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Unveiling Vietnam's Economic Growth Dynamics Pre-Pandemic: A Bayesian Inquiry Into Cd, Ces, Or Ves Specifications

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ABSTRACT

This study investigates the growth trajectory of Vietnam's transition economy before the COVID-19 pandemic. Three production functions, namely Cobb-Douglas (CD), Constant Elasticity of Substitution (CES), and Variable Elasticity of Substitution (VES), are specified within a neoclassical one-sector growth framework. Utilizing Bayesian non-linear hierarchical regressions on a time-series macroeconomic dataset spanning 1986-2019, the research reveals that the VES specification offers the most suitable lens for analyzing Vietnam's economic growth dynamics during the examined period. Notably, the estimated value of the elasticity of capital-labor substitution surpasses unity in the specified VES framework, indicating the attainment of unbounded endogenous growth by the Vietnamese economy. These findings underscore the imperative of bolstering investments to further propel sustained economic expansion.

INTRODUCTION

Since 1986, Vietnam's economy has undergone a transformation from a central planning system to a market mechanism. Similar to China but distinct from many Eastern European countries and the former Soviet Union, Vietnam implemented a gradual and successful reform policy, resulting in impressive economic growth rates. Over the period from 1990 to 1999, the economy averaged a growth rate of 7.8%, followed by 6.8% from 2000 to 2009, and 6.2% from 2010 to 2019. One of the key factors contributing to Vietnam's long-run economic growth is capital deepening. Physical capital growth averaged 12%, 10%, and 7.3% respectively in the three periods mentioned, while engaged labor growth only reached 2.4%, 2%, and 1.3% (Penn World Tables, version 10.01). The growth outcomes indicating significant capital deepening over several decades, suggest that the Vietnamese economy may be transitioning towards an endogenous growth trajectory. To validate this hypothesis, conducting a robustness test using an appropriate model and an efficient estimation method is imperative.

A variety of mathematical forms for production functions are available to analyze economic growth dynamics, with the CD, CES, and VES specifications being among the most prominent. The CD model, introduced in 1928, has gained widespread adoption due to its simplicity and compatibility with logarithmic functional forms in regression analysis. However, its assumption of unitary elasticity of factor substitution is overly restrictive and does not accurately reflect real-world scenarios. Empirical analyses have consistently shown that the elasticity of factor substitution varies from unity, highlighting its significant role in the economic development process. K. Arrow et al. (1961) introduced the CES production function as a more flexible alternative, allowing the elasticity of substitution to range from zero to infinity. Subsequent studies by O. de La Grandville (1989) and R. Klump & O. de La Grandville (2000) have demonstrated a positive correlation between the elasticity of factor substitution and economic growth within the CES framework. Since then, numerous articles have utilized the normalized CES function to explore the causality between factor substitutability and growth. Despite its flexibility, the CES suffers from limitations, including a weak conceptual basis and the assumption of constant elasticity of substitution. The rigidity of this assumption is evident, given that the elasticity of factor substitution varies with economic development levels. As argued by K. Arrow et al. (1961) and T. Piketty & E. Saez (2014), the elasticity of substitution between capital and labor tends to increase over the development process, reflecting diverse uses and forms of capital and increasing possibilities for substituting capital for labor. Building upon this approach, N. Revankar (1971) introduced the VES framework, which elucidates the interaction between per capita capital, output, and the elasticity of factor substitution. In this context, the VES approach highlights the potential for unbounded endogenous growth, as demonstrated by L. Jones & R. Manuelli (1990, 1997) and Karagiannis et al. (2005).

Hence, this study aims to assess the applicability of a VES framework in contrast to the CD and CES specifications, in elucidating the growth dynamics of the Vietnamese economy during its pre-COVID-19 era. The primary contributions of this research to growth economics are twofold: Firstly, it unveils that the VES production function better elucidates the intricacies of Vietnam's economic growth preceding the pandemic, surpassing the explanatory power of both the CD and CES models. Secondly, given the accelerated growth of physical capital stock relative to labor input throughout the study period, the Vietnamese economy has transitioned into a path of unbounded endogenous growth.

1. ELASTICITY OF CAPITAL-LABOR SUBSTITUTION, REVANKAR VES PRODUCTION FUNCTION, ENDOGENOUS GROWTH, AND EMPIRICS ANALYSIS

1.1 Elasticity of capital-labor substitution

In growth theory, the concept of factor substitution traces back to Hicks (1932), who laid the groundwork for theoretical exploration into the connections between economic growth, technological advancements, the elasticity of capital-labor substitution, and the distribution of factor shares. In a scenario where technology remains constant, a faster growth rate of physical capital compared to labor supply results in a decline in the relative prices of capital and labor. This prompts a shift towards substituting capital for labor, leading to a continuous increase in the capital-labor ratio until optimal levels are attained. Eventually, the elasticity of factor substitution falls below one, signifying diminishing returns to capital and a decrease in the share of capital, while the share of labor rises. This, in turn, leads to a decrease in profits and investment, culminating in the economy reaching a state of equilibrium. To offset the decline in marginal productivity and the income share of capital, as well as to prevent the factor substitution elasticity from falling below one, it is imperative to implement labor-saving technological advancements at a pace that maintains capital's productivity (Bruton, 1956). Most notably, advancements in technology often manifest in new machinery and equipment, underscoring the crucial role of investment growth in driving technical progress. Consequently, it becomes essential to identify an appropriate production function to quantify the types and pace of technological change, distinguish the impacts of technological advancements and capital accumulation on overall output, and account for shifts in substitution elasticity due to changes in the relative growth rates of labor and capital.

Consider a closed economy with a population growing exponentially at a rate $n>0$. Income Q is generated using capital K and labor L (equivalent to the population size). The technology is captured by a production function $Q=F(K,L)$ with constant returns to scale concerning both capital and labor. Hence, the intensive form of this production function is $q=f(k,1)$, where $q=Q/L$ represents the income-labor ratio and $k=K/L$ represents the capital-labor ratio. The elasticity of capital-labor substitution, denoted by ES, is commonly defined as:

$$ES(k) = \frac{f'(k)}{kf(k)} \frac{f(k)-kf'(k)}{f''(k)} \quad \text{................} \quad (1)$$

1.2 Revankar VES production function and endogenous growth

Endogenous economic growth refers to the theory in economics that emphasizes the role of internal factors, such as human capital, innovation, technological progress, and institutional development, in driving long-term economic growth. Unlike exogenous growth theories, which attribute economic growth primarily to external factors like capital accumulation or technical progress driven by external forces, endogenous growth theory suggests that growth is driven by factors that are endogenously determined within the economy itself. In the context of endogenous growth theory, the term "endogenous" refers to factors that are generated from within the economic system rather than being externally imposed. These internal factors are considered to be influenced by policy choices, institutional arrangements, investments in education and research, and other determinants that are under the control of policymakers and economic agents.

The study delves into N. Revankar's (1971) VES framework to examine the potential for unbounded endogenous growth within an economy. Revankar introduced the standard VES production function, which shares similarities with the CES, particularly in capturing the relationship between capital and labor substitution. However, a crucial distinction lies in their treatment of elasticity: while the CES maintains a constant elasticity of capital-labor substitution along an isoquant, the VES maintains this constancy only along a ray from the origin. Unlike the CES and CD models, the VES framework allows for an analysis of how changes in per capita capital (capital deepening) influence the elasticity of factor substitution. These adjustments have ripple effects throughout the economic system, impacting both physical investment and economic growth (Karagiannis et al., 2005). The Revankar standard VES production function is the following:

$$Q = F(K,L) = AK^{\alpha}(BK+L)^{1-\alpha} \quad (2)$$

where $A > 0, 0 < \alpha < 1$.

In case $B=0$, (2) is transformed to the CD. Furthermore, (2) can be expressed in intensive form:

$$q = f(k) = f(k,1) = Ak^{\alpha}(Bk+1)^{1-\alpha} \quad (3)$$

We have

$$f'(k) = \alpha\frac{q}{k}+\alpha(1-\alpha)B\frac{q}{1+ABk}k^{\alpha-1} > 0 \quad (4)$$

$$f''(k) = \alpha A(\alpha-1)(\alpha Bk+1)^{-\alpha-1}k^{-1} < 0 \quad (5).$$

The Revankar VES production function has the limiting properties:

$$\lim_{k\to 0} f(k) = 0, \lim_{k\to\infty} f(k) = \infty \text{ if } B > 0.$$

$$\lim_{k\to B^{-1}} f(k) = A(-B)^{-\alpha}(1-\alpha)^{1-\alpha} > 0 \text{ if } B < 0$$

From (4), we have

$$\lim_{k\to 0} f'(k) = \infty, \ \lim_{k\to\infty} f'(k) = A(B\alpha)^{1-\alpha} \text{ if } B > 0$$

$$\lim_{k\to B^{-1}} f'(k) = A[-B(1-\alpha)]^{1-\alpha} \text{ if } B < 0$$

$$\lim_{k\to\infty} f'(k) = 0 \text{ if } B = 0$$

Keep in mind that $f'(k)$ represents the marginal product of capital. Thus, if *B* is greater than 0, it implies a violation of one of the two Inada conditions, meaning that the marginal product of capital is strictly constrained from falling below a certain threshold.

From (3), the labor share (L_s) is: $L_s = \frac{1-\alpha}{1+B\alpha K}$ and the capital share (K_s) is: $K_s = 1 - L_s = \frac{\alpha+B\alpha K}{1+B\alpha K}$.

So, the variable elasticity of capital-labor substitution is:

$$ES(k) = 1 + Bk > 0 \quad (6)$$

Clearly evident from equation (6), when *B* is positive, *ES(k)* exceeds unity, whereas it falls below unity when *B* is negative. Additionally, *ES(k)* increases with per capita capital, suggesting economic advancement. Furthermore, an increase in *k* leads to an augmentation in the elasticity of factor substitution if *B>0*, and a reduction if *B<0*.

To examine how the elasticity of capital-labor substitution impacts economic growth, we can reformulate equation (2) as follow:

$$Q = AK^{\alpha}L^{1-\alpha}(1 + B\alpha\frac{K}{L})^{1-\alpha} \quad (7)$$

Combining (6) with (7) yields:

$$Q = AK^{\alpha}L^{1-\alpha}(1 - \alpha + \alpha ES(k))^{1-\alpha} \quad (8)$$

(8) is written in intensive form:

$$q = Ak^{\alpha}(1 - \alpha + \alpha ES(k))^{1-\alpha} \quad (9)$$

Now, we incorporate this VES specification into the Solow-Swan model. We remember that $\frac{\dot{k}}{k} = s\frac{f(k)}{k} - n \quad (10)$

where s is saving rate and n is the growth rate of population.

From (9), we have

$$\frac{f(k)}{k} = Ak^{\alpha-1}(1 - \alpha + \alpha ES(k))^{1-\alpha} \quad (11)$$

Combining (10) and (11), we have

$$\frac{\dot{k}}{k} = sAk^{\alpha-1}(1 - \alpha + \alpha ES(k))^{1-\alpha} - n \quad (12)$$

As > 0, $ES(k) > 1$, the limiting properties of the growth rate of per capita capital are as follows:

$$\lim_{k\to 0}\frac{\dot{k}}{k} = \infty \text{ and } \lim_{k\to\infty}\frac{\dot{k}}{k} = sA(B\alpha)^{1-\alpha} - n$$

Therefore, if the condition $sA(B\alpha)^{1-\alpha} > n$ holds, the model demonstrates unbounded endogenous growth. In other words, it signifies the existence of an asymptotic balanced growth path characterized by the positive growth of per capita capital. This reasoning aligns with the discoveries of L. Jones & R. Manuelli (1990, 1997), who established an unbounded growth even in the presence of non-reproducible factors and in the absence of exogenous technological advancement, provided that the marginal product of capital remains strictly bounded from below. This conclusion is in accordance with the findings of T. Palivos & G. Karagiannis (2004) and G. Karagiannis et al. (2005), who demonstrated that an elasticity of substitution asymptotically greater than one is both necessary and sufficient for the presence of a lower bound on the marginal product of capital.

$$Q = F(K, L) = AK^{\alpha}(BK + L)^{1-\alpha} \quad (2)$$

where $A > 0, 0 < \alpha < 1$.

1.3 Empirical analysis

Since its inception, the Revankar VES function has garnered widespread application across various analytical approaches, including time-series, cross-section, and panel empirical analyses. Notable recent studies include:

Cross-section studies: R. Meyer & K. Kadiyala (1974), U. Kazi (1980), and A. Zellner & R. Ryu (1998), among others. Meyer & Kadiyala (1974), based on an agricultural experimental data sample, favored the VES over the CD and the CES. Similarly, U. Kazi (1980) preferred the VES over the CES in most cases. A. Zellner & R. Ryu (1998) estimated the CES and VES specifications for various industries without directly comparing the production functions. Notably, most cross-section analyses yielded estimates of the elasticity of capital-labor substitution below unity, except for Kazi (1980).

Time-series analyses: R. Sato & R. Hoffman (1968), K. Roskamp (1977), E. Bairam (1990), and T. Ngoc (2020). Sato & Hoffman (1968), accessing data from the Japanese and U.S. private non-farm sectors, found the VES outperforming the CES. Bairam (1990) favored the VES over the CD in Japanese and Soviet economies. These studies generally yielded estimates of the factor substitution elasticity smaller than one, except for K. Roskamp (1977), who found a substitution elasticity exceeding one in some German manufacturing industries.

Panel investigations: J. Duffy & C. Papageorgiou (2000), G. Karagiannis et al. (2005), F. Grassetti & G. Hunanyan (2018), and N. Thach (2020). Duffy & Papageorgiou (2000) utilized a CES production function on a panel encompassing 82 nations and found that the elasticity of capital-labor substitution is more than one in advanced economies and less than one in less developed economies. Karagiannis et al. (2005) advocated for a VES function with a higher-than-unity substitution elasticity utilizing a panel sample consisting of 82 economies spanning 1960-1987. F. Grassetti & G. Hunanyan (2018) demonstrated that economies with greater substitution elasticity achieve higher levels of capital and income per capita equilibrium using a restricted VES production function within the Solow-type growth model. Most recently, N. Thach (2020) revealed that the Vietnamese economy exhibits endogenous growth using micro data within a non-restricted VES framework.

The gap in previous studies lies in two main aspects: Firstly, most studies predominantly rely on frequentist estimators, overlooking the potential advantages of Bayesian methodologies, and secondly, none of the existing studies have specifically assessed Vietnam's endogenous growth dynamics within a VES framework using Bayesian non-linear hierarchical regression techniques.

2. ESTIMATION METHOD, MODEL AND DATA

2.1 Method

The Bayesian framework has been unitized more and more commonly due to availability and accessibility of computer technology. Utilized first in decision theory and macroeconomics, Bayesian statistics has expanded its application to various social disciplines. The increasing popularity and accessibility of the Bayesian approach result from its superiority over conventional frequentist statistics (Briggs, 2023):

Probabilistic interpretation of uncertainty: Bayesian analysis directly provides a probability distribution for the income elasticities (α and β) through the posterior distribution.

This distribution represents the uncertainty in the parameter estimates, taking into account both the observed data and prior beliefs. Unlike frequentist methods that provide confidence intervals, Bayesian credible intervals have a natural probabilistic interpretation. These credible intervals give a range of plausible values for the parameters along with their probabilities of being within that range.

Incorporation of prior information: One of the significant strengths of Bayesian analysis is the ability to incorporate prior knowledge or beliefs about the parameters into the analysis. This is particularly valuable when there is existing information or expert knowledge about the income elasticities. The prior distribution acts as a regularization or "shrinkage" term that can stabilize the parameter estimates, especially in situations with limited data.

Flexibility with complex models and small sample sizes: Bayesian methods can handle complex models more effectively than frequentist approaches. The incorporation of prior information can be especially beneficial in cases with small sample sizes, where the prior can help in obtaining more stable and reasonable estimates. This is important when dealing with economic data, where the number of observations might be limited.

Better handling of multicollinearity: In the MRW model, there might be a high correlation between human capital and productivity, leading to multicollinearity issues. Bayesian analysis can handle multicollinearity more robustly by incorporating prior information, regularizing the estimates, and providing a more stable and interpretable result.

Decision-making and policy implications: Bayesian analysis allows researchers to make probabilistic statements about the income elasticities, which is valuable in decision-making and policy analysis. Policymakers can consider the full range of plausible parameter values and their associated probabilities when making policy decisions.

Iterative updating of beliefs: Bayesian analysis has an iterative nature; as more data become available, the posterior distribution can be updated to incorporate the new information. This updating process allows for a dynamic understanding of the parameters and their uncertainty as more data is collected over time.

Differentiating itself from previous analyses, this study employs a Bayesian hierarchical non-linear regression methodology, allowing for the consideration of the specific characteristics of various periods of economic development in Vietnam.

2.2 Models

Compared to the CES and CD models, the VES framework allows for variable returns to scale (ε≠1). While the CES follows the formulation by Arrow et al. (1961), the CD retains its traditional structure. To mitigate the impact of extreme values and normalize the data, the study employs the logarithm of income per capita. This transformation is particularly useful given the skewed distribution of incomes, with a few observations having significantly higher values. By applying the logarithmic transformation, the data distribution becomes more symmetrical, facilitating statistical analysis. Thus, the study operates with log-log functions for estimation:

$$\text{VES: } lnQ = a0 + \alpha \varepsilon lnK + (1-\alpha)\varepsilon \ln(L + \alpha BK) \quad (13)$$

$$\text{CES: } lnQ = b0 - \frac{1}{\rho}\ln\left(\delta K^{-\rho} + (1-\delta)L^{-\rho}\right) \quad (14)$$

$$\text{CD: } lnQ = c0 + \beta lnK + (1-\beta)lnL \quad (15)$$

where $a0, b0, c0$ are constants, ε is return to scale, ρ is substitution parameter, δ is distribution parameter, and β is income share of physical capital.

In terms of prior specifications, we opt for mildly informative priors to regularize the posterior results. Therefore, we assign weakly informative priors to the parameters in the VES, CES, and CD models:

$$a0, b0, c0 \sim N(0, 100)$$

$$\varepsilon \sim N(0, 1)$$

$$\alpha \sim uniform(0, 1)$$

$$B \sim N(0, 1)$$

$$\delta \sim uniform(0, 1)$$
$$\rho \sim gamma(1, 1)$$
$$\beta \sim uniform(0, 1)$$
$$Variance \sim Igamma(0.01, 0.01),$$

2.3 Data

The study utilizes a time-series dataset covering real GDP, physical capital stock, and labor engagement in Vietnam from 1986 to 2019. This period encompasses the onset of market reforms in Vietnam up to the onset of the global COVID-19 outbreak in early 2020. The entire dataset is sourced from the Penn World Tables, version 10.01. GDP and physical capital stock data are presented in constant 2017 national prices (in millions of 2017 US dollars), while labor input is measured by the number of persons engaged (in millions). In contrast to Ngoc (2020), where labor force data were sourced from the national statistical office, potentially containing errors and of low quality, this study employs the number of working people provided in the Penn World Tables as a proxy for labor input. Additionally, while Ngoc (2020) employs a non-linear approach, the current study utilizes a Bayesian non-linear hierarchical regression methodology to capture the nuances of different stages of development more comprehensively.

3. OUTCOMES AND INTERPRETATION

3.1 Fit comparison between the CD, CES, and VES

The study employs graphical tools to assess the goodness-of-fit of three growth models: CD, CES, and VES. Firstly, Q-Q plots for residuals (Fig. 1) are presented. These plots evaluate the alignment of points with the expected diagonal line, which represents the quantiles of the theoretical distribution compared to the quantiles of the observed data. A good fit is indicated if the points closely follow the diagonal line, suggesting that the residuals are approximately normally distributed. Secondly, the residuals plots (Fig. 2) depict the spread of residuals around the regression line in the context of regression analysis. Residuals represent the differences between observed and predicted values. A consistent and uniform spread of residuals indicates that the model's predictions are consistent across different levels of the predictor variables. Thirdly, the observed vs. predicted plot (Fig. 3) is useful for evaluating how well the model's predicted values match the actual data across the range of predicted values. The diagonal line (y = x) represents the "line of equality". The degree of alignment with this line indicates the extent to which the model's predicted values match the actual observed values.

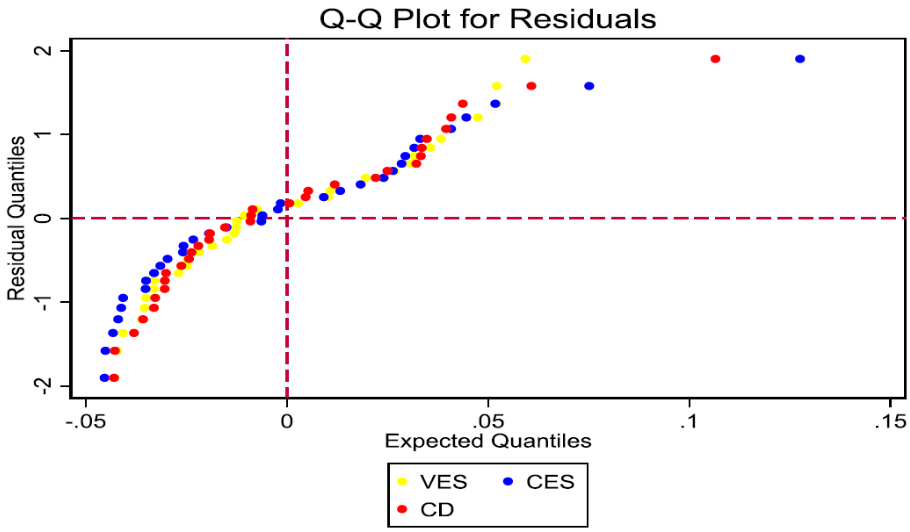

Figure 1. Comparing the VES, CES, and CD

Source: own

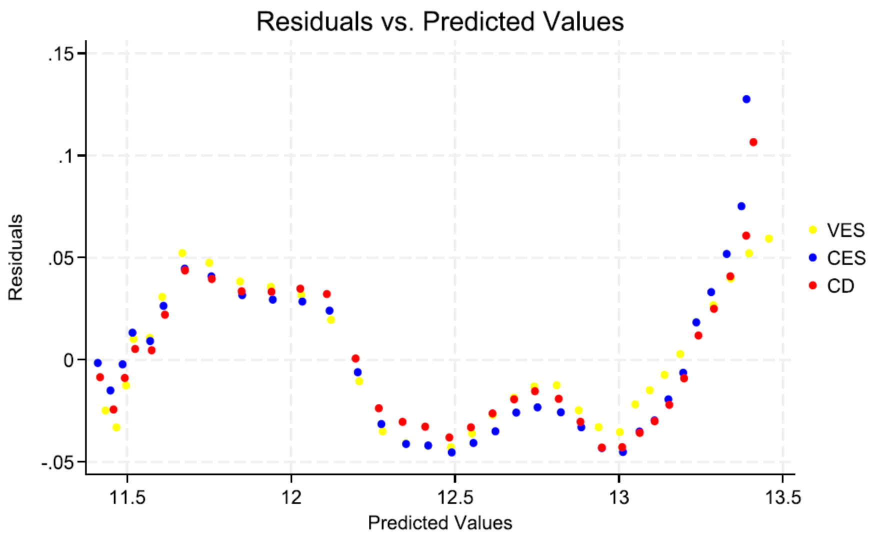

Figure 2. Comparing the VES, CES, and CD

Source: own

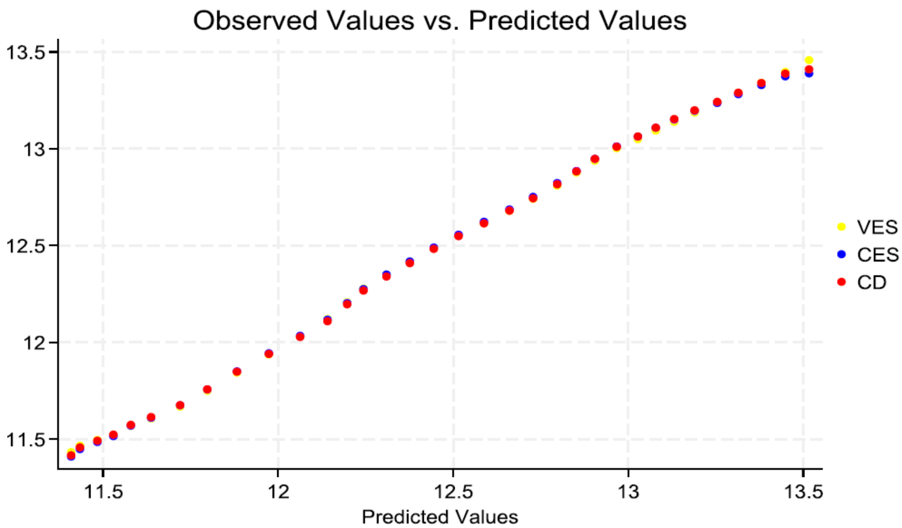

Figure 2. Comparing the VES, CES, and CD

Source: own

Upon reviewing Figures 1, 2, and 3, it becomes evident from a close look that the VES model appears more favorable compared to the CES and CD models, especially considering that the latter two exhibit a greater number of outliers than the VES model. Additionally, the numerical findings presented in Table 1 further confirm the superior performance of the VES model relative to the CES and CD models when the DIC value of the VES is smaller, while its log(ML), log(BF), and P(M|y) values are greater compared to the CES and CD.

Table 1. Comparing the VES, CES, and CD using Bayesian information criteria

	DIC	*log(ML)*	*log(BF)*	*P(M|y)*
VES	-755.265	48.897	.	0.743
CES	-168.749	47.445	-1.451	0.174
CD	-125.829	46.701	-2.195	0.083

Source: own

3.2 Stability test for the VES model

To conduct Bayesian inferences, the study verifies Markov Chain Monte Carlo (MCMC) convergence for all model parameters. Various diagnostic tools are available for this purpose, among which histogram plots are utilized. Generally, the histograms derived from the MCMC samples closely resemble those generated from samples of the expected distribution for all parameters, indicating sequence convergence. In the case of MCMC convergence to the stationary distribution, we can affirm the estimation robustness.

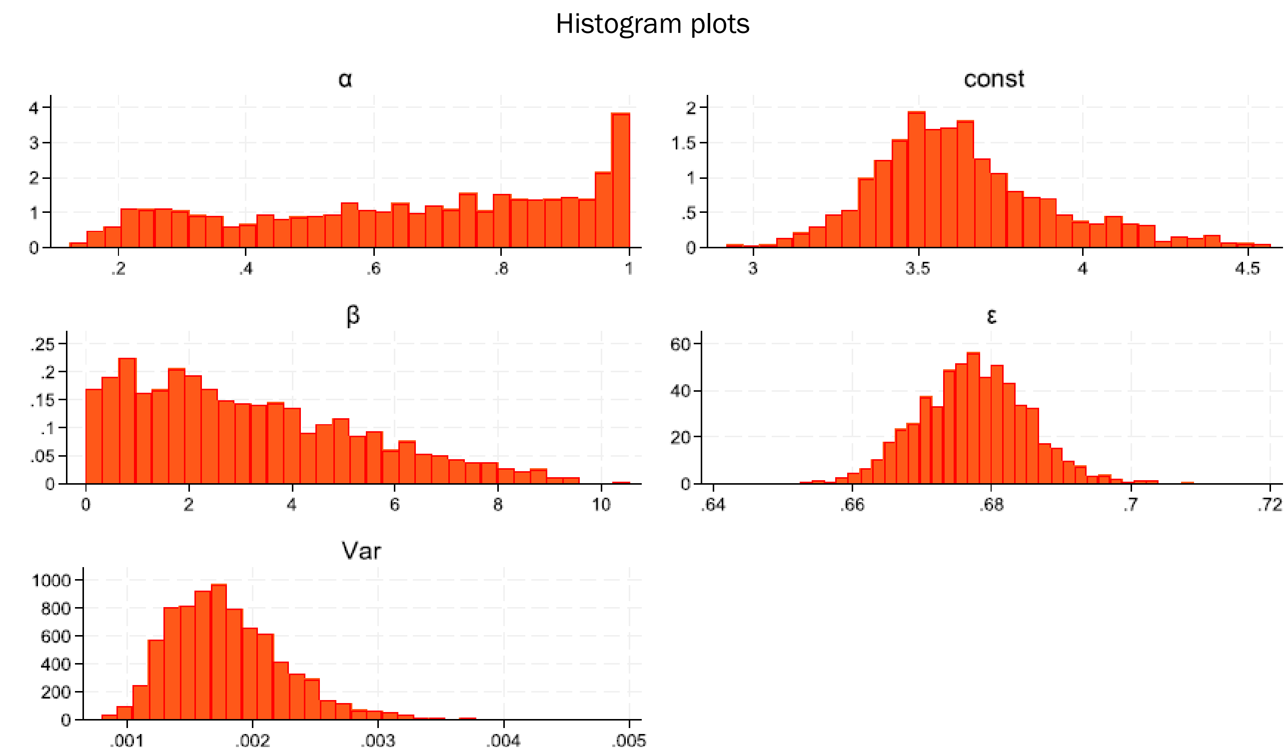

Figure 4. MCMC diagnostics

Source: own

3.3 Estimates and interpretation

The findings depicted in Table 2 reveal that the estimated value of B stands at 3.170 within the VES model, surpassing 0. This outcome indicates that ES(k) > 1, meeting the necessary and sufficient condition for unbounded endogenous growth. Consequently, the Vietnamese economy has sustained continuous endogenous growth throughout the pre-pandemic transformation period. Moreover, with ε = 0.677 (≠ 1), the possibility of non-constant returns to scale in this economy is feasible. These results are consistent with the theoretical and empirical predictions of Jones & Manuelli (1990, 1997), Palivos & Karagiannis (2000), and Karagiannis et al. (2005). Given that the growth rate of physical capital surpasses that of labor supply by fivefold during the study period, these findings are logical and robust.

Table 2. Estimates of the VES, CES, and CD

Production function	*Sample period*	*Parameter*	*Mean*	*MCSE*	*PPI*
VES	1986-2019	α	0.654	0.037	[0.194, 0.998]
		B	3.170	0.538	[0.207, 8.261]
		ε	0.677	0.000	[0.663, 0.693]
		a0	3.637	0.050	[3.186, 4.283]
		Var1	0.002	0.000	[0.001, 0.003]
CES	1986-2019	δ	0.820	0.022	[0.765, 0.897]
		ρ	0.137	0.019	[0.097, 0.203]
		b0	2.175	0.121	[1.651, 2.546]

		Var2	0.002	0.001	[0.001, 0.003]
CD	1986-2019	β	0.574	0.000	[0.557, 0.591]
		c0	3.411	0.004	[3.248, 3.568]
		Var3	0.001	8.6e-06	[0.001, 0.002]

Note: MCSE is Monte Carlo standard error; PPI is a credible interval, within which the population mean lies with a 95% probability.

Source: own

CONCLUSION AND LIMITATION

The study endeavors to delve into the economic growth dynamics of Vietnam during the pre-COVID-19 transition era. For this purpose, it scrutinizes and contrasts three production functions: VES, CES, and CD, employing Bayesian non-linear hierarchical regressions on a time series spanning from 1985 to 2019. Remarkably, the VES outperforms both the CES and CD models. With the estimated value of the capital-labor substitution elasticity exceeding unity in the non-restricted VES framework, the study suggests that the Vietnamese economy has unlocked the potential for unbounded endogenous growth.

However, a notable limitation lies in the absence of human capital as a crucial determinant in modern growth models. Consequently, future growth specifications must incorporate this variable to provide a more comprehensive analysis.

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