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

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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: $(\text{bribe price/catch probability}) * (\text{total money in corrupt activities}) = \text{annual bribe tax}$. 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. Y_{it} denotes the actual production of the i th country at period t . Then Battese and Coelli (1995) can express production as

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

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 v_{it} stands for random error and u_{it} for inefficiency. The system describes the error.

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

The random error, v_{it} , is a normally distributed variable with a mean of zero and a variance. It is independently and identically distributed. Where u_i is a normally distributed, non-negative, zero-truncated variable. It has mean δz_{it} and variance. Z_i stands for factors that affect efficiency. δ is an unknown coefficient to be estimated. The technical inefficiency can be illustrated.

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

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$$TE_{it} = E[\exp(u_{it}) \setminus \epsilon_{it}] \dots \dots \dots (4)$$

$$TE_{it} = \left\{ \frac{\theta(r_i - \sigma_*)}{\theta(r_i)} \right\} \exp \left\{ -\mu_{*it} + \frac{1}{2} \sigma_*^2 \right\} \dots \dots \dots (5)$$

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

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

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.

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

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. K_{it} is the capital for country i at time t , in millions of dollars. L_{it} is the number of workers in country i at time t , in millions. DS_{it} is the money allocated in millions of dollars for military purposes in country i at time t . It includes military expenditures and equipment. T_{it} 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:

$$\ln GDP_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 (T_{it}) + 0.5 [\beta_4 (\ln K_{it})^2 + \beta_5 (\ln L_{it})^2 + \beta_6 T_{it}^2] + \beta_7 (\ln K_{it})(\ln L_{it}) + \beta_8 (T_{it})(\ln K_{it}) + \beta_9 (T_{it})(\ln L_{it}) + v_{it} - u_{it} \dots \dots \dots (8)$$

$$u_{it} = \delta_0 + \delta_1 Cor_{it} + \delta_2 Def_{it} + \omega_{it} \dots \dots \dots (9)$$

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

<i>Variables</i>	<i>coefficient</i>	<i>standard-error</i>	<i>t-ratio</i>
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	$\frac{\partial LY}{\partial LK}$	$\frac{\partial LY}{\partial LL}$	$\frac{\partial LY}{\partial T}$	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

<i>Country</i>	<i>Average</i>	<i>max</i>	<i>min</i>	<i>std</i>	<i>obs</i>	<i>rank</i>
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

<i>Country</i>	<i>Loss in GDP due inefficiency</i>					
	<i>mean</i>	<i>max</i>	<i>min</i>	<i>std</i>	<i>sum</i>	<i>Rank of mean</i>
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

<i>Country</i>	<i>The Gain from 1% increase in corruption control</i>					
	<i>mean</i>	<i>max</i>	<i>min</i>	<i>sum</i>	<i>std</i>	<i>Rank</i>
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.

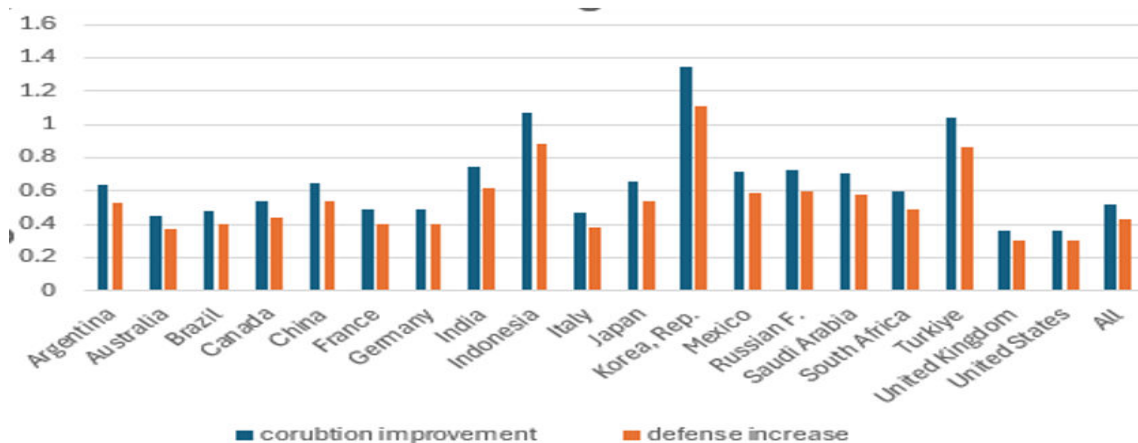


Figure 1. The effect of a 1 % average yearly increase in corruption control over the average annual GDP and the impact of 1 B\$ yearly increase in Military expenditure over the yearly average GDP
Source: Authors calculations

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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