provides an empirical basis for the subsequent classification of regions by procedural workload and allows for a differentiated approach to the implementation of artificial intelligence tools in verbal procedural procedures based on economic efficiency, return on investment, and optimization of public expenditures.

To assess the economic efficiency of implementing artificial intelligence tools in verbal procedural procedures, it is crucial to analyze not only the dynamics of pre-trial investigations but also the amount of labor resources saved, measured in investigator time. In this regard, the table presents an estimated regional estimate of potential savings in investigator time for 2025, based on the actual volume of pre-trial investigations initiated and the prevalence of electronic case management.

Time savings are calculated as a function of the region's procedural workload, the average intensity of verbal procedures, and the effect of their automation using AI tools (automated transcription, intelligent text processing, protocol templates). This approach allows digitalization to be interpreted not as an abstract technological improvement, but as a measurable economic effect, expressed in hours of freed labor and full-time equivalents (FTE).

These indicators allow us to compare regions by the absolute volume of potential time savings, identify areas with the greatest concentration of benefits, and justify the priority of implementing AI solutions in the context of limited budgetary resources. In the context of this study, this table forms the empirical basis for subsequent cost-benefit analysis (CBA) and return on investment (ROI) calculations, as well as for

developing a differentiated model for the digitalization of verbal procedural procedures in the criminal justice system of the Republic of Kazakhstan (Table 3).

Table 3. Time savings by leading regions of the Republic of Kazakhstan for 2025

Region	Beginning 2025	Share 2025	Saving time, hours	Full-time equivalent, FTE
Almaty city	20495			
Astana city	14830	12,8	35592	20,2
Almaty	8382	7,2	20117	11,4
Karaganda	7434	5,5	15442	8,8
Shymkent city	5725	4,9	13740	7,8
Aktuibinsk	5345	4,6	12828	7,3
Pavlodar	5040	4,3	12096	6,9
Kostanay	4870	4,2	11688	6,6
Akmola	4717	4,1	11321	6,4
Turkestan	4666	4,0	11198	6,4

Source: compiled by the authors

Time savings amounted to 278,016 hours/year

Full-time equivalent ≈ 158 FTE

To calculate time savings for leading regions of Kazakhstan for 2025, the following were used:
- $S_{2025} \approx 1.0$ (share of electronic format ≈ 100%)
- average number of verbal procedures per case: $m=3$
- labor costs for 1 verbal procedure before AI: $t_0=2$ hours
- after the implementation of AI (transcription + protocol templates + fact extraction): $t_1=1.2$ hours.
Save time on 1 task:

$$\Delta\tau = m \cdot (t_0 - t_1) = 3 \cdot (2.0 - 1.2) = 2.4 \text{ hours/case}$$

annual time savings in the region:

$$\Delta T_{r,2025} = N_{r,2025} \cdot s_{2025} \cdot 2.4$$

Using an estimated cost per hour of investigator labor in the range of 4,000-7,000 tenge/hour (salary + accruals + overhead), the potential economic impact is:
- at 4,000 tenge/hour ≈ 1.11 billion tenge/year;
- at 7,000 tenge/hour ≈ 1.95 billion tenge/year.

The 2025 share shows where the greatest absolute time savings will be—the pilot/scaling priority (in your case: Almaty, Astana, Almaty region, Karaganda region).

CAGR and %Δ (2019–2025) allow you to assess whether the impact will be sustained: with a rapid decline in N_r, the potential savings decrease, and the payback period lengthens. Δ(2019–2025) reflects the redistribution of workload between regions and helps justify why a unified AI implementation strategy is ineffective (a differentiated approach is needed).

Regional indicators of initiated pre-trial investigations are used as a proxy indicator of procedural workload, determining the potential savings for investigators' time by integrating AI into verbal procedural procedures. Given the dominance of the electronic format in 2022–2025, AI applicability in 2025 is assumed to be close to 100%, and annual time savings are estimated using the model $\Delta T_r = N_r \cdot m \cdot (t_0 - t_1)$. Calculations show that the maximum concentration effect is achieved in the regions with the highest share in 2025 (large agglomerations and industrial regions), which forms the basis for prioritizing implementation and subsequent calculation of CBA/ROI.

CONCLUSION

The economic efficiency of implementing artificial intelligence tools in verbal procedural procedures is determined by their ability to measurably reduce labor and time costs while simultaneously improving the quality of pre-trial proceedings.

An analysis of the dynamics and regional structure of pre-trial investigations in the Republic of Kazakhstan for 2019–2025 revealed that, despite a steady decline in the overall number of investigations, a qualitative transformation of pre-trial proceedings is taking place, driven by the transition to an electronic format and the digitalization of procedural procedures. This process creates the institutional and technological preconditions for implementing artificial intelligence tools in verbal procedural actions as a key factor in increasing the economic efficiency of criminal proceedings.

A regional breakdown revealed a high concentration of procedural workload in a limited number of territories, primarily in cities of national significance and industrially developed regions. It is in these territories that the potential impact of automating verbal procedures is greatest due to their widespread applicability and the potential to reduce specific labor costs per case. Calculations show that the implementation of AI tools can provide significant savings in investigators' work time, equivalent to hundreds of thousands of man-hours per year, which can be interpreted as a significant release of human resources without increasing staffing levels.

A comparison of absolute and relative growth rates (Δ, %Δ, CAGR), as well as the share of regions in the national total, made it possible to substantiate the need for a differentiated approach to digitalization. Universal solutions prove less cost-effective than targeted implementation of AI in regions with a stable or high procedural workload, while for territories with low investigation volumes, centralized or modular digital services are more rational.

Overall, the obtained results confirm that the introduction of artificial intelligence into verbal procedural procedures should be viewed not only as a technological innovation, but also as an economic tool for optimizing public spending, increasing labor productivity, and rationally allocating law enforcement resources. This creates a scientifically sound basis for subsequent cost-benefit analysis and return on investment calculations, as well as for the formation of management decisions in the field of digital transformation of criminal proceedings in the Republic of Kazakhstan.

ACKNOWLEDGMENT

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Mind Over Market: How Psychology Drives Consumer Decisions Through Neuromarketing?

ABDULLAH AL-ADAMAT[1], NASIEM ALYAMI[2], OMAR AL-ADAMAT[3], SARA ABU-MAHFOUZ[4] and HANAN ALMOMANI[5]

[1]Associate Professor, Department of Business and Public Administration, School of Business, Al al-Bayt University, Mafraq, Jordan, email: aaladamat@aabu.edu.jo, ORCID ID: https://orcid.org/0000-0003-4820-729X

[2]Assistant Professor, Department of Marketing and E-Commerce, Faculty of Business Administration, Najran University, Saudi Arabia, email: nmalyami@nu.edu.sa, ORCID ID: https://orcid.org/0009-0000-4861-8377

[3]Lecturer, Ministry of Education, Al-Mafraq, Jordan, email: adamat88@gmail.com, ORCID ID: https://orcid.org/0000-0002-9767-5754, corresponding author

[4]Researcher, Department of Business and Public Administration, School of Business, Al al-Bayt University, Mafraq, Jordan, email: saramhfouz0@gmail.com, ORCID ID: https://orcid.org/0009-0009-9861-0707

[5]PhD Candidate, Department of Economics and Social Sciences, Universitat Politècnica de València, Valencia, Spain, email: halmoma@doctor.upv.es, ORCID ID: https://orcid.org/0000-0002-2812-7594

ARTICLE INFO

ABSTRACT

This study explores the psychological underpinnings of consumer behavior through the lens of neuromarketing, employing an Exploratory Sequential Mixed-Methods Design. The research aimed to uncover how neuromarketing strategies—such as emotional analytics, sensory cues, and behavioral triggers—affect consumer decision-making and perception. In the qualitative phase, in-depth interviews were conducted with 60 experts in neuromarketing, neuroscience, and marketing strategy. Thematic analysis revealed key insights into emotional engagement, ethical considerations, and practical applications of neuromarketing tools. These expert-informed themes formed the basis for a structured questionnaire administered to 60 consumer behavior experts in Jordan. Quantitative data were collected using a 5-point Likert scale and analyzed through SPSS to assess trends and validate qualitative findings. The results indicate strong alignment between expert perspectives and broader patterns in consumer response, confirming the influential role of neuromarketing techniques. This study offers theoretical and practical contributions to the field by bridging qualitative depth with empirical generalizability and highlights the importance of ethical and context-sensitive implementation of neuromarketing strategies in consumer markets.

INTRODUCTION

Understanding how subconscious factors are influencing how customers behave has become crucial in a time of hyper-personalization and data-driven decision-making. Self-reports and behavioral data are common components of traditional marketing strategies, but they may not adequately capture the underlying cognitive and emotional processes that actually influence consumer behavior. This gap can be

bridged by exploring brain responses to marketing stimuli through "neuromarketing". According to Kumar et al. (2024), neuromarketing is a multidisciplinary field combining neuroscience, psychology, and marketing, whose purpose is to decode consumer behavior by analyzing how brain functioning, as well as physiological responses contribute to buying decisions.

Key methods of neuromarketing include Functional Magnetic Resonance Imaging (fMRI) - which detects changes in blood flow to identify brain regions activated by distinct marketing stimuli (e.g. Alsharif & Mohd Isa, 2024; Ariely & Berns 2010; Morin 2011); Electroencephalography (EEG) which tracks electrical brain activity, providing real-time insights into emotional /cognitive reactions (e.g. MacKay et al., 2024; Khondakar et al., 2024); Eye Tracking and Monitoring of eye movements is also employed to understand visual attention and engagement with ad or product displays (e.g. Wedel & Pieters, 2008); Galvanic skin response (GSR)-measuring variances in the conductive properties within the skin-space linked arousal due emotions/the dopamine effect/noted as affecting physiological sensation business targets (Ohme et al., 2009). Neuromarketing operationalizes this model by incorporating these methodologies to streamline and optimize marketing techniques, and product designs that appeal directly to consumers' subconscious urges and emotional responses thereby bridging the gap.

Neuromarketing remains underutilized in practice despite its increasing popularity, in part because of its high cost, ethical issues, and technological complexity (Goncalves et al., 2024). Furthermore, there is little agreement on how to convert neuroscientific discoveries into workable marketing plans successfully. Although some studies have demonstrated how neuromarketing tools can improve product design and advertising efficacy, there is a noticeable lack of thorough, practical assessments of these strategies by subject-matter experts. Moreover, studies that combine qualitative expert insights with quantitative validation to evaluate the true usefulness, constraints, and future directions of neuromarketing tactics are especially lacking.

Therefore, this study will focus on how neuromarketing techniques are perceived and applied by professionals in fields related to consumer behavior. This study will use an exploratory sequential design, firstly qualitative gains through depth expert interviews and then validate emerging themes with quantitative data from a larger sample of specialists. Specifically, it attempts (1) to investigate expert attitudes on the way neuromarketing techniques influence consumer behavior and decision-making, (2) to reveal the important practical, technological, and ethical challenges in the implementation of such techniques in marketing contexts, and finally (3) to provide empirical recommendations for integrating neuromarketing insights into marketing strategies towards boosting consumer engagement and brand impact. This study has the potential to tie theoretical gains and practical applications together into a more refined understanding of how neuromarketing can feed into consumer engagement strategies.

This study will add to the academic discussion with a rare blend of qualitative depth and quantitative rigor in studying neuromarketing. In practice, it serves as a guide for marketers, product designers, and business strategists interested in using the new neuroscientific tools ethically for competitive advantage. This study will provide a rounded perspective on the role of neuromarketing in evolving consumer decisions, focusing on contemporary practices, technological developments, ethical issues, and future expansions.

1. LITERATURE REVIEW

1.1 Evolution of Neuromarketing

The Neuromarketing field started being considered one more discipline at the beginning of 2000, driven by advances in neuroscience and marketers' developing interest in learning more about how consumers behave. Neuromarketing was famously rolled out with the scholarly work of scientists like Read Montague and Antonio Damasio (Montagne, 2007; Damasio, 1994) who at that time connected action preferences to brain processes. The findings from these core studies have primed the study of consumer behavior using neuroscientific techniques to reveal how emotional-cognitive interactions shape brand evaluations and their associated choice preferences.

The field surged in the mid-2000s, due to advancements of state-of-the-art neuroimaging methodologies specifically real-time methods like Functional Magnetic Resonance Imaging (FMRI) and Electroencephalography (EEG). Researchers were able to see timely brain activities in marketing stimuli live, which offered an unmatched perspective on the reactions of consumers (Ariely & Berns, 2010; Iloka & Onyeke, 2020; Morin, 2011; Smidts et al., 2014). Insights from neuromarketing research also became valuable to major corporations that began investing in it, using these insights to power advertising strategies; and tweak product design by optimizing the aesthetics profiles of their products and/or services more precisely against marketing targets' subconscious tastes.

Neuromarketing matured as a validated technique for improving marketing outcomes in the 2010s (Stipp, 2015). Its applications heralded more integrated approaches, for example, the fusion of neuroscience data with traditional marketing metrics. Further, potential emerging new technologies and approaches will keep the gradual addition of a diverse range of methodologies to the evolving discipline to suit new, more complicated consumer environments (Rawnaque et al., 2020).

1.2 Recent Advances in Neuroscience Imaging

Novel neuroimaging approaches should increase spatial and temporal resolution for more accurate brain measurements. Vizioli et al. (2021) use this as background to note the increasing advancements in neuroimaging methods that help much more detailed data become available. The development of portable neuroimaging devices, such as those outlined by Krampe (2022), has enabled field studies that demonstrate how wearable brain-imaging technology can provide actionable insights into consumer behavior in real-world environments.

1.3 Sentiment Analytics and Instant Optimization

Emotional analytics serves as a tool to design marketing that suits consumers while also effectively engaging them. Lindstrom (2016) stressed how emotional analytics are fundamental in customizing content to enhance consumer enjoyment. Wan et al. (2023) also emphasize the same findings showing how reaction monitoring in real-time and A/B testing (also known as split testing) lead to the optimization of marketing campaigns with immediate feedback.

1.4 Optimizing Ads with Eye Tracking

Eye-tracking technologies allow consumer attention and visual engagement to be examined in detail. As Casado-Aranda et al. (2023) show, the gaze patterns produced by such tools provide marketers with a means to design the ad better. Complementarily, when emotional analytics are introduced, eye tracking enhances the understanding of how visual components trigger emotions and affect comprehension (Kim & Lee, 2021). In turn, this multi-method approach strengthens the strategic logic governing the design of advertising content.

1.5 Multisensory Integration and Sensory Marketing

Sensory Marketing encompasses engagement through various sensory modalities. According to Ranson et al. (2022) and Zha et al. (2024), matching sensory cues with the identity of a brand guarantees consistent and memorable consumer experiences. Modern research endorses the claim that balanced sensory stimuli, which include scent, texture, and sound, promote emotional resonance and product recall (Zha et al., 2024). This kind of sensory integration reflects a wider trend toward comprehensive consumer experiences design.

1.6 Ethical Issues, Challenges, and Solutions

Objective issues such as ethical implications, complexity, and costs of neuromarketing which mentioned by several authors in the literature. According to Vuković (2024), neuromarketing causes many controversies and ethical dilemmas. Ferrell et al. (2025) argue that the potential for consumer manipulation and privacy concerns should be countered with more robust ethical guidelines, and rigorously enforced transparency. Casado-Aranda and Sanchez-Fernandez (2022) discussed the high costs and data analysis intricacies of neuromarketing techniques.

2. METHODOLOGY

2.1 Research Design

An exploratory sequential mixed-methods design was used in this study, which entails conducting a qualitative phase first then a quantitative phase. This method was chosen in order to obtain a thorough grasp of professional viewpoints on neuromarketing tactics in the first qualitative phase and to empirically validate the themes that emerged with a larger population in the second quantitative phase. Rich, exploratory insights and statistical generalizability were easily integrated by design, guaranteeing a thorough analysis of the ways in which neuromarketing strategies affect consumer behavior (Creswell & Clark, 2017; Hirose & Creswell, 2023). This mixed-methods framework offered empirical robustness and contextual depth by fusing the advantages of qualitative investigation and quantitative validation.

2.2 Qualitative Phase: Expert Interviews

Twenty experts with experiences in neuromarketing, consumer psychology, neuroscience, and marketing strategy engaged in in-depth, semi-structured interviews as a part of the study's first phase. This stage sought to investigate professional viewpoints on fundamental elements of neuromarketing, such as behavioral triggers, emotional engagement, ethical issues, and the useful application of neuroscientific instruments in marketing settings. For optimal alignment with key themes and current debates in consumer behavior and neuromarketing, these interview questions were developed after a thorough review of the literature. This made it feasible to conduct a theoretically based investigation that addressed both existing and new problems in the field.

The outcomes of this phase were applied (1) to develop a conceptual framework of important neuromarketing strategies and obstacles and (2) to govern the building of the quantitative tool utilized in the second phase, making sure that it was based on knowledge from experts.

2.3 Quantitative Phase: Consumer Survey

A structured questionnaire was designed to quantitatively evaluate the influence of neuromarketing tactics on consumer attitudes and behaviors, building on the thematic insights produced during the qualitative phase. In order to ensure content validity and alignment with practical applications of neuromarketing, the survey instrument was directly informed by the recurrent themes found in expert interviews.

Ten statements pertaining to neuromarketing dimensions, including eye tracking, emotional analytics, sensory marketing, and ethical considerations, made up the final questionnaire. A 5-point Likert scale, with 1 denoting "strongly disagree" and 5 denoting "strongly agree," was used to rate each item.

A secure, user-friendly online platform (i.e. Google Forms) was used to administer the survey, allowing for widespread participation while protecting respondent anonymity. A purposive sample of sixty Jordanian experts in consumer behavior was sought, and participants were gathered through academic mailing lists, professional networks, and marketing and behavioral science-related social media sites. Before starting

the questionnaire, digital informed consent was acquired, and participation was entirely voluntary. Due to the specialized nature of the field and the scarcity of qualified individuals, recruiting expert participants presented practical challenges, even though larger samples are typically preferred for broader generalizability. Because of this, the sample size was considered adequate for exploratory purposes, especially considering the participants' depth of expertise and relevance (Guest et al., 2006).

2.4 Data Analysis

The exploratory sequential design of the study was in line with the two-phase structure of the data analysis. Every interview was precisely transcribed and examined by thematic analysis during the qualitative phase (Braun & Clarke, 2006). This allowed for the discovery of recurrent themes, patterns, and insights in the responses of the participants. Both inductive and deductive thematic coding were used, with the interview questions helping as a guide but remaining receptive to any new patterns that might emerge in the data. After that, the themes were arranged and grouped according to the main areas of investigation, offering a methodical comprehension of the advantages and disadvantages of neuromarketing techniques. The items in the quantitative instrument were constructed based on these findings.

The Statistical Package for the Social Sciences (SPSS), version 24, was used to analyze the structured survey data during the quantitative phase. In order to verify the applicability and relevance of the themes found during the qualitative phase, participant responses were analyzed using descriptive statistics, and trends were evaluated.

3. RESULTS

The research results are divided into two stages to give an in-depth understanding of how neuromarketing tactics are viewed and used. While the first describes expert-derived insights based on thematic analysis, the second measures expert consensus on these insights. When taken as a whole, these results provide a strong understanding of how emotional, sensory, and cognitive marketing techniques work in a variety of Jordanian consumer situations.

3.1 Insights from Expert Interviews: Thematic Analysis

The thematic analysis of the qualitative data is presented in the next section, arranged according to each interview question. This format makes it possible to thoroughly examine professional opinions on important facets of neuromarketing tactics, moral dilemmas, and real-world uses.

1. Do you think neuroimaging techniques need to be improved to understand consumer behavior patterns?

1. **Technological Advancements:** Enhancing resolution, accuracy, temporal resolution, and developing portable devices.
2. **Data Integration:** Combining neuroimaging with machine learning, physiological measures, and self-report data.
3. **Methodological Improvements:** Longitudinal studies, standardization of protocols, and larger sample sizes.
4. **Interdisciplinary Collaboration:** Working with neuroscientists, marketers, and ethical reviews.
5. **Practical Applications:** Real-world simulations, cultural context, and individual differences.

2. In what ways can emotional analytics be used to create more impactful marketing campaigns?

1. **Customization:** Tailoring content, segmenting audiences, and developing personas.
2. **Measurement and Optimization:** Monitoring real-time reactions, A/B testing, and enhancing UX (User Experience).

3. **Storytelling and Engagement:** Enhancing storytelling, building brand communities, and leveraging user-generated content.
4. **Integration with Business Strategy:** Informing product development, improving customer service, and enhancing loyalty programs.
5. **Corporate Responsibility:** Aligning with social causes and improving brand authenticity.

3. What are the key factors that make eye tracking a useful tool for optimizing advertisements?

1. **Precision and Insight:** Providing detailed gaze patterns, attention data, and visual pathways.
2. **Optimization:** Enhancing layout, design, and placement of CTAs (Call to Action).
3. **Integration:** Combining with emotional analytics and comparing different ad formats.
4. **Audience Understanding:** Revealing demographic differences and interaction patterns.
5. **Practical Applications:** Improving various ad types, including video and out-of-home advertising.

4. How can sensory marketing be effectively implemented in product design?

1. **Multisensory Integration:** Incorporating textures, scents, sounds, colors, and tastes.
2. **Customer Experience:** Enhancing packaging, displays, and unboxing experiences.
3. **Personalization:** Tailoring sensory elements to target markets and individual preferences.
4. **Technology and Innovation:** Using technology for interactive experiences and sensory testing.
5. **Brand Consistency:** Ensuring sensory cues align with overall brand strategy and values.

5. Can you describe a situation where customer journey mapping significantly improved the customer experience?

1. **Process Enhancements;** new checkouts, returns, and account openings.
2. **Personal Services and support:** Improving personalization
3. **Incorporating technology:** Enhancing experience and engagement with technology-driven tools.
4. **Cross-Industry Use Cases:** Retail, Banking & Finance, Healthcare/ Life Sciences / Social care and Hospitality
5. **Outcome-Based:** Improve satisfaction, decrease churn, and drive retention.

6. What strategies have you found most effective in developing emotional branding?

1. **Authenticity & storytelling:** Les histories
2. **Aesthetic Appeal:** How you use visuals, music, and sound to evoke feelings.
3. **Social Media Users Development:** Social media - talking to consumers, asking a question and then utilizing the user content.
4. **CSR:** Documenting Social Initiatives & Establish Trust Beneficiary Machine Learning Site
5. **Customer-centric focus:** Make it personal and celebrate milestones.

7. How can marketers ethically use priming techniques to influence consumer behavior?

1. **Truthfulness and Openness:** Being clear about the concepts of priming you use, avoiding manipulation.
2. **Social Marketing:** Affecting positive change in our communities and workplaces, working for a healthier happier world.
3. **Cultural Sensitivity:** Honor diversity and avoid offensive stereotyping.
4. **Consumer Control:** Making sure priming always respects consumer autonomy and privacy also adhering to Ethical guidelines and being reviewed.

8. What behavioral triggers do you find most effective in increasing conversion rates?

1. **Create a Sense of Urgency with Scarcity:** Limited-Time Offers and Stock Levels
2. **Social Proof:** Featuring customer reviews and testimonials.

3. **Customization:** Provide custom recommendations and exclusive offers
4. **Convenience:** Making checkout easier, more flexible, and including various payment options.

9. How does biometrics provide a deeper understanding of consumer reactions compared to traditional methods?

1. **Signals:** self-reported physiological responses and subconscious reactions.
2. **Live Data:** Obtaining spontaneous and neutral information.
3. **Emotion and Engagement:** Genesis of emotion, levels of engagement.
4. **Comparison & Validation:** Mapping against traditional methods and offering a holistic view.
5. **Replication Value:** Improve product design, brand, and consumer trust.

10. What are the biggest challenges you face when implementing neuromarketing strategies?

1. **Expense and Complexity:** Interpretation of data was expensive (and still is) and difficult.
2. **Ethical:** Making sure it is being used ethically and legally
3. **Integration Challenges:** Neuromarketing meets tradition.
4. **Skepticism & Bias:** Reduce bias and skepticism.
5. **The logistics:** collecting samples elegantly represented by body and mind requires an interdisciplinary effort.

Experts agreed that combining neuroimaging with machine learning and real-world simulations represents the next frontier in decoding consumer behavior. For more clarity, data is presented in a tabular form below in Table 1.

The findings section shows a review of the themes and insights, identifying results from this qualitative data on neuromarketing strategies. In the context of advancements in neuroimaging techniques, they highlighted that it should improve by technologically improving resolution and devising portable devices for human beings as well as through integration with machine learning to combine data with physiological measures. These researchers have discussed the need for methodological improvements, including standardizing protocols and longitudinal studies; as well as an interdisciplinary collaboration between neuroscientists and marketers. In addition, embedding practical examples in the form of real-world simulations was deemed crucial for improving neuroimaging benefits.

Respondents pointed out emotional analytics' capacity to segment audiences, customize content, and boost campaign efficacy. A/B testing and real-time feedback mechanisms are crucial for optimizing user experience, according to a number of experts. While incorporating emotional analytics into more general business strategies—like product development and customer service—was regarded as a crucial differentiator, storytelling and consumer engagement were seen as essential to creating emotional connections with brands. Furthermore, it was thought that connecting brand messaging with social causes would lead to greater customer trust and authenticity.

Table 1. Thematic Summary of Expert Interview Responses

Sr.	Question	Themes
1	Do you think neuroimaging techniques must be improved to understand consumer behavior patterns?	Technological Advancements, Data Integration, Methodological Improvements, Interdisciplinary Collaboration, Practical Applications
2	In what ways can emotional analytics be used to create more impactful marketing campaigns?	Customization, Measurement and Optimization, Storytelling and Engagement, Integration with Business Strategy, Corporate Responsibility
3	What are the key factors that make eye tracking a useful tool for optimizing advertisements?	Precision and Insight, Optimization, Integration, Audience Understanding, Practical Applications

4	How can sensory marketing be effectively implemented in product design?	Multisensory Integration, Customer Experience, Personalization, Technology and Innovation, Brand Consistency
5	Can you describe a situation where customer journey mapping significantly improved the customer experience?	Process Improvement, Personalization, Technology Integration, Cross-Industry Applications, Outcome-Based
6	What strategies have you found most effective in developing emotional branding?	Storytelling and Authenticity, Visual and Sensory Appeal, Community Building, Corporate Responsibility, Customer-Centric Approach
7	How can marketers ethically use priming techniques to influence consumer behavior?	Transparency and Honesty, Positive Impact, Cultural Sensitivity, Consumer Autonomy, Ethical Standards
8	What behavioral triggers do you find most effective in increasing conversion rates?	Urgency and Scarcity, Social Proof, Personalization, Ease and Convenience, Incentives
9	How does biometrics provide a deeper understanding of consumer reactions compared to traditional methods?	Subconscious Insights, Real-Time Data, Emotion and Engagement, Comparison and Validation, Practical Applications
10	What are the biggest challenges you face when implementing neuromarketing strategies?	Cost and Complexity, Ethical Concerns, Integration Issues, Skepticism and Bias, Logistical Challenges

Source: own

Eye tracking can offer a level of detail on gaze patterns and focus of attention that is difficult to achieve in any other configuration, helping us understand how people are looking at ads at all levels from layout choices to design decisions. It needs to be connected with emotional analytics and used for audience differentiation. Optimal outcomes in sensory marketing require multifaceted coordination such as including multiple senses during product design/packaging, experiential enhancements for customers, and refraining from brand uniformity. Lastly, neuromarketing faces challenges due to the price and complication of the technology used in measuring brain signals inner from privacy concerns amongst others meaning it should strive towards overcoming both skepticism upon application as well as receiving high enquire demand without losing ethical credibility.

3.2 Expert Perspectives: Quantitative Insights

The quantitative results from the study's second phase, which sought to confirm and measure the major themes found in the qualitative phase, are shown in this section. Sixty consumer behavior experts were given a structured questionnaire with ten closed-ended statements. Descriptive statistics like means and standard deviations were used to evaluate the degree of agreement among participants in the analysis of the gathered data using SPSS version 24. The statistical findings for each statement are compiled in Table 2 below, which provides a concise summary of professional opinions on different neuromarketing techniques.

The data analysis for the close-ended statements in Table 2 reveals several trends and insights about respondents' views on neuromarketing strategies. Respondents generally exhibit a slight agreement that neuroimaging enables concluding consumer behavior, with a mean of 3.26 and a standard deviation (SD) of 1.16, indicating some variability in opinions. Emotional analytics, on the other hand, shows a stronger agreement, with a mean of 3.36 and an SD of 1.14, suggesting that respondents believe emotional analytics significantly enhances the emotional impact of advertisements.

The use of eye tracking to measure consumer attention is viewed with neutral to slight agreement, reflected in a mean of 3.20 and an SD of 1.20, indicating mixed feelings about its effectiveness. Similarly, sensory marketing is seen with slight agreement, with a mean of 3.22 and an SD of 1.11, suggesting that while it may enhance product preference, opinions vary. Respondents also agree that customer journey mapping helps identify areas for improvement in customer experience, with a mean of 3.28 and an SD of

1.06, showing a general consensus on its utility. Emotional branding is considered effective in strengthening brand loyalty, evidenced by a mean of 3.36 and an SD of 1.12, reflecting strong agreement among respondents.

Table 2. Quantitative Analysis of Expert Consensus on Neuromarketing Strategies

Sr.	Statement	SDA	DA	N	A	SA	Mean	SD
1	Neuroimaging enables one to conclude consumer behavior.	3	5	10	20	12	3.26	1.16
2	Emotional analytics improves the emotional impact of advertisements.	1	18	10	20	11	3.36	1.14
3	Consumer attention in advertisements is measured by eye-tracking.	5	14	14	18	9	3.20	1.20
4	Consumer preference for products is enhanced through sensory marketing.	2	17	15	18	8	3.22	1.11
5	Areas of improvement in the customer experience are identified through customer journey mapping.	2	14	16	21	7	3.28	1.06
6	Emotional branding helps strengthen the brand loyalty of consumers.	4	10	15	23	8	3.36	1.12
7	Briefing is helpful in molding consumer decisions.	4	13	14	20	9	3.28	1.17
8	Scarcity and urgency lead to higher conversion.	0	12	23	13	12	3.42	1.03
9	Neurofeedback tools are useful for measuring the impact of marketing strategies.	2	15	16	18	9	3.28	1.11
10	Neuromarketing provides a competitive advantage in the market.	0	18	17	11	14	3.35	1.15
Frequency: Number of respondents selecting each response option, **Mean:** The average score calculated by assigning values (1 = Strongly Disagree (SDA), 2 = Disagree (DA), 3 = Neutral (N), 4 = Agree (A), 5 = Strongly Agree (SA)) and computing the average, **Standard Deviation (SD):** A measure of the amount of variation or dispersion of responses.								

Source: own

The statement about briefing being helpful in molding consumer decisions shows slight agreement, with a mean of 3.28 and an SD of 1.17, indicating some variability in perceptions. Scarcity and urgency are terms that point to a single thing, but we had a 45% agreement which although could be interpreted as significant duress due to sustained levels of scarcity is likely also an indication that consistency in output was not achieved. The mean score for neurofeedback tools is 3.28, with an SD of 1.11 which indicates that the degree to which they are viewed as helpful Is agreeable between participants but also varies according to individual opinion. The last function of our definition was tested with the support in mean 3.35 and SD=1.15 this indicates a consensus towards benefiting from marketing competitive advantages.

Collectively, however, the emotional analytics effect is well understood along with sensory marketing impact and customer journey-mapping as well as the importance of incorporating emotion into brand positioning to better enhance overall marketing strategies. Strength of conversion rates for scarcity & urgency Eye tracking as well as neurofeedback tools furnish mixed opinions but one thing is sure - if you use neuromarketing against your competitors, it may lead to unethical results. This breakdown here provides more insight into both arguments and the quality of evidence used in neuromarketing strategies.

4. DISCUSSION

This study presents rich data about neuromarketing tactics, a growing area of research and interest in the field. Participants in this study suggested technological advancements for neuroimaging, including improvements in the resolution of images and the development of mobile solutions. This is consistent with recent advancements in neuroimaging methodologies, focusing on advancing spatial and temporal resolution of imaging techniques for recording more precise brain activity information (Vizioli et al., 2021). Higher-resolution imaging is also more informative and can additionally be accomplished with portable neuroimaging devices, allowing for the expansion of field studies (Guo et al., 2022; Parasuram et al. 2023). Second, neuroimaging combined with machine learning and physiological measures shows a trend for incorporating multiple measurements in consumer behavior studies that have been previously shown to increase predictive power (Pérez et al., 2024).

Emotional granularity is not the only issue implicated by Alqahtani and Alothaim (2022), but emotional analytics itself highlights that this has become a narrative of personalization and real-time optimization. This corresponds with recent ideation emphasizing emotional analytics as a way to adjust marketing content for the benefit of consumer engagement and satisfaction (Lindstrom, 2016). The ability to monitor reactions in real time and carry out dynamic A/B testing of push notifications is fundamental for the optimization of marketing strategies (Wan et al., 2023). Combining emotional analytics with measures of key business outcomes, such as product development and customer service (Plassmann et al., 2012), would also be consistent empirically if the successful affective engagement were to stimulate brand loyalty by improving customer experience more broadly.

Eye tracking is a well-established method that allows for capturing exactly where participants look and which areas they focus on (Casado-Aranda et al., 2023)-and its precision, insights are corroborated by concurrent research showing how using eye-tracking can assist the understanding of consumer attention or in layout optimization when designing ads. Eye tracking accompanied by emotional analytics provides a more complete view of what visual elements bring about specific emotions. This is also in line with recent research endorsing a combined effect of the multisensory integration taking on special meaning and new importance, developing more holistic approaches to dealing with sensory information presented at point-of-purchase for profound impact on product appeal and consumer satisfaction (Kim & Lee, 2021). So, hyper-branding your marketing mix with meticulous attention to sensory elements will strengthen brand identity and enhance trust (Zha et al., 2024).

These challenges, however, have also been identified in the existing literature: cost, complexity, and ethical issues. Applying neuromarketing strategies usually requires great investment and complicated data analysis (Casado-Aranda & Sanchez-Fernandez, 2022). There is concern about the ethics of influencing consumers and protecting their privacy using neuroscientific techniques, with recent research indicating that neuromarketing practices need more stringent ethical guidelines to increase transparency (Ferrell et al., 2025; Kumar et al., 2024; Goncalves et al., 2024). This issue of addressing skeptical attitudes and logistical challenges continues to be a significant obstacle as researchers and practitioners are put in the position of integrating forward-thinking methodologies with their ethical, yet constraining landscape (Chowdhury & Mandal, 2023).

Consequently, the results of this study provide support for existing research on emotional analytics or emotions-based marketing (7), sensory marketing (10), and eye tracking in influencing promotional strategies. The focus on new technologies, proprioceptive captures and real optimizations with ethical oversight dovetails into the latest movements within this discipline that shows us both what is possible and also near-complete lack of compliance in many neuromarketing attempts.

CONCLUSION

This study has offered essential inputs on the usage of neuromarketing strategies and their capability to drive purchaser behavior. Top insights include the importance of neuroimaging technological progress, emotional analytics, and eye tracking in boosting marketing strategies. One way to improve the accuracy of consumer behavior data is through technological advancement for better neuroimaging - high resolution and portable scanners. This improves the quality of campaign performance for marketers by delivering tailored editorial content as well as real-time reactions, based on emotional analytics. Highly valuable in planning ad layouts and designs, eye tracking provides detailed visuals of where people look at particular elements. Moreover, incorporating multisensory aspects with product design as well as the sensory experience in some aspects of marketing is likely to improve consumers' experiences and views about their brand.

Although strides have been made in this direction, some challenges such as the expense and complexity (both logistical and ethical) of neuromarketing remain. These are challenging issues causing them to require careful attention based on ethical norms as well as being possible and practical in scope, skepticism, and logistical problems.

The present study presents several useful consequences for companies trying to use neuromarketing in influencing customer behavior and improving strategic decision-making. First, more exact, context-sensitive measurements in both laboratory and real-world environments depend on investment in advanced neuroimaging technologies with enhanced spatio-temporal resolution and portability. By means of A/B testing and adaptive campaign optimization, including emotional analytics in marketing strategies can help support personalized content delivery and enable real-time optimization. By means of eye-tracking technologies, marketers can better grasp consumer attention patterns and create aesthetically appealing material that grabs and maintains interest. Furthermore, adding multisensory components to product design—such as texture, scent, sound, color, and flavor—can enhance the consumer experience and forge closer emotional bonds with the brand.

Neuromarketing approaches must always center on ethical issues, which call for openness about data use, respect for consumer privacy, and avoidance of manipulative techniques. Businesses should simplify neuromarketing procedures, work with multidisciplinary experts, and guarantee transparent interpretation and communication of results in order to solve logistical problems and uncertainty. Crucially, neuromarketing ideas should not exist in a vacuum but rather should be ingrained in more general marketing plans to produce consistent messaging and propel competitive advantage all around.

While this study provides valuable insights into neuromarketing strategies and their influence on consumer behavior, several limitations should be acknowledged. First, the qualitative phase relied on expert interviews, which, while rich in depth, may reflect subjective interpretations influenced by personal or professional biases. Second, although the subsequent quantitative validation enhanced the study's robustness, the sample was limited to experts in consumer behavior, potentially restricting the generalizability of findings to broader consumer populations. Additionally, the rapid evolution of neuromarketing technologies and methodologies means that some insights may become outdated as new tools and techniques emerge. Finally, logistical and ethical constraints limited the exploration of real-time consumer data in naturalistic settings, which could have offered more comprehensive behavioral validation. These limitations suggest the need for continued research across diverse populations and real-world environments to build on the foundation established in this study.

There are some interesting areas in neuromarketing, and the same concept can be applied to other fields such as physiology-behavior for consumer response. Second, the emphasis is placed on real-world applications and field studies to demonstrate that neuromarketing strategies work outside of the laboratory environment. Furthermore, as the technology grows more complex and sophisticated ethical implications and consumer privacy should be considered to make sure it is transparent and respectful. Comparing results of cross-cultural studies will aid in understanding how cultures differ and influence consumer responses to global marketing initiatives based on different regions. Finally, evolving emotion analytics

technology for capturing and analyzing subtle emotional nuances on the go can give birth to stronger and individualized marketing campaigns. These opportunities have a large potential to improve the efficacy of neuromarketing strategies, as long they always remain ethical.

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IT Usage and the Perceived Importance of Audit Applications

MOHAMMAD EBRAHIM NAWAISEH[1] and HALA NOUR AL-NAWAISEH[2]

[1]Professor, Al-Zaytoonah University of Jordan, Amman, Jordan, email: m.nawaiseh@zuj.edu.jo
[2]Assistant Professor, Middle East University, Amman, Jordan, email: dr.halanawaiseh@gmail.com

ARTICLE INFO

ABSTRACT

This main objective of the title is to investigate the extent to which information technology (IT) is used and how important it is in the auditing industry. The study provides new evidence on the extent to which auditors understand the use and importance of audit technologies in emerging markets. It investigates the types of audit technology tools used and the factors that affect their use; it examines the relationship between perceived use and the importance of the tools and the size of the audit company. Using a quantitative survey across diverse Jordan professional auditing firms' levels, Based on a survey of 84 respondents obtained from Jordanian CPA in 2023, the results reflect the importance of using audit technology for technical and administrative procedures, especially to assess risks. We found that the use and importance of audit technology for Big4 audit firms was relatively higher, providing guidance to policy makers on opportunities and challenges to use information technology in audit process.

The originality of this research lies in its focus on Jordan—a less developed, emerging country—offering a unique context for studying the adoption of IT in auditing. It explores how audit factors (e.g., Usage of IT in audit planning (AP), usage of IT in audit testing (AT), usage of IT in Audit completion process (AC): Perceived obstacles of using IT in audit (OB). the study provides fresh insights into IT usage in auditing, revealing limited adoption of specialized IT audit tools. It contributes to the broader understanding of the benefits and challenges in less developed countries, offering implications for practitioners, policymakers, and researchers.

This study has some limitations, including a small sample and low response rates caused by time constraints, competitive concerns, and language barriers in the English questionnaire. These restrictions limit generalizability, but offer directions for future research.

INTRODUCTION

Because auditing certifies that the information complies with accounting principles and standards, accounting gives information about financial transactions. The differences in audit methods for conventional accounting systems and the growing dependence on information technology (IT) in business operations, nonetheless, present issues for the auditing profession (Reynolds, 1989; Bader, A., & Khoshnaw, N. S. S. (2023). In order to handle these developments and ensure the integrity of financial information, new

IT audit methodologies are now required due to the extensive usage of IT, including the internet, real-time accounting systems, e-commerce, and social media (Kotb and Roberts, 2011; Wanger, 2001). The structure of accounting records, Client operations, and audits have all developed because of information technology (IT). It improves productivity and internal controls and lowers audit risk (Shipeng Han, Rezaee, Xue, and Zhang, 2016). While the impact of information technology (IT) in audit has grown exponentially in the past two decades; few studies examine the use and perceived importance of IT outside of the largest audit firms (Fischer 1996). However, auditors have difficulties due to IT complexities, making it difficult to confirm the internal controls and find financial errors. Understanding the relationship between audit risk and IT investments requires research. Identifying irregularities in accounting (Shipeng et al., 2016). Further analysis suggests that auditors from local firms tend to use work paper review methods, email, and telephone, as do auditors employed by smaller firms rather than Big 4 firms. Results indicate that some audit applications are used extensively, but others are not. Our results identify related research opportunities; future research could determine the extent to which auditors and audit firms plan to adopt internal control documentation IT. Auditors indicated that several audit applications were important, but not used extensively, smaller audit firms may not be able to compete with larger firms on IT investments, resulting in potential economic barriers to entry as well as audit effectiveness and efficiency issues, IT has significantly impacted the audit profession in the past two decades. First, firms are increasingly using electronic work papers to facilitate documentation (PricewaterhouseCoopers 2003). The paper is about the perceived importance of IT, the application of remarkable IT audit tools; explores the types of IT used in audit firms in the audit. Our descriptive study fills this void by examining audit IT use and perceived importance in the current audit environment across Big 4, and local firms. The study sets out to assess the perceived usage and importance of audit technology by auditors in Jordan; explore types of audit technology tools used in the audit process; identify factors influencing the obstacles of IT audit use in the audit process; and investigate whether use of audit technology in audit procedures is associated with the audit firm characteristic. Auditors mainly perceive audit technology to be important to enhance audit quality - however, the auditors' lack of relevant training and lack of expertise/understanding of IT are viewed as the main constraints of the use of audit technology, finally, the paper concludes with a discussion of the findings and their implications. This section presents the background to IT and the auditing profession in Jordan, and the use of IT in auditing. It is unclear whether audit IT use or perceived importance varies by firm size. The abundant resources available to Big 4 firms may enable these firms to purchase and implement superior IT, and use IT specialists more largely than non-big 4 firms, these resources should enhance and facilitate improved audit processes leading to better audits. Our research questions are as follows: What types of IT do auditors rate as more important? Does audit IT (importance, use, obstacles) vary by audit firm size? The paper highlights audit technology tools' importance in improving performance and identifying auditors' tools, and explores auditors' perceptions of audit IT use and importance, addressing literature gap in developing countries.

The structure of the study is as follows: the second part presents the study literature review and hypotheses development. The third part presents the method, sample and variables. Part four presents the analysis results, while the fifth describes the Discussion, conclusion, limitations and future perspective.

1. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

According to Charles (2001), the use of computer devices and networks to provide the information needed for auditing, and use as a tool is included in the concept of information technology (IT) in auditing, it assists in understanding the purpose of working with automated accounting systems as well as the environment in which contemporary technology operates and the necessity of keeping up with new developments to be able to deal with them. According to Ashton and Willingham (1988), the use of information technology in the audit process helps overcome some of the human limitations when exercising professional judgment. As a result, the audit process can be made more effective and efficient. Additionally, some studies have shown that using information technology in the audit process reduces the time needed for administrative and mathematical tasks related to a variety of issues. The research conducted by Thunaibat (2003) also seeks to identify the areas in which auditors in Jordan utilize IT, as well as assess the degree to which IT is employed in particular areas and its impact on the efficacy and efficiency of the audit process.

There are a number of findings, including that audit offices use information technology in various planning processes at a lower rate than the national average and that there is a direct correlation between audit offices' experience in the field of auditing and their use of technology in various planning processes. while auditors frequently use a variety of IT tools, including analytical methods and electronic work documents, they also value some tools more than others, such as fraud review systems, nevertheless, they rarely utilize them (Diane Janvrin, James B, and D. Jordan, 2008). Large audit firms have made substantial financial commitments to information technology (IT), as documented by Banker et al. (2002) and O'Donnell and Schultz (2003). Due to their limited IT expenditures, smaller audit firms may find it difficult to compete with the larger ones. The efficiency and effectiveness of their audit systems may be affected, and there may be significant financial obstacles to joining as a result. The Public Oversight Board (POB) in 2000 and the General Accounting Office (GAO) in 2003 both called attention to these issues. The audit judgment may be affected by decision tools. Researchers must thus determine the decision-making resources (including IT) that auditors employ in order to understand audit judgment. Researchers in information systems have put out a number of theories including the theory of reasoned action (Ajzen and Fishbein, 1980); (Ajzen, I. 1991) the social cognition theory (Bandura ,1986), and the technology adoption theory (Davis ,1989) , to clarify why individuals and firms adopt IT. However, it is important to identify and document the existing usage and perceived significance of IT amongst auditors before gaining an understanding of why auditors and audit firms recognize specific types of IT. Few studies suggested that this is an important factor in explaining why Big 4 audit firms are perceived to provide higher quality audits and greater credibility to clients' financial statements compared to small audit firms (Lennox, C, 1999); (Palmrose, Z-V, 1988) , Big four firms have an abundance of resources that enable them to purchase, implement, and hire excellent IT systems and IT specialists, which can improve audit processes and result in better audits (Riemenschneider, C., D; Harrison; P. Mykytyn, Jr, 2003). Regulators are concerned about the IT investment capabilities of smaller auditors since research demonstrates that Big 4 firms utilize IT in audits more extensively than the smaller ones. Further study is necessary to determine whether national firms behave more like the Big 4 firms or smaller firms in terms of IT audit procedures (Manson, S., S; McCartney; M. Sherer , 1998) . One research issue (RQs) has been selected by the article's researchers as areas of focus. Previous research has shown that auditors make substantial use of IT tools. For instance, a study by (Alles, Michael; Gerard Brennan; Alexander Kogan; Miklos A; Vasarhelyi, 2006) found that auditors conduct numerous audit responsibilities using IT tools such spreadsheets, databases, and audit software. In a similar vein, (Vasarhelyi, M. A; Halper, F. B; Ezawa,K.J , 1991) revealed that auditors utilize IT technologies to improve audit effectiveness and efficiency. The majority of the research points to the usage of audit IT tools by auditors as a critical component of the audit process. The researchers want to offer insights into the existing application and perceived value of IT in the audit profession through investigating these issues , and the perceived importance by the auditors .The first research hypothesis is :

H1. Audit IT tools used vary significantly by audit firm size

The limited and widespread characteristics of research in this field may be attributable to the increasing role of information technology (IT) in auditing and the rapid developments in IT. Furthermore, the findings of prior studies are not readily applicable to the current audit environment due to the continuous changes in IT. There is a shortage of research that examines how information technology (IT) is actually utilized in audits and the variables that affect that use, such as the size of the auditing firm. This subject has been covered in previous studies by Fischer (1996) and Arnold and Sutton (1998), which indicate the need for more research on audit IT use and its impact on variables. It is unclear if the usage and perceived relevance of IT in audits change dependent on company size since nearly all of the research on auditors' use of IT has focused on its effect on large audit firms. From small, local firms with one office to large, Big 4 firms, the audit profession includes a wide variety of firm sizes. Recent changes, such as the Sarbanes-Oxley Act of 2002, provided non-Big 4 businesses growth potential, generating a greater interest in what they do and increasing the likelihood of clients who had previously been served by Big 4 firms may choose them as auditors.

Big 4 auditing firms are more likely to have more powerful IT skills and use IT professionals more frequently than non-Big 4 firms due to their numerous resources (Riemenschneider et al. 2003) . This is expected to improve audit procedures and result in better audits. Previous studies show that Big 4 firms

have more audit IT adoption than smaller firms (Manson et al.,1998), creating concern that smaller firms would find it difficult to stay ahead in terms of IT expenditure. The purpose of the study is to determine whether there are any differences in IT importance and use perceived between Big 4 and non-Big 4 firms in Jordan. The researchers expect that the perceived significance and usage of IT (information technology) may differ between Big 4 audit firms and non-Big 4 firms based on the data provided. In addition, it is yet unknown if local firm' IT audit procedures reflect those of the Big 4 or smaller firms because there is not enough research on these topics. The purpose of the study questions is to ascertain any possible differences in the use and significance of IT among different audit firm types. Based on the above discussion, The following other main four research hypotheses are as follow:

2- Audit IT used and perceived in planning process vary significantly by audit firm size diversity
3- Audit IT used and perceived in testing process vary significantly by audit firm size
4- Audit IT used and perceived in completing process vary significantly by audit firm size
5- Audit IT perceived constraints vary significantly by audit firm size diversity

The lack of research on national firms' IT audit processes raises the question of whether they perform differently from Big 4 firms or smaller firms. By formulating study questions, the researchers want to learn more about this by investigating the differences in IT audit techniques used by both local and Big 4 firms as well as how important each is considered in relation to firm size. The current study was complementary to the majority of the previous research and tended to examine the factors affecting the use of information technology from the perspective of an auditor, regardless of the size of the audit office or firm to which he/she belongs, as most of the prior studies focused on large audit firms. In addition, the A survey that included aspects in most of them that differ from the aspects addressed by previous research.

2. METHODOLOGY

The data for this study has the total number of completed questionnaires 84, while the number of all respondents is 103. The percentage of all eligible participants in the analysis was 81.55%. The participants included 21 from big 4 auditors and 63 from national or local audit firms. After a pilot study with 12 auditors from the Big 4 and non-Big 4 firms ,some items were removed to improve the study. We reviewed previous publications to identify audit application groups. These applications include previous investigations: for example, analytical procedures (Knechel 1988), internal control evaluations (Bailey etal 1985) and sampling tasks (Kachelmeier and Messier 1990). The questionnaire was divided into six parts included the demographic variables. In order to address the previously mentioned study hypotheses, this section describes how the variables are measured. The purpose of this study is to examine the effect of IT on the auditing sector. Table 1 lists the study's variables, along with how they are measured. These variables, including their frequencies, importance, use in the planning phase of an audit, testing, and process of completion, are frequently employed by auditors. Some apps are considered essential by auditors even though they are infrequently utilized. Typically do auditors who examine clients with complicated IT use IT specialists. We will look into if the results suggest that firm size affects the extent of use and perceived importance of IT applications for auditing or not. While the data describe audit IT use, it is essential to point out this.

Table 1. Summary of the study variables

#	Variable	measurement
1	IT tools frequency	A dummy (1) represents the usage, (0) not
2	IT importance	Five point scale
3	IT usage in audit planning	Five point scale
4	IT usage in audit testing	Five point scale
5	IT usage in audit completion process	Five point scale
6	The level of constraints of IT in audit	Five point scale

Source: own

3. PRELIMINARY ANALYSIS

3.1 Descriptive statistics

Table 2 shows frequencies and percentages for the two variables of gender and audit firm type; 34.5% of respondents are from Big4 audit firms, while 65.5% are from National & Regional audit firms. Males made up 84.50% of the responders, while females made up 15.5%. This analysis has a few ramifications: The findings could be more applicable to non-Big 4 businesses given the larger percentage of non-Big 4 audit firms in the sample; this will reflect on the findings when applying to the whole audit profession or merely to the Big 4 firms. The Big4 refers to firms that are one of the Deloitte, PwC, EY, and KPMG group of Big Four accounting firms. Moreover, the significant difference in gender ratios does not draw attention to probable discrimination against women in the auditing industry in Jordan, but the profession necessitates giving things away and working hard, including traveling and staying up late. It may also entail being available in several places and working past traditional office hours; all these necessitate travel and remaining up late to fulfill the necessary duties. Readers should consider these limitations while reviewing the findings. One more thing is to be known: it is essential to encourage diversity in research to get a whole perception of the audit profession.

Table 2. Respondents' profile

Audit firm type	Frequency	%
Big4	29	34.5%
National	43	51.2%
Regional	12	14.3%
Gender		
Male	71	84.5%
Female	13	15.5%
Total	84	100%

The descriptive statistics includes Mean, standard deviation and frequency are used for the study variables. These variables are; the frequency of IT tools (Tools = 5 items), importance of using IT (IM= 9), use of IT in audit planning (AP =9), use of IT in audit testing (AT = 5), use of IT in Audit completion process (AC = 3), and the Perceived obstacles of using IT in audit (OB =9).
Source: own

3.2 Frequency of audit IT tools used on a regular basis

Table 3 shows the descriptive statistics for the types of IT tools used by auditors. These tools are Microsoft office, IDEA, ACL, Wireless network, and Software tailored by firm.
The paper defines audit IT as a "tool kit" (Fischer 1996); (Elliott, R. K; P. D. Jacobson, 1987) for auditors that consists of IT experts, technology for reviewing work documents, productivity tools, and audit software. These technologies enhance the auditors' capacity to carry out tasks like analytical procedures, report writing, and sampling. The research shows that there is a wide range in the significance of using information technology for audit. The frequency percentages varied from 6% to 31% for the tools as shown in Table 3, indicating that the respondents gave certain items excellent ranks for the usage. We comment on the result that auditing firms usually select commercial software's, or Microsoft office over sophisticated alternatives like ACL, or IDEA because of criteria including usability, price, capability, support, and compatibility. Software that is easily accessible has a user interface that is clear and doesn't require any programming experience. It is also less expensive since no longer needing customization or specific training. These software packages provide a broad variety of features to satisfy various auditing requirements. Their sizable user community also provides a wide range of opportunities for support and knowledge-sharing. Just to mention that commercial software is accessible with frequently used programs, making data exchange and integration simple. Due to these advantages, off-the-shelf software is a preferred choice for auditing firms searching for practical and affordable solutions.

Table 3. Categories of audit IT tools frequency and percentage of applications

IT tools used	Type				Gender				All
	Frequency		Relative frequency		Frequency		Relative frequency		
	Big4	Non	Big4	Non	F	M	F	M	%
Microsoft office	0	25	0.0%	29.8%	5	20	6.0%	23.8%	29.8%
IDEA	11	1	13.1%	1.2%	4	8	4.8%	9.5%	14.3%
ACL	13	3	15.5%	3.6%	2	14	2.4%	16.7%	19.0%
Wireless net work	4	1	4.8%	1.2%	0	5	0.0%	6.0%	6.0%
Software tailored	1	25	1.2%	29.8%	2	24	2.4%	28.6%	31.0%
Total	29	55	34.5%	65.5%	13	71	15.5%	84.5%	100.0%

Source: own

Data on the perceived importance of using IT in various audit applications was obtained by study [Table 1, panel A]. For each of these factors, participants were asked to rank the perceived importance of using IT on a scale of 1 to 5, while this study offers additional research of the general importance of IT use in various audit applications. Factors affecting the perceived importance (IM) in the audit profession shown in Table 4: where, strongly agree/Agree [4–5], Neither [3], Strongly disagree/ Disagree [1–2], the descriptive statistics include Mean, Std. dev. and the relative frequency [Percentage]. The text discusses the factors affecting the importance of using of audit technology in the audit profession. According to the respondents, the most important reasons for using audit technology include obtaining information quickly (Mean=3.583) and to achieve greater efficiency to audit tasks (mean=3.405). But the respondents think that other factors, such as encouraging the recruitment of new clients (mean=3.119), and reducing audit risks, increasing productivity, and increasing fees for utilizing audit technology, are less significant (means 3.119 and 3.262, respectively). On the other hand, the combined average across all factors shown in Table 4, Panel A is (3.317), with average standard deviation (0.566), this means that the auditors moderately perceive the importance of using IT in the auditing profession. This suggests that the respondents considered using IT in the auditing profession an acceptable level of importance. More than moderate auditors agree with or consider criteria to be essential to employing audit technology in their line of work, the higher the average score. With regard to using IT in auditing work, an overall average score of 3.317 indicates that auditors typically see these elements as somewhat moderately significant.

In this study, 17 audit applications were found. The applications are made to help auditors with a number of duties, including analytical analysis, internal control evaluation, sampling, fraud review, online transaction testing. The activities of audit task classifications, such as audit planning [Panel B],   testing [Panel C], completion and report writing [Panel D], are utilized for grouping these applications. In addition to the Perceived obstacles of using IT in audit [Panel E]. The methodology of the study offers a basis for understanding the function of IT in the audit procedure. Recent apps have been added, which emphasizes the adjustments IT is making to the audit procedure.

According to the findings in Panel B of Table 4, the majority of respondents believe that gathering information on audit tasks and evaluating audit evidence are the two most important reasons for employing audit technology in audit planning (means: 3.393 and 3.357, respectively); audit programs and tests of balances respectively. In contrast, Panel B shows that financial ratio tools (Mean=3.119) and materiality (means=3.202) are the least significant factors. These results highlight the significance of IT in audit planning (AP) for the effective adoption and application of audit technology through the audit planning process. The average across every factor is 3.214, with an average standard deviation of 0.537, as indicated in Table 4, Panel B. It indicates that the use of IT in the planning process is essential for the efficient implementation and application of audit technologies with a percentage of 64.28% . Based on data [Table 1, Panel C], auditors typically utilize previous tools like audit sampling and E-working papers with an average and percentage of [3.524], [70.48%], and [3.690], [73.81%] respectively, while utilizing newest ones with an average and percentage like testing of online transactions [4.583], and [91.67%], digital analysis less frequently with an average [3.857] and percentage of [77.14%]. These more recent apps have higher perceived importance scores than the more experienced applications, we concluded that the use of IT in the audit testing process is essential for the efficient implementation and application of audit technologies

with a combined average of all [3.91] with a relative percentage is [78.20%]. In Panel D, the researcher asked the auditors on how they perceived the three separate tasks of fraud review, auditor's report, and client financial statement disclosure were dealt with by IT during the audit completion process. On a scale of 1 to 5, the numbers indicate the auditors' responses. For instance, 57 auditors gave fraud review a high perceived use score (between 81 and 100), while just 9 auditors gave it an unacceptable perceived use rating (between 0 and 20). In a similar manner, disclose client financial statements and the auditor's report, the combined average was 3.718 with 74.36%.

Table 4. Factors affecting IT perceived importance/usage in the audit profession

Panel A: usage of IT in audit planning (AP)				Perceived importance of IT in audit planning		
Audit application	Mean	%	Std.dev.	Mean	%	Std.dev
Engagement planning	3.27	65.48%	1.302	3.95	79.06%	0.815
Materiality	3.2	64.05%	1.342	3.88	77.65%	0.851
Internal control testing	3.23	64.52%	1.302	3.89	77.88%	0.859
Financial ratios	3.12	62.38%	1.401	3.82	76.47%	0.966
Client acceptance	2.88	57.62%	1.321	3.66	73.18%	0.946
Gathering data	3.23	64.52%	1.434	3.87	77.41%	0.997
Audit programs	3.39	67.86%	1.353	3.91	78.12%	0.983
Audit evidence evaluation	3.25	65.00%	1.241	3.85	76.94%	0.866
Test of balances	3.36	67.14%	1.267	3.79	75.76%	1.013
Combined average	**3.21**	**64.28%**	**0.537**	**3.85**	**76.94%**	**0.070**
Panel B : usage of IT in audit testing (AT)				Perceived importance of IT in audit testing (AT)		
Test of online transactions	4.58	91.67%	0.68	3.89	77.88%	0.772
Digital analysis	3.86	77.14%	1.243	3.74	74.82%	0.941
E-working papers	3.69	73.81%	1.38	3.94	78.82%	0.807
Data base modelling	3.52	70.48%	1.357	3.84	76.71%	0.937
Audit sampling	3.89	77.86%	1.317	4.01	80.24%	0.852
Combined average	**3.91**	**78.20%**	**0.784**	**3.88**	77.69%	**0.068**
Panel C: usage of IT in Audit completion process (AC):				Perceived importance of IT in Audit completion process (AC):		
Fraud review	3.69	73.81%	1.405	3.96	79.29%	0.73
Client financial statement dis-	3.89	77.86%	1.03	3.89	77.88%	0.77
Auditor's report	3.57	71.43%	1.45	3.94	78.82%	0.85
Combined average	**3.72**	**74.36%**	**0.882**	**3.93**	78.67%	**0.049**

Panel D: Perceived obstacles of using IT in audit (OB)

Obstacles	Strongly agree/ Agree [4 – 5]	Nei-ther [3[	Strongly disagree/ Disagree [1-2]	Mean	%	Std.Dev
lack of local legislation governing the use of IT	46	20	18	3.476	69.52%	1.357
Lack of electronic accounting systems for client	40	21	23	3.333	66.67%	1.383
Weakness of staff in E. language to follow IT developments	61	8	15	4.071	81.43%	1.306
Insufficient courses to auditors training on IT	51	7	26	3.417	68.33%	1.600
Highly cost if compared to audit fees	43	9	32	3.310	66.19%	1.439
lack of local legislation governing the use of IT	60	8	16	3.964	79.29%	1.375
Lack of electronic accounting systems for client	47	10	27	3.393	67.86%	1.537
Lack of auditors' experties in IT	51	14	19	3.631	72.62%	1.438
Complexity of IT	45	7	32	3.000	60.00%	1.353
Combined average				**3.511**	**70.22%**	**0.855**

Auditors from Big 4 firms are more likely to employ and use audit applications more highly than auditors from non-Big 4 firms. IT use and perceived importance differ by firm size. Big 4 firms utilize IT professionals more than non-Big 4 firms since they have the resources to acquire and develop superior solutions

for IT. The use and weighting of specific audit applications, such as (Materiality, Internal control testing, financial ratios, auditor's report and internal control evaluation,), are similar between national firms and the Big 4 firms, but differ in other areas, like (Engagement planning, client acceptance, test of balances, test of online transactions, Data base modelling, digital analysis, e-working papers, fraud review and client financial statement disclosure. The obstacles differ significantly between Big4 and nonBig4 (lack of electronic accounting systems for client, highly cost if compared to audit fees, lack of electronic accounting systems for client, and lack of auditors' expertise in IT).

4. ANALYSIS OF RESULTS AND HYPOTHESES TESTING

In addition to using Pearson correlation coefficients, tolerance values and variance inflation factors (VIF) for the independent variables are calculated to check for multicollinearity, which can arise from the combined influence of multiple predictors. A high tolerance value and a low VIF indicate the absence of multicollinearity. According to Hair et al. (2010), a tolerance value below 0.10 and a VIF above 10 signal potential issues. In this analysis, all tolerance values exceed the 0.10 threshold, with the lowest being 0.222—still well above the cutoff. Similarly, all VIF values are below 10. Therefore, these results confirm that multicollinearity is not a concern among the variables.

Table 5. Pearson correlation matrix and VIF

#	AP1	AP2	AP3	AP4	AP5	AP6	AP7	AP8	AP9	AT1	AT2	AT3	AT4	AT5	AC1	AC2	AC3
AP1	1																
AP2	0.099	1															
AP3	0.084	-0.130	1														
AP4	0.193	0.083	.223*	1													
AP5	0.047	0.034	0.212	0.034	1												
AP6	0.115	-0.037	-0.163	-.254*	0.046	1											
AP7	0.054	0.029	0.106	0.166	-0.061	-0.015	1										
AP8	-0.021	0.157	0.203	0.038	0.158	0.103	.278*	1									
AP9	-0.133	0.141	.235*	0.200	0.112	-.357**	0.065	0.172	1								
AT1	.231*	0.017	0.169	0.048	0.073	0.198	0.191	0.026	-0.100	1							
AT2	0.185	0.187	0.086	0.199	0.077	-0.019	.260*	0.067	0.088	.253*	1						
AT3	0.179	-0.143	0.128	0.058	0.013	0.130	0.015	-0.212	-0.170	.351**	-0.105	1					
AT4	.230*	0.083	.227*	0.105	0.111	-0.104	-0.156	-0.086	0.075	0.067	0.158	.217*	1				
AT5	-0.046	-0.048	.224*	0.064	0.029	-.234*	0.028	0.155	0.147	.288**	0.140	0.022	0.040	1			
AC1	0.053	-0.060	-0.117	-0.002	.376**	0.121	-0.096	0.173	-0.125	0.097	0.000	0.098	0.151	0.143	1		
AC2	0.027	.243*	-0.140	0.067	-0.113	0.039	0.198	0.031	0.045	-0.009	0.043	-0.117	0.056	0.041	-0.159	1	
AC3	0.090	-0.048	0.142	-0.119	.252*	-0.011	-.256*	0.167	0.006	0.110	0.061	-0.048	0.120	.243*	.571**	-0.119	1
Tol	0.323	0.433	0.239	0.368	0.335	0.262	0.222	0.306	0.539	0.589	0.454	0.619	0.584	0.598	0.379	0.746	0.388
VIF	3.099	2.307	4.177	2.715	2.983	3.821	4.513	3.269	1.854	1.698	2.204	1.616	1.713	1.672	2.636	1.341	2.579

Note: Tolerance (Tol), Variance inflation factor (VIF)
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Source: own

The research found minimal pearson correlations among all independent variables before proceeding with the statistical analysis, with the largest relationship between AC1 and AP5, 0.376, and the lowest between AP6 and AP4, 0.254, indicating no multicollinearity.

The study examined the significance of IT (Information Technology) usage in the profession of auditors. The study found that, on average, with a score of (3.317) out of (5) (see Table 4, Panel A). Auditors believe

utilizing IT is extremely important. This indicates that they regard utilizing IT as essential for their profession. Both the large audit firms (also referred to as the Big4) and the smaller ones (commonly referred to as the NonBig4) believe that IT is important, however larger audit firms scored marginally higher, with an average of (3.370) compared to the smaller firms' (3.218) (Table 5, Panel A). This difference, however, is not significant, indicating that both large and small audit firms value IT equally. H1 is not supported by the study's finding that there are no significant differences in the importance of employing IT dependent on the size of the audit firm. This indicates that, regardless of how big or small a firm is, auditors continue to prefer utilizing IT in their work. IT is believed to assist auditors in a variety of ways. For instance, it meets their clients' expectations, improves their efficiency, and lowers the risks related to audits. In addition, it speeds up gathering data for auditors and improves the level of their duties. In conclusion, the questionnaire shows that auditors, regardless of the size of their audit firms, believe that adopting IT is very essential. It enables them to do their duties more effectively and give their clients better services. The study's findings show that auditors, regardless of the size of their firms, think adopting IT is important to their work. This means that all audit firms, regardless of size, recognize the value of utilizing technology to improve their auditing processes and offer better services to their clients. For audit firms of all sizes to carry out their jobs efficiently, IT is important.

Data regarding technology's perceived use in audit planning (AP) by Big4 and non-Big4 firms is shown in (Table 6, Panel B). The nine key elements of audit planning that make up the study's measurement of perceived IT use are designated as AP1 through AP9. The results are shown in Table 5. For both Big4 and non-Big4 entities, the perceived use of IT in every part of audit planning is reported individually for BIG4 (3.195) and non-Big 4 scored (3.224) with a total average of the perceived usage of IT across all parts of audit planning is (3.214) as shown in (Table 4, Panel B). Analysis of variance (ANOVA) is a statistical test that assesses if there is a significant difference in the data, and the ANOVA column gives the p-value for this test (0.817 > 0.05). Applying ANOVA, it can be found whether there is a significant difference in how Big4 and non-Big4 firms perceive the usage of IT across all nine parts of audit preparation. The findings indicate that Big4 firms generally perceive a little higher usage of IT in audit planning than non-Big4 firms. The ANOVA findings show that this difference is not statistically significant, so H2 is not supported, indicating that it might simply be a matter of chance. The perception of IT use differs throughout the many audit planning aspects, with some indicating a higher perception of IT use than others. For instance, AP1 , AP5 and AP9 has a p-value of 0.019, 0.001 and 0.031 has a lower perceived use of IT than the other parts AP2, AP3,AP4, AP6,AP7,and AP8 . Data in the Table 5 highlights the findings of a study on how Big4 and non-Big4 firms examine the use of information technology (IT) in audit testing (AT). A few details are included in the table: For both Big4 and non-Big4 firms, the perceived use of IT in each audit testing item is given separately, and the overall average of the perceived use of IT in each part of audit testing is presented individually. In order to determine whether there is a significant difference in the perceived usage of IT between Big4 and non-Big4 firms across every aspect of audit testing, the ANOVA column gives the p-value for an analysis of variance (ANOVA) test. The combined average of the perceived use of IT in audit testing (AT) for Big4 firms (3.462), it is higher if compared to (4.146) for non-Big4. This shows that Big4 firms employ IT for audit testing more frequently than is generally believed. The findings indicate differences in the perceived use of IT across several audit testing aspects. Consider this: AT1: With a p-value of 0.000, Big4 firms are determined to employ IT much more than non-Big4 firms. With a p-value of 0.009, AT2 finds that Big4 firms view their use of IT as being less than that of non-Big4 firms. Big4 firms are perceived as using IT less frequently than non-Big4 firms in AT3, AT4, and AT5, but the differences are not statistically significant (p-values of 0.044, 0.019, and 0.085, accordingly). The P-value for the ANOVA test is 0.000, which shows that there is a significant difference regarding the way the two groups examine their use of IT. It has significance to keep in mind that these findings are distinctive to this study. It is advised to explore other research studies and literature on the perceived usage of IT in audit testing by Big4 and non-Big4 firms in order to obtain a thorough understanding of the subject. In order to identify whether there were significant differences in the use of IT between the two groups, the study examined the perceived usage of IT between Big4 and non-Big4 firms. H3 thus becomes supported. Table 6 includes the perceived use of IT in each aspect of the audit completion process is reported separately for Big4 and non-Big4 firms. The combined average of the perceived use of IT in all aspects of the audit completion process is reported separately for Big4 and non-Big4 firms. The table presents the findings of a study on how Big4 and non-Big4 firms considered the usage of information technology (IT) in the audit completion process (AC). For

both Big4 and non-Big4 firms, the perceived use of IT in every phase of the audit completion process is reported separately, the overall average of the perceived use of IT in each phase of the audit completion process is provided individually. The ANOVA column provides the p-value for the ANOVA test. In comparison with Big4 firms (3.345), the combined average of the perceived usage of IT in the audit completion process exceeds that for non-Big4 firms (3.915). It indicates that, on a typical basis, non-Big4 firms perceive greater usage of IT in the audit completion process. Particulars: The findings reveal differences in how IT is regarded to be used during different phases of the audit completion process. For instance: With a p-value of 0.021, Big4 firms are perceived as using IT less than non-Big4 firms. With a p-value of 0.002, AC2 states that Big4 enterprises are less likely than non-Big4 firms to consider them as using IT. With a p-value of 0.473, Big4 enterprises are seen to employ IT similarly to non-Big4 firms. The ANOVA test's p-value of 0.004 shows a significant difference between the two groups in how they perceive using IT. It is significant to keep in mind that these results are distinctive to the research outlined in the search results. Additional research studies and literature on the perceived the use of IT in the audit completion process by Big4 and non-Big4 businesses are suggested to get a thorough understanding of this topic.

Table 6. ANOVA analysis of Importance and use of IT applications in audit

Panel A: Measuring extent of Perceived importance of using IT (IM)

IT perceived importance	Big4	NonBig4	Value
IM1	2.931	3.436	0.109
IM2	2.896	3.490	0.058
IM3	3.206	3.290	0.787
IM4	3.310	3.345	0.911
IM5	3.172	3.309	0.671
IM6	2.759	3.309	0.071
IM7	3.344	3.345	0.999
IM8	3.793	3.472	0.315
IM9	3.551	3.327	0.386
Combined average	3.218	3.370	0.247

Panel B: Perceived use of IT in audit planning (AP)

IT perceived AP	Big4	Non	P. value
AP1	3.241	3.291	0.019
AP2	3.345	3.127	0.807
AP3	3.207	3.236	0.557
AP4	3.207	3.073	0.260
AP5	2.345	3.164	0.001
AP6	3.138	3.273	0.250
AP7	3.724	3.218	0.470
AP8	3.345	3.200	0.977
AP9	3.207	3.436	0.031
Combined average	3.195	3.224	0.817

Panel C: Perceived use of IT in audit testing (AT)

Type	Big4	Non	P. value
AT1	4.069	4.855	0.000
AT2	3.000	3.800	0.009
AT3	3.483	4.055	0.044
AT4	3.207	3.945	0.019
AT5	3.552	4.073	0.085
Combined average	3.462	4.146	0.000

Panel D: perceived use of IT in Audit completion process (AC):

Type	Big4	Non	P. value
AC1	3.207	3.945	0.021
AC2	3.414	4.145	0.002
AC3	3.414	3.655	0.473

| Combined average | 3.345 | 3.915 | 0.004 |

Source: own

Table 7 presents the perceived obstacles to the use of Information Technology (IT) in auditing, comparing responses from Big4 and non-Big4 audit firms. The mean scores (on a Likert scale) reflect the degree to which each group perceives a particular obstacle as significant. The table also includes ANOVA p-values to determine if differences between the two groups are statistically significant. OB1, OB3, OB4, OB6, OB9 showed no statistically significant differences between Big4 and non-Big4. This suggests shared challenges across all firm sizes, such as: Inadequate local legislation (OB1, OB6), Weak English skills among staff (OB3), Limited IT-related training (OB4), and Complexity of IT tools (OB9). The Combined Average Perception of Obstacles of Big4 average: 3.203 , Non-Big4 average: 3.673 , p-value = 0.016 (significant) , Overall, non-Big4 firms perceive greater obstacles in adopting IT.

Future efforts should focus on removing cost, training, and infrastructure barriers to ensure more equitable and widespread use of IT in the audit profession. We conclude that Auditors universally value IT, regardless of firm size. Non-Big4 firms perceive higher use of IT in audit testing and completion than Big4 firms. Results suggest smaller firms may be compensating with greater IT reliance or possibly perceive higher benefits from using IT tools in specific audit phases.

Table 7. The obstacles perceived by respondents

Type	Description	Big4	Non	(ANOVA) P. value	Significant
OB1	lack of local legislation governing the use of IT	3.103	3.673	0.067	No
OB2	Lack of electronic accounting systems for client	2.828	3.600	0.014	Yes
OB3	Weakness of staff in E. language to follow IT developments	4.207	4.000	0.493	No
OB4	Insufficient courses to auditors training on IT	3.103	3.582	0.194	No
OB5	Highly cost if compared to audit fees	2.724	3.618	0.006	Yes
OB6	lack of local legislation governing the use of IT	3.862	4.018	0.624	No
OB7	Lack of electronic accounting systems for client	2.897	3.655	0.031	Yes
OB8	Lack of auditors' experties in IT	3.034	3.945	0.005	Yes
OB9	Complexity of IT	3.069	2.964	0.737	No
Combined average		3.203	3.673	0.016	Yes

Source: own

Only Four obstacles show statistically significant differences in perception: OB2 (Lack of electronic accounting systems for clients), OB5 (High cost compared to audit fees), OB7 (Lack of electronic accounting systems for clients), and OB8 (Lack of auditor expertise in IT). IT is valued across all audit firms, regardless of size. Non-Big4 firms report greater use of IT in audit testing and completion phases. This may suggest that smaller firms either rely more heavily on IT to offset resource limitations or perceive more value in IT during specific audit processes. Overall, non-Big4 firms perceive greater obstacles in adopting IT, indicating a need for targeted support and training.

CONCLUSION

Demographics; Audit Firm Type: 34.5% of respondents are from Big 4 firms; 65.5% from national or regional firms. Gender: Majority of respondents are male (84.5%); female auditors represent only 15.5%. Implication: The findings may better reflect non-Big 4 practices. The gender imbalance may be attributed to the demanding nature of the auditing profession in Jordan, not necessarily discrimination. Usage Frequency of IT Tools, the most frequently used tool is firm-tailored software (31%), followed by Microsoft Office (29.8%). Less frequent tools include ACL (19%), IDEA (14.3%), and Wireless networks (6%). Auditors prefer user-friendly, affordable, and familiar tools like Microsoft Office or tailored software over advanced options like ACL or IDEA. Perceived Importance of IT in Auditing, the overall average importance rating of IT in auditing is moderate (Mean = 3.317, SD = 0.566). Top reasons for IT importance: Faster information retrieval (Mean = 3.583) Greater efficiency in audit tasks (Mean = 3.405), Less important factors: Attracting new clients (Mean = 3.119), Reducing audit risk (Mean = 3.262), IT Usage Across Audit Stages, Audit Planning (AP) Most important uses: Audit programs (Mean = 3.39), Gathering data (Mean = 3.23), Audit evidence evaluation (Mean = 3.25), Combined average: Mean = 3.21, 64.28%, IT in planning is perceived as moderately important. Audit Testing (AT), Most important tools: Test of online transactions (Mean = 4.58, 91.67%), Audit sampling and e-working papers also rated highly. combined average: Mean = 3.91, 78.20%, IT is highly valued in testing, particularly for advanced tools. Audit Completion (AC), Most important task: Client financial statement disclosure (Mean = 3.89), Combined average: Mean = 3.72, 74.36%, IT is viewed as important in final reporting and fraud review. Perceived Obstacles to IT Usage, Top barriers: Weak English skills among staff (Mean = 4.071, 81.43%), Lack of local legislation (Mean = 3.964, 79.29%), Lack of IT expertise (Mean = 3.631), Combined average: Mean = 3.511, 70.22%, These findings suggest systemic challenges in integrating IT, especially in smaller or local firms. 6. Firm Size Comparison, Big 4 vs non-big 4: Big 4 auditors use more advanced tools and rate IT applications higher due to better resources and in-house IT expertise. However, both types of firms agree on the importance of some tools (e.g., internal control testing, audit evidence evaluation). No Multicollinearity Detected, the statistical results (tolerance values > 0.10 and VIF < 10) confirm that the dataset is free from multicollinearity, enhancing the validity and reliability of the regression outcomes. Perceived Importance of IT (H1 Not Supported), Both Big4 and non-Big4 auditors perceive IT as equally important. This suggests a consensus across firm sizes regarding the essential role of IT in auditing, reflecting the profession's evolution towards technology-integrated practices. IT Usage in Audit Planning (H2 Not Supported). The analysis showed no significant difference in how Big4 and non-Big4 firms perceive the use of IT in the audit planning phase. This may reflect industry-wide standards or similar client expectations during audit preparation. IT Usage in Audit Testing (H3 Supported), there is a significant difference in the perceived use of IT in audit testing, with non-Big4 firms scoring higher. This could reflect smaller firms' need to maximize efficiency and reduce human error through automation.IT Usage in Audit Completion (H4 Supported), Non-Big4 firms also report significantly higher usage of IT in audit completion tasks. This implies that smaller firms may be leveraging technology more actively to compensate for limited human resources and improve accuracy and efficiency.

For Audit Firms (Both Big4 and Non-Big4), Continue investing in IT training and infrastructure, as all firms recognize its importance. Emphasize uniform IT adoption across all audit phases, especially in areas like audit completion where discrepancies exist. Establish best practice frameworks that ensure consistent IT utilization regardless of firm size. For Non-Big4 Firms, Leverage the competitive edge in audit testing and completion by documenting successful IT use cases and developing standardized procedures. Seek strategic partnerships with IT vendors to ensure access to affordable, scalable audit technology solutions. For Big4 Firms, examine why perceived IT use is lower in testing and completion phases despite available resources, and consider revising internal practices or training to increase actual utilization. Explore opportunities to innovate audit technologies to reclaim technological leadership. For Professional Bodies and Regulators, Encourage the development of industry-wide benchmarks for IT integration in auditing processes. Support research and continuing professional education (CPE) on audit technology usage to ensure uniform standards across the profession. For Future Research, Investigate the reasons behind higher IT use in non-Big4 firms in testing and completion stages. Conduct longitudinal studies to track changes over time in IT adoption trends. Explore the effectiveness of IT tools in terms of audit quality and efficiency, not just perception. The lack of significant difference in IT use during the audit planning phase implies a standardized industry approach, potentially driven by audit regulations, client systems, and risk

assessment frameworks that necessitate similar procedures regardless of firm size. This may also indicate that many audit planning tools are widely accessible and affordable, thereby reducing the technological gap between larger and smaller firms in the initial stages of audit engagement. One interpretation of lower perceived IT usage in Big4 firms during testing and completion phases could be a form of overreliance on traditional procedures or legacy systems, or perhaps a centralization of IT services, which makes them less visible to front-line auditors. In contrast, non-Big4 auditors may be more directly engaged with IT tools, thus perceiving higher usage. Organizational Culture and Innovation Adoption. one of the recommendations is to bridge the enhance communication between IT departments and audit staff to ensure that technological tools are being used optimally at all stages of the audit. And to define quantitative metrics to monitor IT tool usage across different phases of the audit cycle to track progress and areas for improvement. Encourage Peer Learning, to Facilitate cross-firm workshops to share best practices in IT use, particularly between Big4 and non-Big4 firms. In addition to Invest in pilot programs and research grants that explore the integration of IT, and data analytics in auditing.

We propose that audit technology includes audit applications, productivity tools, paper review technology and the use of IT experts. E-mail, mobile phones and remote network access rates have the highest use rates, while respondents are placing lower use rates on extensive commercial reporting languages and instant messaging. Respondents rated the "use scope of each audit application in a typical audit" using a five-point scale of 1 none and 5 extensive. Auditors working in national enterprises assessed their use and importance for the preparation of audit reports, knowledge management systems and audits on client web financial disclosure applications for small auditors. Auditors from national companies considered the use and significance of electronic working documents, sampling, fraud examination and internal control examinations to be consistent with the four main auditors.

Along with contributing to developing guidelines and policies, recognizing popular tools, and offering suggestions for auditing firms and academics researching emerging market audit technology, this study aims to assist auditing professionals to recognize the value of audit technology in the audit planning, testing, and reporting phases. The study investigates the way IT is used and how important it is in Jordanian auditing practice, as well as reveals significant differences between Big 4 and non-Big 4 firms. It found no significant differences between the two types in terms of the importance of IT, and audit planning.

Big 4 firms have more resources and knowledge, which results in better audit testing and better audits generally. To compete, non-Big 4 firms could have to make greater investments in the testing and completion of audits. The Big 4 firms may charge additional fees as a result of differences in the audit testing and completing processes. Both types of audit firms recognize the value of IT and audit planning. Therefore, the findings suggesting there are no significant differences in the importance of IT and audit planning between the two types of firms suggest that these areas are equally important for both types of firms. To compete with Big 4 entities, non-Big 4 firms ought to emphasize IT and audit strategy. Analyzing significant differences in audit testing and completion processes may indicate up areas that need improvement and assist firms come up to the Big 4 firms. This study has an opportunity to promote best practices and improve audit quality throughout the board of directors. IT risks must be recognized and controlled by auditors, who must also put software security measures into effect and keep electronic evidence for a limited period of time. To effectively do audit work, auditors must be aware of IT usage and risks. They ought to identify and reduce IT-related risks as well as take advantage of IT as a resource. The importance of privacy in auditing should be represented in the plans, planning, and handling of assignment files and reports by auditors. Effectiveness may be increased and accurate risk identification and management can be assured by using audit results in client risk management. The study looks at how IT is used in Jordanian auditing processes and highlights the need for businesses to invest funds on testing and completion processes in order to provide high-quality audits. This improves the level of audit quality, encourages trust in financial reporting, and emphasizes the significance of continuing education for auditors in light of the business environment's rapid change. With their audit process to be more efficient and effective, auditors have to make investments in IT infrastructure and software. Tools for data analytics can be used to examine vast amounts of data and identify potential problems. A risk-based strategy can improve audit quality and ensure proper risk identification and addressing while taking into account client IT systems and business environments. To increase trust in financial reporting and ensure independent, independent auditors, audit

firms have to establish an atmosphere of morality and honesty. In order to increase audit quality and reliability, the report highlights the significance of audit firms engaging with authorities and standard-setting the law enforcement officials. It also highlights how IT affects decisions regarding policies and regulatory frameworks, which has an effect on the auditing profession in developing countries. For effective audit work, auditing firms must gain an adequate understand of the clients' company and information technology the environment. The study highlights the significance of maintaining good client interactions, understanding company processes, and IT systems. For generalization, a bigger sample size and various kinds of audit firms are required. It's also important to think about how IT impacts audit quality and planning effectiveness. The study additionally suggests establishing Jordan auditing regulations for use in this automated environment to direct auditors as they work. The study also reveals that firm size influences the perceived importance and use of IT in auditing. A study examines IT's role in audit processes, highlighting the need for increased usage in specific situations. A study found that auditors use IT extensively but perceive them as important, infrequently. Firm size affects IT use, with larger firms having more extensive use. The self-reported data used in this study, its focus on auditors' perceptions of audit technology in developing countries, being susceptible to response bias, the lack of a full description, and the lack of an analysis of audit process weaknesses are some of its limitations.

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Critical Factors Affecting Customer Loyalty at the Digital Banks in Vietnam: The Moderating Role of Digital Competence

TRANG NGUYEN THI THU[1] and PHAN THANH TAM[2] (Corresponding author)

[1]Faculty of Banking, Ho Chi Minh University of Banking (HUB), Ho Chi Minh City, 84, Vietnam
email: trangntt@hub.edu.vn; https://orcid.org/0009-0002-2952-2032
[2]Faculty of Postgraduate Studies, Lac Hong University (LHU), Dong Nai Province, 84, Vietnam, email: tampt@lhu.edu.vn; https://orcid.org/0000-0003-2387-7756

ARTICLE INFO

ABSTRACT

The rapid growth of digital banking has intensified competition in the financial sector, making customer loyalty a critical factor for sustainable development, particularly in emerging economies such as Vietnam. This study aims to identify the key determinants of customer loyalty at digital banks and to examine the moderating role of digital competence. Drawing on relationship marketing theory and information systems success theory, the proposed research model integrates five antecedents, including customer trust, service quality, multi-channel integration, web quality, and perceived security and privacy, along with digital competence as both a direct predictor and a moderating variable. A mixed-methods approach was employed. Qualitative discussions with 45 banking managers in Ho Chi Minh City were conducted to refine the measurement scales. Quantitative data were collected through an online survey of digital banking customers in Ho Chi Minh City and Dong Nai province, yielding 570 valid responses. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4.0. The results reveal that all proposed factors have significant positive effects on customer loyalty, with perceived security and privacy exerting the most decisive influence. Digital competence not only directly enhances customer loyalty but also positively moderates the relationship between customer trust and customer loyalty. These findings provide important theoretical contributions by extending digital banking loyalty research in an emerging market context and offer practical implications for digital banks seeking to strengthen customer retention through trust-building, enhanced security, and improved digital capabilities.

INTRODUCTION

The rapid advancement of digital technologies has fundamentally transformed the global banking industry, reshaping how financial services are designed, delivered, and consumed (Adam et al., 2021; Verhoef et al., 2015). Digital banking, characterized by the extensive use of mobile applications, internet platforms, and integrated digital channels, has become a strategic priority for banks seeking to enhance operational efficiency and customer reach (Soeharso, 2024; Raza et al., 2020). In emerging economies

such as Vietnam, the adoption of digital banking has accelerated significantly in recent years, driven by widespread smartphone usage, government initiatives promoting cashless payments, and the growing digital literacy of the population. In this context, understanding the determinants of customer loyalty in digital banking environments has become an increasingly important research agenda.

Customer loyalty is widely recognized as a critical driver of long-term profitability, sustainability, and competitive advantage in the banking sector (Paul et al., 2016). Loyal customers are more likely to continue using banking services, engage in cross-buying, and generate positive word of mouth, while exhibiting lower price sensitivity and reduced switching behavior (Ladhari, 2009; Kashyap et al., 2024). However, in digital banking, customer loyalty is more challenging to sustain due to the intangible nature of services, limited face-to-face interaction, and low switching costs between digital platforms. Consequently, digital banks must rely on a combination of relational and technological factors to foster enduring customer relationships (Hamouda, 2019).

Existing studies on digital banking loyalty have predominantly focused on isolated determinants such as service quality, perceived usefulness, or trust. While these studies provide valuable insights, they often overlook the complex and interactive effects of multiple factors that jointly influence customer loyalty in technology-driven financial services (Dhingra et al., 2020; Amin et al., 2013). Moreover, most prior research has been conducted in developed economies, limiting the generalizability of findings to emerging markets, where institutional conditions, technological readiness, and customer characteristics differ substantially. Vietnam, as a rapidly developing digital economy with a dynamic banking sector, offers a compelling context for extending digital banking loyalty research.
Trust remains a cornerstone of customer–bank relationships, particularly in digital environments where perceived risk and information asymmetry are high. Customers must trust that digital banks are reliable, competent, and capable of safeguarding their financial transactions and personal information (Alharthi et al., 2022; Fauzi & Suryani, 2019). Alongside trust, service quality continues to play a vital role in shaping customer perceptions and behavioral intentions. In digital banking, service quality encompasses not only traditional dimensions such as reliability and responsiveness but also system efficiency and personalization enabled by digital technologies.

In addition to relational factors, technology-related attributes are increasingly important in determining customer loyalty. Multi-channel integration allows customers to seamlessly interact with banks across mobile, online, and offline platforms, enhancing convenience and consistency in service delivery (Kumar & Mokha, 2022). Web quality, reflected in system usability, interface design, and information accuracy, directly affects customer experience and satisfaction during digital interactions. Furthermore, perceived security and privacy have emerged as critical concerns in digital banking, as cyber threats and data breaches continue to undermine customer confidence. Customers who perceive digital banking platforms as secure are more likely to develop trust and maintain long-term relationships with banks. Another important yet underexplored factor in digital banking research is digital competence, the ability of customers to use digital technologies and online services effectively. In emerging markets such as Vietnam, digital competence varies considerably across demographic groups, influencing how customers perceive and interact with digital banking platforms (Gonu et al., 2023). Customers with higher digital competence are generally more confident in using digital services, better able to evaluate system reliability, and less susceptible to technology-related anxiety. As a result, digital competence may not only directly enhance customer loyalty but also strengthen the effects of other determinants, particularly customer trust (Kant & Jaiswal, 2017).

Against this background, the present study aims to investigate the key factors affecting customer loyalty in digital banks in Vietnam by developing and empirically testing an integrated research model. Specifically, this study examines the effects of customer trust, service quality, multi-channel integration, web quality, and perceived security and privacy on customer loyalty, while also exploring the direct and moderating role of digital competence. By employing a mixed-methods approach and Partial Least Squares Structural Equation Modeling (PLS-SEM), this research seeks to contribute to the literature on digital banking and customer loyalty and to provide practical insights for bank managers seeking to enhance customer retention in an increasingly digitalized financial landscape.

1. THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

1.1. Theoretical Foundations

The present study is grounded in an integrated theoretical framework that combines insights from relationship marketing theory, the information systems (IS) success model, and technology acceptance theory to explain customer loyalty in digital banking contexts (Kumar & Lata, 2021). Relationship marketing theory emphasizes the importance of long-term relationships built on trust, commitment, and value creation between service providers and customers. In banking services, where offerings are largely intangible and high in credence attributes, strong relational bonds are essential for fostering customer loyalty (Yilmaz et al., 2018; Zhao et al., 2022; Oliver, 1999).

Complementing this perspective, the IS success model highlights the role of system quality, information quality, and service quality in shaping users' satisfaction and behavioral intentions toward information systems (Supriyanto et al., 2021). In digital banking, websites and mobile applications function as primary service interfaces, making technological attributes such as web quality, system reliability, and security central to customer evaluations. Technology acceptance theory further suggests that users' perceptions of ease of use, usefulness, and technological competence influence their adoption and continued use of digital systems. Together, these theoretical perspectives provide a comprehensive lens for examining how relational and technological factors jointly determine customer loyalty in digital banking.

1.2. Customer Trust and Customer Loyalty

Customer trust refers to customers' belief that a bank is reliable, honest, and capable of delivering promised services while safeguarding customers' interests in a digital environment. In digital banking, trust plays a particularly critical role due to the absence of physical interactions and the heightened perceived risk associated with online financial transactions (Singh & Singh, 2024). Customers must trust not only the bank as an institution but also the digital platforms through which services are delivered. Prior research consistently demonstrates that trust reduces perceived uncertainty and risk, thereby increasing customers' willingness to engage in long-term relationships with service providers (Boonlertvanich, 2019; Wolfinbarger & Gilly, 2003). In the context of digital banking, trust has been found to influence continuance intention, satisfaction, and loyalty positively. When customers trust a digital bank, they are more likely to use its services repeatedly, resist switching to competitors, and recommend it to others. Accordingly, this study proposes the following hypothesis:

H1: Customer Trust positively influences Customer Loyalty.

1.3. Service Quality and Customer Loyalty

Service quality is defined as customers' overall evaluation of the excellence and performance of a bank's services. In digital banking, service quality extends beyond traditional dimensions such as reliability and responsiveness to include system efficiency, accuracy, and the ability to deliver timely, personalized services through digital channels (Boonlertvanich, 2019; Parasuraman et al., 1988). High service quality enhances customer satisfaction and strengthens the emotional bond between customers and banks. Numerous empirical studies have confirmed the positive relationship between service quality and customer loyalty in both traditional and digital banking contexts. Customers who perceive digital banking services as reliable, efficient, and responsive are more inclined to continue using them and develop long-term loyalty. Based on these arguments, the following hypothesis is formulated:

H2: Service Quality positively influences Customer Loyalty.

1.4. Multi-channel Integration and Customer Loyalty

Multi-channel integration refers to the degree to which different service channels, such as mobile banking, internet banking, call centers, and physical branches, are seamlessly coordinated to provide a consistent customer experience (Prentice et al., 2020; Saleem et al., 2016). In the digital era, customers increasingly interact with banks through multiple channels and expect smooth transitions between them. Effective multi-channel integration enhances customer convenience, reduces service disruptions, and improves overall service consistency (Yousafzai et al., 2003; Shaikh & Karjaluoto, 2015). Previous studies suggest that well-integrated channels increase customer satisfaction and engagement, which in turn foster customer loyalty. In digital banking, the ability to access services anytime, anywhere, across multiple channels, is a key competitive advantage. Therefore, this study proposes:

H3: Multi-channel Integration positively influences Customer Loyalty.

1.5. Web Quality and Customer Loyalty

Web quality refers to customers' perceptions of a digital bank's website or mobile application, including usability, visual design, information quality, and system reliability (Tabrani et al., 2018; Ladhari et al., 2011). As digital platforms serve as primary interfaces between banks and customers, web quality plays a crucial role in shaping customer experiences. High web quality reduces transaction errors, enhances ease of use, and increases customers' confidence in digital banking platforms (Gunasekar et al., 2021; Ariffin et al., 2018). Prior research in e-services and online banking has shown that web quality significantly influences customer satisfaction, trust, and loyalty. Customers who perceive digital banking platforms as user-friendly and reliable are more likely to maintain long-term relationships with banks. Accordingly, the following hypothesis is proposed:

H4: Web Quality positively influences Customer Loyalty.

1.6. Perceived Security and Privacy and Customer Loyalty

Perceived security and privacy refer to customers' beliefs regarding the protection of their personal and financial information when using digital banking services (Caruana, 2002). Security and privacy concerns remain among the most significant barriers to digital banking adoption, particularly in emerging markets where awareness of cyber risks is increasing (Dam & Dam, 2021; Kalia et al., 2021; Solimun & Fernandes, 2018). When customers perceive digital banking platforms as secure and trustworthy, they are more willing to engage in online transactions and maintain long-term relationships with banks. Empirical studies consistently demonstrate that perceived security and privacy positively influence trust, satisfaction, and loyalty in digital financial services. Therefore, this study posits:

H5: Perceived Security and Privacy positively influence Customer Loyalty.

1.7. Digital Competence and Customer Loyalty

Digital competence refers to customers' ability to effectively use digital technologies, including mobile applications, online platforms, and electronic payment systems (Shankar & Jebarajakirthy, 2019; Bolton et al., 2018). In emerging economies such as Vietnam, digital competence varies significantly across individuals due to differences in education, age, and exposure to technology. Customers with higher digital competence tend to experience lower technology-related anxiety, greater perceived ease of use, and stronger engagement with digital banking services (Endara et al., 2019). As a result, digital competence is expected to directly enhance customer loyalty by facilitating more positive user experiences. Based on this reasoning, the following hypothesis is proposed:

H6: Digital Competence positively influences Customer Loyalty.

1.8. Moderating Role of Digital Competence

Beyond its direct effect, digital competence may also moderate the relationship between customer trust and customer loyalty (Arli et al., 2024; Mugova et al., 2025). Customers with higher digital competence are better able to evaluate digital banking systems, understand security mechanisms, and interpret online information, thereby strengthening the effect of trust on loyalty (Omoregie et al., 2019). In contrast, customers with lower digital competence may rely more on traditional banking interactions and be less influenced by trust in digital platforms. This moderating perspective is supported by technology acceptance theory, which emphasizes the role of individual capabilities in shaping technology-related behaviors. Accordingly, this study proposes:

H7: Digital Competence positively moderates the relationship between Customer Trust and Customer Loyalty.

1.9. Proposed Research Framework

Based on the above theoretical arguments, this study proposes an integrated research framework in which Customer Trust, Service Quality, Multi-channel Integration, Web Quality, and Perceived Security and Privacy directly influence Customer Loyalty. At the same time, Digital Competence exerts both a direct effect on Customer Loyalty and a moderating effect on the relationship between Customer Trust and Customer Loyalty. This framework provides a comprehensive basis for empirically examining customer loyalty in digital banking within the Vietnamese context.
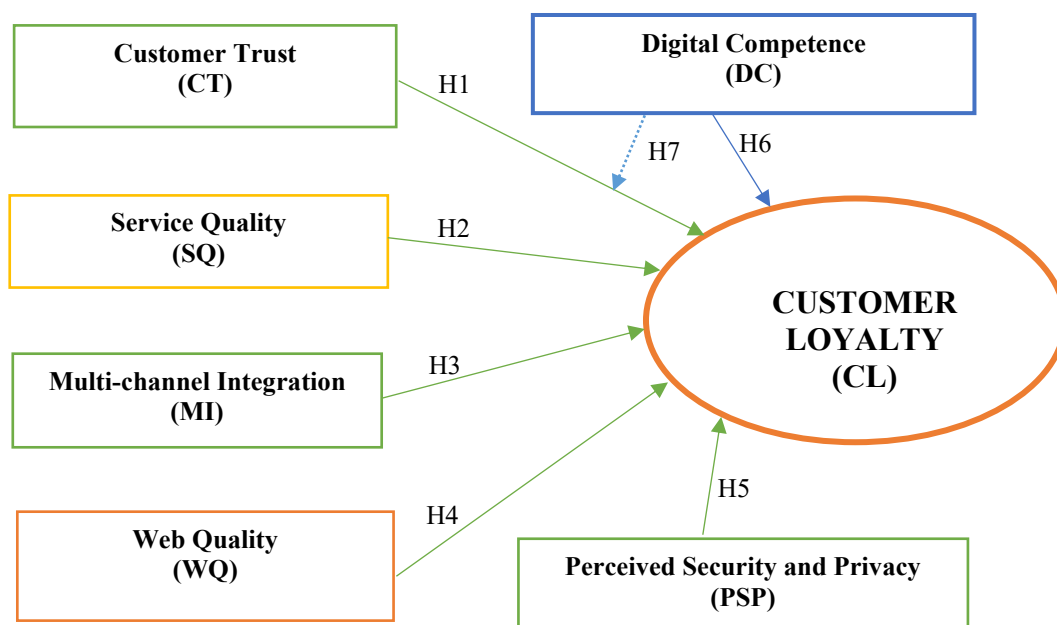

Figure 1. A research model for critical factors influencing customer loyalty

Figure 1 presents the proposed research model examining the key factors influencing customer loyalty in the context of digital banking. Customer Loyalty (CL) is positioned as the central dependent variable. It is directly affected by five antecedents: Customer Trust, Service Quality, Multi-channel Integration, Web Quality, and Perceived Security and Privacy. In addition, Digital Competence plays a dual role in the model by exerting a direct effect on Customer Loyalty and moderating the relationship between Customer Trust and Customer Loyalty. Overall, the model highlights the combined influence of relational and technological factors in shaping customer loyalty in digital banking services in Vietnam.

2. RESEARCH METHODOLOGY

2.1 Qualitative Research Method

This study employed a qualitative research approach as an initial step to develop a robust conceptual framework and refine the measurement scales used in the subsequent quantitative analysis. The qualitative phase aimed to ensure content validity and contextual relevance of the research constructs within the digital banking environment in Vietnam.

Data were collected through in-depth group discussions with 45 banking managers directly involved in digital banking operations, strategy, and customer service management in Ho Chi Minh City, Vietnam's most significant financial and commercial hub. The participants were selected through purposive sampling to ensure they had substantial professional experience and practical insights into digital banking services and customer behavior. Their average managerial experience exceeded 5 years, particularly in digital transformation, service quality management, and customer relationship management (Hair et al., 2019).

The discussion sessions focused on identifying key factors influencing customer loyalty in digital banking, evaluating the relevance and clarity of measurement items adapted from prior studies, and exploring emerging issues specific to the Vietnamese context, such as digital literacy gaps and security concerns. Open-ended questions were used to encourage participants to share their perspectives freely, enabling a comprehensive understanding of both the relational and technological dimensions of digital banking.

The qualitative data were analyzed using thematic analysis. Key themes and recurring patterns were identified and compared with existing theoretical frameworks and empirical findings from the literature. Based on the insights obtained, several measurement items were refined, reworded, or eliminated to enhance clarity and suitability for Vietnamese digital banking customers. The results of this qualitative phase played a crucial role in shaping the final research model and questionnaire design, thereby providing a solid foundation for the subsequent quantitative study.

2.2 Quantitative Research Method

Following the qualitative phase, a quantitative research approach was employed to test the proposed research model and hypotheses empirically. The quantitative stage aimed to examine the relationships among customer trust, service quality, multi-channel integration, web quality, perceived security and privacy, digital competence, and customer loyalty in the context of digital banking in Vietnam.

Data Collection and Sample: Data were collected through an online survey administered to customers who actively use digital banking services. The survey was conducted in Ho Chi Minh City and Dong Nai province, two economically dynamic regions with high levels of digital banking adoption. A non-probability convenience sampling method was applied due to the accessibility of respondents and the exploratory nature of the study within an emerging market context (Hair et al., 2019).

A total of 600 questionnaires were distributed via email and social media platforms. After screening for completeness and consistency, 570 valid responses were retained for analysis, yielding a high response rate and exceeding the minimum sample size recommended for Partial Least Squares Structural Equation Modeling (PLS-SEM). This sample size is considered adequate to ensure statistical power and reliability of the results.

Measurement Instrument: The questionnaire was developed based on validated measurement scales adapted from prior studies in digital banking, electronic services, and information systems literature. All constructs were measured using multiple items on a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The measurement items were refined based on insights from the qualitative

research phase to ensure clarity, relevance, and contextual appropriateness for Vietnamese digital banking users.

Data Analysis Technique: The collected data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4.0. PLS-SEM was selected due to its suitability for complex research models involving multiple constructs and moderating effects, as well as its robustness in handling non-normal data distributions. The analysis followed a two-step approach: first, the measurement model was assessed to evaluate reliability and validity; second, the structural model was assessed to test the hypothesized relationships. To guarantee convergent validity, the measurement model was evaluated using Cronbach's alpha and composite reliability (both above 0.70), as well as an average variance extracted (AVE) exceeding 0.50. The Fornell-Larcker criterion and the HTMT ratio (HTMT < 0.85) were used to assess discriminant validity. The factors used to assess the structural model were path coefficients (β), t-statistics (≥ 1.96, $p < 0.05$), R^2 values, and the moderating effect's significance as measured by the interaction term (Hair et al., 2019).

Bootstrapping with 5.000 resamples was employed to assess the significance of path coefficients, t-values, and p-values. This approach allowed for rigorous testing of both direct and moderating effects. Overall, the quantitative research method provided strong empirical evidence to validate the proposed model and offered meaningful insights into the determinants of customer loyalty in digital banking in Vietnam.

3. RESEARCH RESULTS

3.1 Descriptive statistics

This section presents descriptive statistics for survey respondents, providing an overview of their demographic characteristics. A total of 570 valid questionnaires were used for the analysis, offering a comprehensive representation of digital banking customers in Ho Chi Minh City and Dong Nai province, Vietnam. The demographic profile includes gender, marital status, age, average monthly income, and duration of digital banking usage.

Regarding gender distribution, the sample consists of 234 male respondents (41.1%) and 336 female respondents (58.9%). The relatively higher proportion of female participants indicates that women are actively engaged in using digital banking services in Vietnam. This distribution suggests that digital banking adoption is not limited to a specific gender group but reflects a broad, inclusive user base, consistent with recent trends in digital financial services.

In terms of marital status, 61.6% of respondents (351 individuals) reported being married, while 38.4% (219 individuals) were single. The dominance of married respondents suggests that digital banking services are widely used by individuals with family responsibilities, who may value convenience, time efficiency, and secure financial management solutions offered by digital banking platforms.

The age distribution shows that the majority of respondents fall within the 35-45 age group, accounting for 53.2% (303 respondents) of the sample. This is followed by the 25-35 age group, with 23.2% (132 respondents). Younger users aged 18 to under 25 represent 8.1%, while respondents aged 45 and above account for 15.6%. These findings indicate that middle-aged customers form the core user segment of digital banking services in Vietnam. This group is likely to have stable income, higher financial needs, and sufficient digital competence to adopt and use digital banking applications continuously.

Regarding average monthly income, the sample reflects a relatively strong earning capacity. Respondents earning above 15 million VND per month account for 37.2%, while those earning between 10 and 15 million VND represent 36.0%. Together, these two groups comprise more than 70% of the sample. Meanwhile, 21.6% of respondents earn between 5 and 10 million VND, and only 5.3% earn below 5 million VND. This income distribution suggests that digital banking users are predominantly middle- to high-income

individuals, who may have greater access to digital devices and a stronger demand for advanced banking services.

Finally, regarding the duration of digital banking usage, a significant proportion of respondents reported long-term usage. Specifically, 37.2% have used digital banking services for 10 to under 15 years, and 35.3% have more than 15 years of experience. In contrast, 21.2% have used digital banking for 5 to under 10 years, and only 6.3% reported using it for 1 to under 5 years. This indicates that most respondents are experienced users, which enhances the reliability of their evaluations of service quality, trust, security, and loyalty. Overall, the descriptive statistics demonstrate that the sample is well-suited for examining customer loyalty in digital banking, as it consists mainly of experienced, economically active, and digitally engaged users.

3.2 Testing for factors affecting customer loyalty

Table 1. Cronbach's Alpha and composite reliability testing for factors affecting customer loyalty

Factors	Code	Items	Mean	Std. Deviation	Cronbach's alpha	Composite reliability	Average variance extracted
1. Customer Trust	CT	4	3.226	0.931	0.892	0.925	0.756
2. Service Quality	SQ	4	3.451	0.927	0.928	0.949	0.822
3. Multi-channel Integration	MI	4	3.350	0.936	0.856	0.879	0.655
4. Web Quality	WQ	4	3.117	0.919	0.919	0.938	0.791
5. Perceived Security and Privacy	PSP	3	3.213	0.928	0.875	0.923	0.800
6. Digital Competence	DC	4	3.189	0.945	0.849	0.893	0.678
7. Customer Loyalty	CL	3	3.385	0.938	0.812	0.887	0.725

Source: The authors' process

Table 1 presents the results of the reliability and convergent validity assessment for the constructs used in the study examining factors affecting customer loyalty in digital banking. The analysis includes descriptive statistics (mean and standard deviation), Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE), which are commonly employed criteria in PLS-SEM to evaluate the quality of the measurement model.

(1) The mean values of the constructs range from 3.117 to 3.451, indicating that respondents generally exhibit moderately positive perceptions toward all constructs. Service Quality (Mean = 3.451) and Customer Loyalty (Mean = 3.385) show the highest mean scores, suggesting that respondents have relatively favorable evaluations of digital banking services and a moderate level of loyalty. The standard deviation values, which range from 0.919 to 0.945, indicate an acceptable level of variability in responses, reflecting diverse customer perceptions without extreme dispersion.

(2) Regarding internal consistency reliability, Cronbach's alpha values for all constructs exceed the recommended threshold of 0.70, ranging from 0.812 (Customer Loyalty) to 0.928 (Service Quality). These results confirm that the measurement items for each construct are internally consistent and reliably capture the underlying latent variables. In addition, the Composite Reliability (CR) values range from 0.879 to 0.949, further reinforcing the reliability of the constructs. Higher CR values than Cronbach's alpha in most cases indicate that the constructs are well-specified and suitable for PLS-SEM analysis.

(3) Convergent validity is assessed using the Average Variance Extracted (AVE). All AVE values exceed the minimum recommended level of 0.50, ranging from 0.655 (Multi-channel Integration) to 0.822 (Service Quality). This demonstrates that each construct explains more than half of the variance of its associated measurement items, confirming satisfactory convergent validity. Notably, Service Quality and Perceived Security and Privacy exhibit particularly high AVE values (0.822 and 0.800, respectively), suggesting strong explanatory power of their measurement items.

Conclusion: The results presented in Table 1 indicate that the measurement model meets the required standards of reliability and convergent validity. All constructs are measured accurately and consistently, providing a solid foundation for subsequent structural model analysis. These findings confirm the appropriateness of the measurement scales for examining customer loyalty in the Vietnamese digital banking context.

Table 2. SEM testing for factors affecting customer loyalty

Factors	Original sample	Sample mean	Standard deviation	T statistics	P values
CT → CL	0.232	0.233	0.039	5.949	0.000
DC → CL	0.135	0.142	0.032	4.232	0.000
DC x CT → CL	0.106	0.103	0.035	2.999	0.003
MI → CL	0.089	0.095	0.040	2.261	0.024
PSP → CL	0.304	0.303	0.040	7.600	0.000
SQ → CL	0.160	0.159	0.035	4.509	0.000
WQ → CL	0.079	0.084	0.038	2.063	0.039

Source: The authors' process

Table 2 presents the results of the Structural Equation Modeling (SEM) analysis conducted using PLS-SEM to examine the factors affecting customer loyalty in digital banking. The table reports the standardized path coefficients (β), sample means, standard deviations, t-statistics, and p-values, which together indicate the strength and significance of the hypothesized relationships. The results demonstrate that all proposed paths are statistically significant, confirming the robustness of the research model. The t-statistics for all relationships exceed the critical value of 1.96, and all p-values are below 0.05, indicating strong empirical support for the hypothesized effects.

(1) Among the direct effects, Perceived Security and Privacy (PSP → CL) exhibits the most decisive influence on Customer Loyalty, with a path coefficient of $\beta = 0.304$ (t = 7.600, p < 0.001). This finding highlights the paramount importance of security and privacy concerns in shaping customer loyalty in digital banking. Customers who perceive digital banking platforms as secure and capable of protecting their personal and financial information are significantly more likely to remain loyal.

(2) Customer Trust (CT → CL) is the second most influential factor ($\beta = 0.232$, t = 5.949, p < 0.001). This result underscores the critical role of trust in digital financial services, where customers rely heavily on intangible systems and technologies. Trust reduces perceived risk and uncertainty, thereby strengthening customers' commitment to digital banks.

(3) Service Quality (SQ → CL) also demonstrates a strong positive effect on customer loyalty ($\beta = 0.160$, t = 4.509, p < 0.001). This indicates that reliable, responsive, and efficient digital banking services remain essential drivers of loyalty, even in highly technology-driven environments.

(4) Regarding individual customer capabilities, Digital Competence (DC → CL) has a significant positive impact on customer loyalty ($\beta = 0.135$, t = 4.232, p < 0.001). This suggests that customers with higher digital skills and confidence are more likely to engage with digital banking services and maintain long-term relationships with their banks.

(5) The interaction effect between Digital Competence and Customer Trust (DC × CT → CL) is statistically significant ($\beta = 0.106$, t = 2.999, p = 0.003). This finding confirms the moderating role of digital competence, indicating that the positive effect of trust on customer loyalty is more substantial for customers with higher levels of digital competence.

(6) Multi-channel Integration (MI → CL) and Web Quality (WQ → CL), although exhibiting relatively smaller effect sizes, both have significant positive influences on customer loyalty ($\beta = 0.089$ and $\beta = 0.079$, respectively). These results emphasize that seamless channel integration and high-quality digital interfaces contribute meaningfully to enhancing customer loyalty.

Table 2 provides strong empirical evidence supporting the proposed structural relationships and high-lights the combined importance of security, trust, service quality, technological factors, and digital competence in fostering customer loyalty in digital banking.
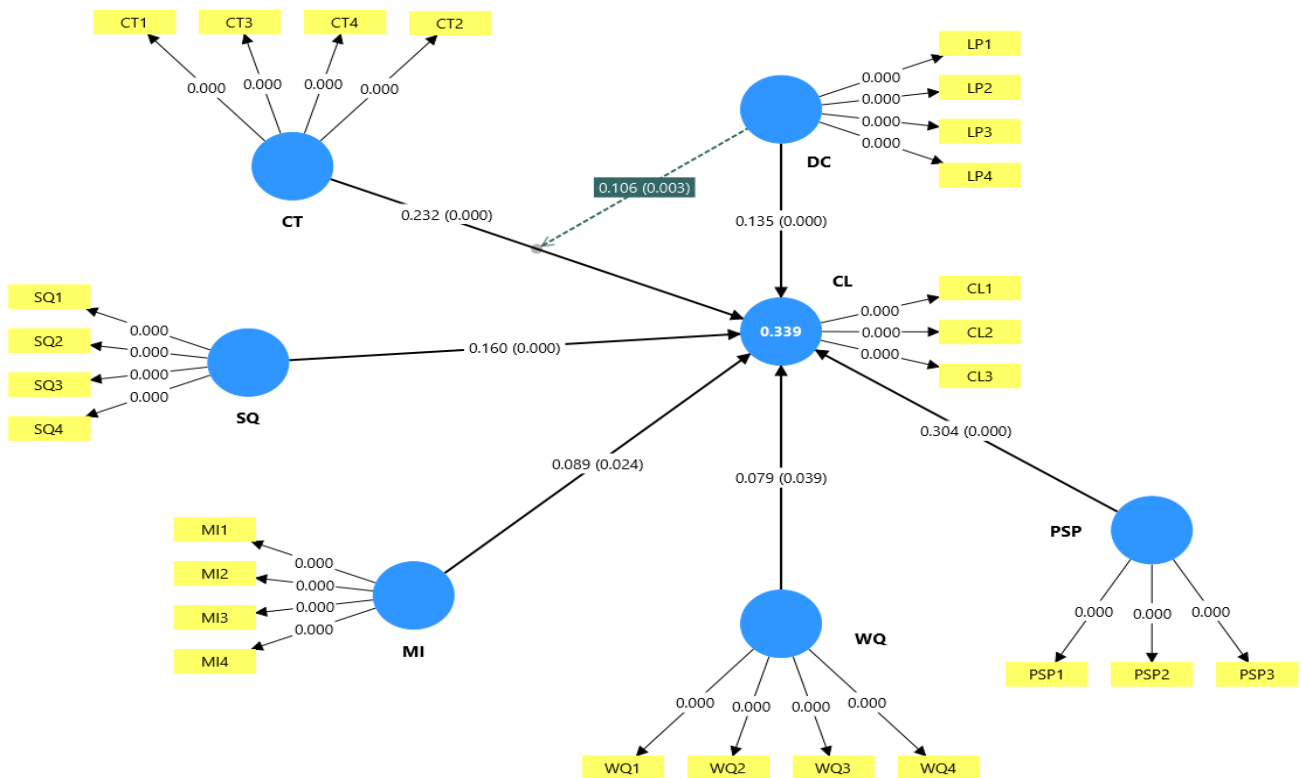

Figure 2. Testing factors influencing customer loyalty

Figure 2 presents the results of the structural model analysis examining the factors influencing customer loyalty in digital banking, estimated using PLS-SEM with SmartPLS 4.0. The model shows that Customer Loyalty (CL) is explained by multiple relational and technological factors, with an R^2 value of 0.339, indicating that the proposed antecedents account for 33.9% of the variance in customer loyalty. This level of explanatory power is considered moderate and acceptable in behavioral and service-related research. All hypothesized direct relationships are statistically significant. Perceived Security and Privacy (PSP) exert the most potent positive effect on customer loyalty ($\beta = 0.304$, $p < 0.001$), highlighting the critical role of data protection and transaction security in digital banking. Customer Trust (CT) also demonstrates a strong influence ($\beta = 0.232$, $p < 0.001$), followed by Service Quality (SQ) ($\beta = 0.160$, $p < 0.001$) and Digital Competence (DC) ($\beta = 0.135$, $p < 0.001$). Additionally, Multi-channel Integration (MI) ($\beta = 0.089$, $p < 0.05$) and Web Quality (WQ) ($\beta = 0.079$, $p < 0.05$) contribute positively, although with smaller effect sizes.

Importantly, the interaction effect between Digital Competence and Customer Trust (DC × CT) is significant ($\beta = 0.106$, $p = 0.003$), confirming the moderating role of digital competence. This finding suggests that customers with higher digital competence are better able to translate trust in digital banks into loyal behavior. Overall, Figure 2 provides strong empirical support for the proposed research model and hypotheses.

Table 3. Hypotheses testing summary for factors affecting customer loyalty

Hypothesis	Path	β	t-value	p-value	Result
H1	CT → CL	0.232	5.949	0.000	Supported
H2	SQ → CL	0.160	4.509	0.000	Supported
H3	MI → CL	0.089	2.261	0.024	Supported
H4	WQ → CL	0.079	2.063	0.039	Supported
H5	PSP → CL	0.304	7.600	0.000	Supported

H6	DC → CL	0.135	4.232	0.000	Supported
H7	DC x CT → CL	0.106	2.999	0.003	Supported

Source: The authors' process

Table 3 summarizes the results of hypothesis testing for the factors affecting customer loyalty in digital banking. The findings indicate that all seven proposed hypotheses (H1–H7) are supported, demonstrating strong empirical validation of the research model.

Specifically, H1 confirms that Customer Trust positively influences Customer Loyalty (β = 0.232, t = 5.949, p < 0.001), highlighting trust as a fundamental determinant of long-term customer relationships in digital banking. H2 is also supported, showing that Service Quality has a significant positive effect on Customer Loyalty (β = 0.160, t = 4.509, p < 0.001). This result underscores the importance of reliable, responsive digital services. H3 and H4 examine technology-related service attributes. The results indicate that Multi-channel Integration (β = 0.089, p = 0.024) and Web Quality (β = 0.079, p = 0.039) both exert significant positive influences on customer loyalty, supporting H3 and H4. Although their effect sizes are relatively smaller, these factors contribute meaningfully to enhancing customer experience and engagement.

Among all direct effects, Perceived Security and Privacy (H5) has the most decisive influence on Customer Loyalty (β = 0.304, t = 7.600, p < 0.001), underscoring the critical role of security and data protection in digital banking environments. H6 confirms that Digital Competence positively affects Customer Loyalty (β = 0.135, t = 4.232, p < 0.001), suggesting that digitally skilled customers are more likely to remain loyal. Finally, H7 validates the moderating role of Digital Competence in the relationship between Customer Trust and Customer Loyalty (β = 0.106, t = 2.999, p = 0.003). This indicates that higher digital competence strengthens the trust–loyalty relationship. Overall, the results provide comprehensive support for the proposed hypotheses and reinforce the robustness of the research framework.

3.3 Discussion of Findings

The findings of this study provide comprehensive insights into the key determinants of customer loyalty in the context of digital banking in Vietnam. Overall, the results confirm that customer loyalty is shaped by a combination of relational, service-related, and technological factors, as well as individual customer capabilities, thereby supporting the integrated theoretical framework proposed in this research.

(1) Among all examined factors, Perceived Security and Privacy emerge as the most influential determinant of customer loyalty. This finding reflects the heightened sensitivity of digital banking customers to data protection, transaction security, and privacy (Tegambwage & Kasoga, 2022; Gonu et al., 2023). In an environment characterized by increasing cyber threats and financial fraud, customers are more likely to remain loyal to digital banks that they perceive as secure and capable of safeguarding their personal and financial information. This result is consistent with prior studies that emphasize security and privacy as critical drivers of trust and continued use in digital financial services, particularly in emerging markets.

(2) Customer Trust is identified as the second most important factor influencing customer loyalty. The significant positive relationship between trust and loyalty underscores the central role of trust in reducing perceived risk and uncertainty in digital banking transactions (Yilmaz et al., 2018; Zhao et al., 2022). Even though digital platforms rely heavily on technology, trust in the bank's integrity and competence remains fundamental for fostering long-term customer relationships. This finding aligns with relationship marketing theory, which highlights trust as a core antecedent of loyalty.

(3) Service Quality also demonstrates a strong positive effect on customer loyalty, indicating that efficient, reliable, and responsive digital services continue to be essential in retaining customers (Boonlertvanich, 2019; Parasuraman et al., 1988). Despite advancements in automation and self-service technologies, customers still evaluate digital banks based on service performance, accuracy, and problem

resolution. This suggests that technology alone is insufficient to secure customer loyalty without high-quality service delivery.

(4) The results further show that Multi-channel Integration and Web Quality, although exhibiting smaller effect sizes, significantly contribute to customer loyalty (Prentice et al., 2020). Seamless integration across digital and physical channels enhances convenience and consistency, while high-quality web and mobile interfaces improve usability and overall customer experience. These findings highlight the importance of delivering a coherent and user-friendly digital ecosystem.

(5) Importantly, Digital Competence plays a dual role in the model. Its direct effect on customer loyalty indicates that digitally skilled customers are more comfortable with digital banking services and are more likely to establish long-term relationships with banks (Arli et al., 2024; Mugova et al., 2025). Moreover, the significant moderating effect of digital competence strengthens the relationship between customer trust and loyalty. This suggests that customers with higher digital competence are better able to assess digital systems and security features, thereby translating trust into more loyal behavior.

Conclusion: these findings contribute to the literature by emphasizing the intertwined roles of security, trust, service quality, and digital capabilities in shaping customer loyalty in digital banking. They also offer valuable insights for bank managers seeking to enhance customer retention in an increasingly competitive digital environment.

4. MANAGERIAL RECOMMENDATIONS

Based on the empirical results of the structural model, this section provides managerial recommendations prioritized according to the magnitude of standardized path coefficients (β values). This prioritization allows digital bank managers to allocate resources more effectively by focusing on the most influential drivers of customer loyalty in the Vietnamese digital banking context.

(1) Strengthening Perceived Security and Privacy ($\beta = 0.304$): Perceived Security and Privacy have the most substantial impact on customer loyalty, indicating that security-related concerns are paramount for digital banking customers. Therefore, digital banks should prioritize investments in advanced cybersecurity infrastructure, including multi-factor authentication, biometric verification, end-to-end encryption, and real-time fraud detection systems. Beyond technical solutions, banks should actively communicate security measures to customers. Transparent communication about data protection policies, privacy practices, and incident response mechanisms can significantly enhance customers' confidence. Regular security notifications, educational campaigns on safe digital banking practices, and visible security certifications can further strengthen perceived security and privacy. From a strategic perspective, positioning security as a core brand value can serve as a strong differentiator in an increasingly competitive digital banking market. Finally, digital banks must implement strict security and data privacy policies, including advanced authentication mechanisms and robust data protection protocols. Transparent communication of privacy practices is equally important. At the macro level, strengthening legal frameworks on cybersecurity and personal data protection is crucial for reinforcing customer confidence in digital banking services.

(2) Enhancing Customer Trust ($\beta = 0.232$): Customer Trust is the second most influential determinant of customer loyalty. To build and sustain trust, digital banks should focus on consistency, transparency, and reliability across all customer interactions. This includes ensuring system stability, minimizing service downtime, and delivering on promised service standards. Trust can also be reinforced through transparent fee structures, clear terms and conditions, and prompt resolution of customer complaints. Personalized communication, ethical data use, and proactive customer support further build trust. Given the strong interaction effect between trust and digital competence, banks should tailor trust-building strategies to different customer segments, ensuring that less digitally competent customers receive additional guidance and reassurance. Finally, digital banks should implement policies that emphasize transparency, reliability, and ethical practices in digital service delivery. Clear communication regarding terms, fees, and transaction processes is essential. At the regulatory level, authorities should strengthen consumer protection

frameworks and disclosure requirements to enhance trust in digital banking systems and promote confidence across the financial sector.

(3) Improving Service Quality (β = 0.160): Service Quality remains a critical driver of customer loyalty, even in highly digitalized banking environments. Digital banks should continuously enhance service reliability, responsiveness, and efficiency. This can be achieved by optimizing system performance, reducing transaction processing times, and ensuring accuracy in digital services. The integration of artificial intelligence (AI) and chatbots for customer support can improve responsiveness, but human support should remain available for complex issues. Service personalization, such as customized financial recommendations and tailored user interfaces, can further enhance perceived service quality. Managers should also regularly monitor service quality metrics and customer feedback to promptly identify and address service gaps. Finally, digital banks need to establish continuous service quality improvement policies focusing on reliability, responsiveness, and personalization. Regular monitoring of service performance and customer feedback should be institutionalized. Policymakers may consider setting minimum digital service quality standards to ensure consistent customer experiences and encourage fair competition among digital banking providers.

(4) Developing Customers' Digital Competence (β = 0.135; Moderating Effect β = 0.106): Digital Competence plays a dual role by directly influencing customer loyalty and moderating the trust–loyalty relationship. This highlights the importance of empowering customers with digital skills and confidence. Digital banks should invest in customer education programs, such as tutorials, instructional videos, in-app guidance, and online workshops, to help users navigate digital platforms effectively. Simplifying application design and providing intuitive user interfaces can reduce technology-related anxiety, particularly for older or less digitally experienced customers. By enhancing digital competence, banks not only improve direct customer engagement but also amplify the positive effects of trust on loyalty, creating a reinforcing cycle of digital adoption and retention. Finally, banks should develop policies to improve customers' digital competence through educational programs, in-app guidance, and user-friendly system design. Enhancing digital skills reduces technology-related anxiety and increases engagement. Policymakers should support national digital literacy initiatives to narrow the digital divide and facilitate inclusive adoption of digital banking.

(5) Enhancing Multi-channel Integration (β = 0.089): Although the effect size of Multi-channel Integration is relatively smaller, it remains a significant contributor to customer loyalty. Digital banks should ensure seamless integration across mobile applications, websites, call centers, and physical branches. Customers should be able to switch between channels without losing transaction continuity or service consistency. Unified customer data systems, synchronized service processes, and consistent branding across channels can significantly enhance the overall customer experience. Managers should view multi-channel integration as a strategic enabler of convenience and reliability, particularly for customers who prefer combining digital and traditional banking interactions. Finally, banks should adopt policies that promote seamless integration across digital and traditional service channels, enabling customers to move effortlessly between platforms. Unified data management and synchronized processes are essential. From a policy perspective, investment in digital infrastructure and interoperability standards can support effective multi-channel strategies within the digital banking ecosystem.

(6) Improving Web and Application Quality (β = 0.079): Web Quality, while having the smallest effect size, still plays a meaningful role in shaping customer loyalty. Banks should focus on improving the usability, interface design, navigation, and system reliability of their digital platforms. Regular usability testing, performance optimization, and updates based on customer feedback are essential. Ensuring fast loading times, minimal errors, and clear information presentation can significantly enhance user experience. Although web quality alone may not strongly drive loyalty, it supports other key factors such as trust, service quality, and digital competence. Finally, digital banks should prioritize policies that enhance the usability, stability, and accessibility of websites and mobile applications. Regular system upgrades and usability testing are critical. Regulators may provide technical guidelines for digital banking platforms to ensure minimum standards of functionality, accessibility, and service continuity for diverse customer groups.

Digital banks of strategic implication: Digital banks in Vietnam should adopt a hierarchical strategy to enhance customer loyalty. Security and privacy should be treated as foundational priorities, followed by trust and service quality. Simultaneously, investments in digital competence development and multi-channel integration can amplify loyalty outcomes. By aligning managerial actions with the relative importance of each factor, banks can achieve more effective customer retention and sustainable competitive advantage in the digital banking era.

4.1 Limitations and future research

Despite its theoretical and practical contributions, this study has several limitations that should be acknowledged and addressed in future research. First, the data were collected from digital banking customers in Ho Chi Minh City and Dong Nai province, which may limit the generalizability of the findings to other regions of Vietnam or to different national contexts. Future studies could expand the sample to include customers from rural areas or other emerging and developed economies to enhance external validity. Second, this study employed a cross-sectional research design, which captures customer perceptions at a single point in time. As customer loyalty and digital banking experiences may evolve, longitudinal studies are recommended to examine changes in customer behavior and to establish stronger causal inferences. Third, the research model focused on selected relational and technological factors. Future research could incorporate additional variables, such as customer satisfaction, perceived value, brand image, and switching costs, to provide a more comprehensive understanding of customer loyalty in digital banking. Future studies may explore alternative moderating or mediating mechanisms, such as customer involvement or technology readiness. Finally, while PLS-SEM is suitable for exploratory and predictive research, future studies may employ alternative analytical techniques or mixed-methods approaches to validate further and extend the findings of this study.

CONCLUSION

This study investigates the key factors influencing customer loyalty in digital banking in Vietnam by integrating relational, service-related, and technological perspectives into a comprehensive research framework. Using a mixed-methods approach and applying Partial Least Squares Structural Equation Modeling (PLS-SEM) to data collected from 570 digital banking customers, the study provides robust empirical evidence on the determinants of customer loyalty in an emerging market context. The findings reveal that perceived security and privacy are the most influential factors affecting customer loyalty, underscoring the critical importance of safeguarding customer information and ensuring secure digital transactions. Customer trust and service quality also play significant roles, highlighting that strong relational foundations and reliable service delivery remain essential even in technology-driven banking environments. In addition, multi-channel integration and web quality both positively contribute to customer loyalty, underscoring the importance of seamless, user-friendly digital experiences. Notably, the study identifies digital competence as both a direct predictor of customer loyalty and a moderating variable that strengthens the relationship between customer trust and loyalty. This dual role emphasizes that customers' digital skills and confidence significantly influence how they perceive and engage with digital banking services. Finally, this research extends the existing literature by providing empirical insights into digital banking loyalty in Vietnam and highlighting the critical interplay among trust, security, service quality, and digital competence. The findings offer a solid foundation for future research and practical strategies to enhance customer loyalty in the rapidly evolving digital banking landscape.

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e.g. Thacher, D., Rein, M. (2004), „Managing Value Conflict in Public Policy", *Governance*, Vol. 17, No. 4, pp. 457-486.

❑ **For published conference proceedings** - Surname, Initials (year of publication), "Title of paper", in Surname, Initials (Ed.), *Title of published proceeding which may include place and date(s) held*, Publisher, Place of publication, Page numbers.

e.g. Draskovic, V., Grego, Z., Draskovic, M. (2011), "Media Concentration, Neoliberal Paradoxes and Increase in Virtuality" in *Media Concentration proceedings of the international conference in Podgorica,* Montenegro, 2011, Elit, Podgorica, pp. 33-45.

❑ **For working papers** - Surname, Initials (year), "Title of article", working paper [number if available], Institution or organization, Place of organization, date.

e.g. Draskovic, V. (2007), "Specificities and problems of Montenegrin transition", working paper, No. ..., Leeds University Business School, TIGER, Warsaw, September.

❑ **For newspaper articles (authored)** - Surname, Initials (year), "Article title", *Newspaper*, date, pages.

e.g. Miller, M. C. (1997), "The Crushing Power of Big Publishing", *The Nation*, 17 March, p. 10.

❑ **For newspaper articles (non-authored)** - *Newspaper* (year), "Article title", date, pages.

e.g. *Vijesti* (2011), „The New Media", 2 December, p. 5.

❑ **For electronic sources** - If available online, the full URL should be supplied at the end of the reference, as well as a date that the resource was accessed.

e.g. Compaine, B.M. (2005), „The Media Monopoly Myth: How New Competition is Expanding our Sources of Information and Entertainment", available at: http://www.NewMillennium Research. org//archive/ final_Compaine_Paper_050205. pdf (accessed 10 december 2011).