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# A FRESH LOOK AT THE DECOMPOSITION OF TOTAL FACTOR PRODUCTIVITY GROWTH: NEW EVIDENCE USING THE FÄRE-PRIMONT PRODUCTIVITY INDEX

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This study assesses Vietnam's economic growth from 2002 to 2019 through the lens of total factor productivity (TFP), using panel data in 63 provinces and cities. It uses the Färe-Primont index built on the stochastic frontier analysis method to decompose TFP into several components and overcome certain methodological shortcomings in previous work. The focus is on the critical roles of TFP and efficient capital allocation mechanisms in sustaining economic growth. The empirical results show that Vietnam has lost its growth momentum since 2015 and that the public sector makes less efficient use of resources than the private sector. The study thus provides some policy implications for Vietnam to target sustainable TFP growth path in the coming years. The findings can be helpful for the future assessment of sustainable (economic) growth during the post-COVID period and further analysis of technical issues in the calculation of TFP.

*Keywords*: Färe-Primont, Stochastic Frontier Analysis, Sustainable Economic Growth, Vietnam
*JEL Classification*: G28, O47, Q01, R11

## 1. INTRODUCTION

Many indicators are used to assess a country's socioeconomic growth, including gross domestic product (GDP), the social progress index, the human development index, and the UN's 17 Sustainable Development Goals (SDGs). GDP remains a common indicator to assess economic growth, especially for developing countries. Maintaining long-term GDP growth is expected to lead to reduced inequality, improved living standards, and improved environmental quality, as predicted by the Kuznets curve.

However, GDP growth does not adequately capture human welfare and is heavily dependent on a country's context (Van den Bergh, 2009). For example, some initiatives in Vietnam, such as pilot policies and promoting competition through state-owned enterprises (SOEs), have imprints of feudal history by respecting the role of the king and mandarins (Malesky and London, 2014). This raises the issue of the appropriate criteria for sustainable economic growth in a transitional country like Vietnam.

The sustainable growth of nations has been an important debate for decades, with productivity approaches becoming increasingly prevalent. Üngör (2017) and Cole et al. (2005) argue that the success or failure of economic development in Asian and Latin American countries comes from a productivity-based outlook, which is supposed to boost the overall economy and improve individual lives when there is a positive linkage between wages and productivity. For example, Eichengreen et al. (2012) show that 85% of strikes worldwide occur due to decreased productivity. Countries should, therefore, base their economy more on productivity and less on capital accumulation. Furthermore, throughout history, successful economic development has required productivity-based growth over several decades (Park, 2012).

Total factor productivity (TFP), also referred to as multi-factor productivity, is the ratio of aggregate output (e.g., GDP) to aggregate inputs like labor, capital stock, and technological and other factors (Sickles and Zelenyuk, 2019). TFP growth can mean increasing aggregate output with the same amount of aggregate inputs, using fewer inputs to produce the same aggregate output, or both. Maintaining a consistent TFP growth rate over time not only ensures long-term economic growth but is also the foundation of higher living standards and social welfare (Baier et al., 2006; Ivanic and Martin, 2018; Koen et al., 2018; Prescott, 1998; Steindel and Stiroh, 2001). Despite its important role, TFP remains a black box that needs to be explored. One of the most popular models, Solow's residual, considers the rise in TFP as output growth in an economy that cannot be explained by the accumulation of labor and capital (Felipe, 1999). There needs to be more research on how to improve TFP by, for example, identifying which components cause TFP sluggishness and how to counteract it.

Improving TFP is especially important in transitional countries like Vietnam. First, Vietnam is gradually losing its low-cost labor advantages because of the rapid growth in the wage-to-productivity ratio, the primary source for attracting foreign direct investment (FDI) (T-H Le and Tran-Nam, 2018), so relying on economic growth through capital accumulation, especially FDI, is not a sustainable option. Second, to join the global value chain, take advantage of technology and gain market share, Vietnamese workers must be highly productive (Anner, 2015). Third, productivity growth is key to achieving the SDGs (Baier et al., 2006; Ivanic and Martin, 2018). Vietnam is also an interesting case study because it has transformed from a centrally planned to a socialist-oriented market economy, it is more open to policy and citizen participation, coupled with many special socio-economic features, that contribute to a more comprehensive picture of economic growth (Malesky and London, 2014); and it has a rapid growth rate in many respects, which facilitates predicting growth trends and testing economic hypotheses. Therefore, the present study seeks insights to reveal details of the black box that is TFP change by breaking TFP down into five components, following O'Donnell (2018), and evaluating its trends over time.

Accordingly, the focus is on Vietnam's productivity and the underlying factors that promote it. Some scholars (e.g., Barker and Üngör, 2019) believe that internal-capacity factors like enhancing technology and allocation efficiency rather than capital accumulation promote stable economic development. More importantly, the inefficient use of capital is the main reason economic growth has yet to reach its potential level, given that the division of capital between private and public sectors is unstable in Vietnam (Barker and Üngör, 2019; Tu-Anh and Perkin, 2021). To investigate the situation, data from 63 Vietnamese provinces and cities from were gathered from 2002 to 2019, spanning three prime ministers and a strong but shifting economic structure (Tu-Anh and Perkins, 2023). Due to the relative independence of policy and the trend of devolving power from the central government, it is most appropriate to examine economic policy problems at the local level. For the rest of this paper, the internal-capacity component is referred to as the sustainable components' TFP (SCTFP). Given the critical role of TFP and efficient capital allocation mechanisms in sustaining economic growth, the study seeks to answer the following research questions:

*(1) Which components drive TFP growth in Vietnam?*

*(2) How does capital structure affect TFP growth in Vietnam?*

Based on the recent econometric model of O'Donnell (2018) and the analytical framework of Thanh et al. (2019), the TFP index, which is built on stochastic frontier analysis (SFA-FP), is used: it enables exploring the components of TFP change, is based on reasonable assumptions and can easily be adapted to the available database; it satisfies all requirements for model tractability without requiring too much data; it allows researchers to capture stochastic signals in the model by determining the appropriate production function (O'Donnell, 2016). Compared with non-parametric data envelopment analysis (DEA) and the Malmquist index, white noise and stochastic fluctuation are the dominant causes of bias in TFP; the solution is often the bootstrap technique. To address the two research questions, we first decompose TFP change into components using the SFA-FP index and then examine the impact of capital structure on TFP and its components using the general method of moments (GMM) estimator (see Section 3).

The study makes several contributions. First, it provides fresh evidence of sustainable TFP growth in Vietnam using the SFA-FP index, a new decomposition method introduced by O'Donnell (2016) and recently applied by Njuki et al. (2018). Second, it proposes applying the new TFP assessment method in the context of Vietnam, which has different functional production structures given specific and clear economic assumptions (compared to the non-parametric approach), thus permitting a consistent design of the TFP index in future studies. Third, given the role of productivity, the study provides evidence of inefficiencies in resource use by the Vietnamese government that lead to unsustainable growth. The empirical results demonstrate that the public sector is

28.75% less productive than the private sector in the use of capital, causing the sluggish TFP growth momentum since 2015. Therefore, the present study provides a practical model for assessing an economy's TFP using flexible economic assumptions, enabling policymakers to improve that TFP.

The paper is structured as follows: Section 2 presents an overview of Vietnam's economic performance in available indicators and its economic potential. Section 3 examines economic growth in countries around the world through the TFP lens to find patterns of sustainable growth. The paper also proposes the ratio of private capital in the economy as a capital-related indicator to improve TFP. Section 4 describes the methodology for calculating TFP through SFA-FP and a practical strategy to examine the impact of capital structure reform on TFP in Vietnam. Section 5 presents the research results and policy implications.

## 2. AN OVERVIEW OF ECONOMIC PERFORMANCE IN VIETNAM

### 2.1. Economic Growth

A consistent assumptions in the present study is that economic growth can be considered using the basic Cobb-Douglas production function commonly used in previous studies (Aigner et al., 1977). Input factors included labor, technological factor, and capital stock (Thanh et al., 2019). Those authors highlight certain some prominent influences on Vietnam's long-term economic growth: labor, technology, and capital structure.

Vietnam's human capital faces several obstacles: a rapidly aging population, unskilled labor, and a low-quality higher education system. The proportion of people over 60 has increased from 6.9% in 1979 to 10.15% in 2019, and 80.8% of the labor force had no skill qualifications in 2019. The ratio of people in the 50–65 age group to that in the 0–14 age group has grown, which will put pressure on younger generations (see Appendix 1). Vietnam faces two serious problems in education: the higher education system has experienced slow or even no growth, especially in research, and there is limited practical applicability of what is taught. Therefore, for this empirical study, the quality of labor is unlikely to have changed and can reasonably be represented through workers over 15 years old in Vietnam.

In technology, Vietnam has made only modest expenditures on science and technology, which amounted to about 0.74% of GDP in 2016, and research shows that Vietnam's science and technology improvement has largely come from FDI. Ni et al. (2017) argue that the spillover effect has improved the quality of technology and thus labor productivity in the domestic sector. Anwar and Nguyen (2014) note that FDI can positively affect the technical efficiency of private sector performance. Thus, although its value added is relatively limited, FDI will still become a crucial factor in Vietnam's short-term economic growth. Beyond technology, energy has a long-term relationship with economic growth in Vietnam (Tang et al., 2016). Therefore, a focused macro-development strategy that links energy, technology, and policies encouraging skilled labor are crucial in the context of limited resources, especially capital stock. For empirical studies, the evolution of technological factors is assumed to have a linear change over time.

### 2.2. Capital Structure

Property rights in Vietnam still have several shortcomings, especially the land use policy known as the all-people ownership regime. Guaranteed property rights contribute not only to creating the foundation for innovative development in the (digital) economy but also to expanding "secret" capital in developing countries (De Soto, 2001). Le (2020), citing losses of 8.03% of GDP per capita due to land-use restrictions in Vietnam, argues that establishing private ownership as quickly as possible is key to sustainable growth.

Vietnam's property regime has many distinctive features due to its history. The impact of property rights on the economy is also uncertain across countries within a certain period (Chang, 2002; Ogilvie and Carus, 2014). For example, Thu and Perera (2011) assert that intermediate levels of property rights in Vietnam create dynamic real estate environments without necessarily being based on a solid private ownership regime. Regarding the process of firmly promoting property rights, the International Monetary Fund (2000, p.118) indicated that the reform strategy employed in China "has been used by pragmatism and flexibility, with different reform approaches often allowed to coexist and compete for a period. Given the difficulties of different implementations in such a large and country such as China, this approach has helped to build local ownership of important improvements and has yielded lessons that then be applied countrywide."

Furthermore, private ownership is an omnibus term that includes the right to possess, use, and dispose of the property. As a result, promoting (outright) property rights is a lengthy, costly process and may be appropriate for all historical stages of development (Chang, 2002; Chimhowu, 2019, p.898). Chimhowu (2019) also emphasizes that property rights can be improved through bottom-up incentives, such as promoting free trade, civic participation, strengthening institutions to protect land tenure, increasing resource access through information transparency, and improving legal literacy, especially among middle-income earners. Therefore, economists should carefully consider the pragmatic and intermediate status of property rights in Vietnam when discussing policy proposals and implications. Finally, for empirical studies, the evolution of ownership reign is difficult to capture in the model, so the present study assumes that its improvement or decline tends to occur over time.

### 2.3. TFP

Barker and Üngör (2019) argue Vietnam's impressive economic growth has mainly come from capital accumulation and agricultural labor, with low-productivity work still accounting for approximately half of the labor force. Furthermore, the unbalanced development in agriculture and non-agriculture is an obstacle to growth. From this perspective, the authors imply that Vietnam’s growth is relatively unsustainable. By contrast, other reports on Vietnamese productivity growth have offered more positive views (e.g., Thanh et al., 2019; Vietnam National Productivity Institute (VNPI), 2017).

With the data envelopment analysis - Färe-Primont (DEA-FP) index, Thanh et al. (2019) show that on one hand, Vietnam’s TFP growth between 2010 and 2017 was impressive, at 3.46% per year, with technical efficiency the driving factor; on the other, the authors warn that sluggish productivity growth in 2010-2017 signifies that Vietnam will lose sustainable growth momentum in the coming years. VNPI reports are often used to measure TFP with the Solow residual approach because its methodology is intuitive, easy to practice, and consistent with previous reports. Accordingly, the contribution of TFP to economic growth in Vietnam was 44.87% in 2016, 46.09% in 2017, 44.76% in 2018, 47.71% in 2019, and 44.43% in 2020, compared to an average of 32.84% between 2011 and 2015.

The methods of assessing TFP have certain shortcomings: they do not control for stochastic portions in the model, they do not fully guarantee economic axioms (Thanh et al., 2019), and the assumption of the Solow residual method is extremely sensitive to fluctuations in institutional performance. To overcome these disadvantages, the present study takes advantage of the Cobb-Douglas production function (Aigner et al., 1977) and the logic of the TFP index based on the SFA estimator; namely, the SFA-FP index (O’Donnell, 2018). The SFA-FP index also offers many technical advantages. Given the importance of productivity growth, the comparative TFP thresholds noted in the literature review, and earlier empirical evidence by Thanh et al. (2019), the present study investigates whether Vietnam’s TFP has lost its growth momentum.

## 3. LITERATURE REVIEW

### 3.1. Production Function and SFA

In economics, the production function represents the relationship between the quantity of inputs like labor, capital, and natural capita used and the amount of output obtained as measured by GDP (Sickles and Zelenyuk, 2019). TFP indicates the amount of product obtained from any combination of inputs with the best possible level of technology used at a given time. In empirical estimation using the stochastic frontier model proposed by Aigner et al. (1977) to measure technical efficiency, the production function is expressed by the formula

$$Y_i = f(x_i, \beta)e^{v_i - u_i}, \quad (1)$$

where $Y_i$ represents the output of the production process of the $i^{\text{th}}$ economy, $x_i$ is an input vector used in the production process, $\beta$ represents a vector of parameters to be estimated, $u_i$ reflects technical efficiency associated with non-negative variables, and $v_i$ are the stochastic signals. Given the Cobb-Douglass form, Eq. (1) becomes:

$$lnY_i = ln\beta_0 + \Sigma_{m=1}^{M} \beta_m \ln(x_i) + v_i - u_i. \quad (2)$$

In empirical research measuring countries' TFPs, two commonly used inputs are labor (L) and capital (K), which is estimated through data on investment (I) in the economy (Schreyer, 2009), corresponding to year $t$, in the following formula:

$$K_t = (1 - \delta) \times K_{t-1} + I_t, \quad (3)$$

where $K_0 = I_0/(\delta + 0)$, $\delta$ is the depreciation rate and θ the growth rate, both in percentages.

### 3.2. The Linkage between TFP and Economic Performance

Economic performance and TFP have had a close nexus throughout recent decades of economic development, especially in Latin American countries, the newly industrialized economies (NIEs) of Taiwan, Singapore, South Korea, and Hong Kong, and emerging and developing countries like China and India. Latin American countries were known for their failure to achieve sustainable economic growth from the 1950s to the 1980s (Baier et al., 2006). The slow growth of TFP was a critical cause; indeed, Cole et al. (2005) show that annual TFP growth for those countries was less than 0.3%. On the contrary, China, India, and the NIEs enjoyed rapid TFP growth. For example, Üngör (2017) reveals that between 1963-2010, Korea's average annual productivity growth was 4.57% in agriculture, 5.7% in industry, and 1.04% in services. Examining productivity growth in Asia from 1970 to 2007, Park (2012) found that annual TFP growth in India, the NIEs, and China was about 2%, 2%-4%, and 4%-7%, respectively.

Looking back on the last 30 years of development in East Asia provides empirical evidence of sustainable economic growth through the TFP lens. In other words, the TFP growth rate in the previous period is the momentum for the current performance of the Asian Miracle. Felipe (1999) summarized TFP growth rates in East Asian countries in the 1960–1990 period and found that high, stable TFP growth in countries like Singapore, China, and Korea has played a key role giving those countries more advanced and powerful economies. By contrast, the decline in the Philippines economy may be due to a prolonged period (1970-1990) without TFP growth. Felipe also indicates that methodological assumptions lead to significant variations in TFP results, making it vital to clarify presumptions regarding the definition of technical progress and research method limitations. Zheng et al. (2009) detail China's productivity growth between 1978 and 2005, showing that annual TFP growth (3.21%-4.27%) has contributed nearly 10% of GDP growth per year.

Levenko et al. (2019) provide empirical evidence on the linkage between economic growth and TFP of 11 European countries between 1996 and 2016. Given the large size of those economies, the results demonstrate the importance of TFP for sustainable growth. Indeed, some countries with relatively high and stable economic performance have annual TFP growth above 2% (e.g., Lithuania, Poland, Latvia, Estonia, and Romania). Levenko et al. (2019) also emphasize that a high TFP growth rate can work as a cushion that softens the blow when an economy faces shocks like the 2007-2008 global economic crisis.

**Table 1**. Perspectives on TFP Growth and Sustainable Development

| Level | Annual TFP growth | Countries (period) |
|---|---|---|
| No growth | < 0.3% | Latin America (1950-1980); South Korea (1975-80); Philippines (1970-1990) |
| Low growth | ≈ 2% [1.6; 2.6] | India (1980-2007); Japan (1970-1985); South Korea (1970-1975); Singapore (1975-1980); Malaysia (1970-1980), (1976-1980), (1980-1990), (1960-1989); Indonesia (1960-1989); Thailand (1960-1989); Poland and Romania (1996-2016) |
| Sustainable growth | ≈ 3% [2.8; 3.5] | Newly industrialized economies (1970-2007); South Korea (1970-1980), (1985-1990); Hong Kong and China (1961-1966); China (1975-1980), (1984-1994), (1993-2005) |
| High growth | > 4% | China (1970-2007), Singapore (1966-1970) |

*Source:* Authors' synthesis of Cole et al. (2005), Felipe (1999), Levenko et al. (2019), Park (2012), Zheng et al. (2009)

The data in Table 1 suggest that to achieve sustainable economic growth, Vietnam must maintain an annual TFP and SCTFP growth rates over 3%. TFP as estimated by the Solow residual method is commonly used in productivity reports. The method considers TFP as including all factors other than capital and labor; then, when environmental factors and stochastic residuals change, biased TFP calculations result. Criticizing the assumption of the Solow residual approach, Felipe (1999: 24) states that an "exogenous technical progress implies that technology is superimposed on the system, in the sense that [technology] is assumed to grow over time for no stated reason and determined outside the economic system considered." The difficulty in relaxing these assumptions in the theory and method makes it more difficult to develop a complete empirical model. That is why a better approach is needed to deal with these rigid assumptions.

Another way of assessing TFP is the non-parametric approach of the Malmquist index (Coelli and Rao, 2005), but it does not fully guarantee the relevant economic axioms discussed in O'Donnell (2016). Thanh et al. (2019) make an effort to apply a more promising approach, the DEA-FP index, to examine TFP in Vietnam in depth. The DEA-FP fully satisfies the relevant economic axioms and allows the decomposition of TFP into multiple constructs. However, their research methodology has some disadvantages: there is no clear growth function structure, and it cannot handle stochastic and error terms in the model. To help deal with these issues, the present study applies the SFA-FP index discussed in detail elsewhere (Njuki et al., 2018; O'Donnell, 2016).

Several notable points emerged from the literature review. TFP is an essential indicator of sustainable economic growth and can offer momentum to future growth and a cushion against economic shocks. Variations in TFP estimates are common, depending on specific research methods and model assumptions. Therefore, studies should determine the assumptions, limitations and advantages of the selected research method. The analysis of TFP growth should be divided appropriately given the research period, spatial context, and economic structure. In addition, measurement error is commonly neglected in papers and is a serious issue in transitional countries because of the significant contribution of the underground economy. It is essential to capture a biased direction of the TFP calculation, in addition to ensuring the appropriate economic assumptions and methodological approach. Finally, studies on TFP measurement often lack implications for policymakers, so researchers must pay more attention to the practicality of TFP evaluation. The present study evaluates TFP using O'Donnell's (2018) approach to address these limitations; details appear in Section 4.

### 3.3. Indicators Improving the Sustainable Growth

In the early stage of development, capital accumulation is essential (Storm and Naastepad, 2005). In particular, promoting private ownership reveals the "secret of capital" (De Soto, 2001). However, in transitional countries with an all-people ownership regime, the privatization of ownership is a long-term effort. Chang (2002) and Chimhowu (2019) note that ownership is an omnibus term and can be improved through bottom-up approaches. Furthermore, the findings in these countries show that despite the absence of solid private ownership, market activities are vibrant, even in the real estate sector (Thu and Perera, 2011).

Therefore, the present study focuses on finding indicators that reflect the mechanism of improving public sector efficiency toward the level found in the private sector. Indeed, like China, one of Vietnam's biggest problems in improving economic efficiency as measured by TFP is the link between resource allocation and the competition mechanism (De Soto, 2001; Tu-Anh and Perkins, 2021). The present study examines the damage caused by concentrating too much capital at the state level at the expense of the private sector.

Vietnam is a transitional country whose growth is driven mainly by capital accumulation rather than technological advances (Barker and Üngör, 2019). Although its investment capital rate is relatively high, its impressive growth rate masks inherent shortcomings. Given that domestic investment capital shows many unsustainable signs, such as the saving rate having decreased to 29.27% of GDP by 2020, foreign investment capital has limited added value. For example, the value added of Intel Vietnam, one of the largest foreign firms in the country, amounted to only 3% of its profits (Fulbright University Vietnam, 2017). Moreover, increasing capital depreciation is also becoming a major obstacle to catching up with other Asian countries.

The present study applies a micro-analytic framework to the theory of capital structure (Harris and Raviv, 1991) and uses macro-empirical evidence, such as that generated by Mokhova and Zinecker (2014), to investigate whether shifting Vietnam's capital structures from the state to the private sector can positively impact its economy by increasing its TFP. Three indicators can be applied to evaluate capital use efficiency: return on assets (ROA), return on equity (ROE), and the velocity of the enterprises (see Appendix 2). Vietnam is a developing socialist country with significant direct government intervention through SOEs, which has led to unpredictable economic consequences. The country has promoted private sector development since implementation of the 1999 Enterprise Law, but Schaumburg-Müller (2005) still found that government expenditure was creating a crowding-out effect, especially during periods of extremely high growth. In particular, the policy of increasing demand in 2008 and 2009 was partly responsible for serious macro-level consequences like hyperinflation. Therefore, a shift of capital used from the public to the private sector is necessary to improve productivity in coming years.

*Hypothesis: A shift in capital structure toward privatization contributes to an increase in TFP in the economy.*

## 4. METHODOLOGY AND DATA

### 4.1. TFP

The TFP of firm $i$ in period $t$ is defined as

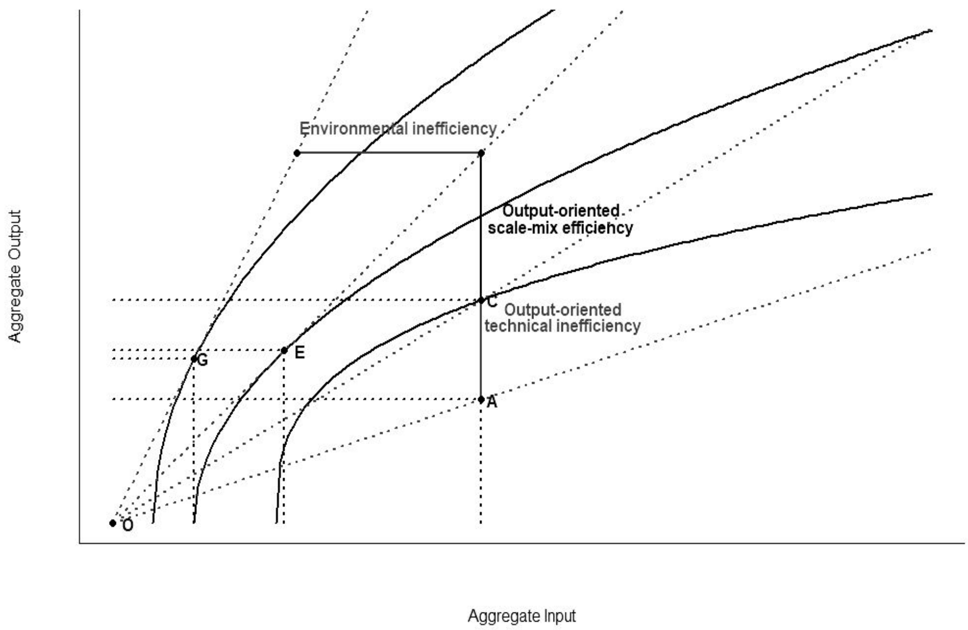
$$TFP_{it} = \frac{Q(q_{it})}{X(x_{it})}, \quad (4)$$

where $q_{it}$ denotes the vector of L outputs, and $x_{it}$ represents the vector of M inputs. $Q(\cdot)$ and $X(\cdot)$ are non-negative, non-decreasing, linear, homogeneous, and scalar aggregator functions. The TFP is decomposed into several components. Following O'Donnell (2016), it includes technical change ($dTECH$) and efficiency change ($dTFPE$), in which technical change shows the change in TFP's potential ($TFP^*$), and efficiency change is constituted by output-oriented technical efficiency ($OTE$) and output-oriented scale-mixed efficiency ($OSME$). Environmental efficiency ($EE$) is discussed in O'Donnell (2016). $TFP_t^*$ denotes the maximum TFP that is possible using period-*t* meta technology, $(= \frac{Q_t^*}{X_t^*})$. In Figure 1, $TFP_t^*$ is shown through the curve passing through point G (= slope of the ray 0G). $TFPE$, which denotes overall firm performance, is TFP efficiency $(= \frac{TFP}{TFP^*})$ (O'Donnell, 2016, 2018). OTE and OSME are shown in Figure 1 as the ratios $\frac{\text{slope 0A}}{\text{slope 0C}}$ and $\frac{\text{slope 0C}}{\text{slope 0E}}$, respectively. TFPE can be changed by the production environment, which is formally defined as variables that are physically involved in the production process but never chosen by firms such as infrastructure and the global supply chain. The role of the production environment is captured by a measure of EE. In Figure 1, the curve passing through point E represents the boundary of the period-and-environment-specific production possibilities set by the following:

$$T^t(z_{it}) \equiv [(x, q)],$$

$x$ can produce $q$ in period t in an environment characterized by $z_{it}$.

The maximum TFP that can be achieved by firm $i$ in period *t* is $TFP_t^*$ (= slope of the ray 0E). Thus, the EE of firm $i$ in period t is $EE_{it} = \frac{\text{slope 0E}}{\text{slope 0G}}$.




*Source:* Authors' work based on O'Donnell (2016).

**Figure 1.** An Output-Oriented Decomposition of TFP Efficiency

Let the period-and-environment-specific output (inputs) distance function be defined as

$$D_O^t(x, q, z) \equiv inf\,[p > 0: (x, q/p) \in T^t(z)]$$
and $$D_I^t(x, q, z) \equiv sup\,[\theta > 0: (x/\theta\,, q) \in T^t(z)], \quad (5)$$

where $T^t(z)$ denotes the production possibilities specific to a period and environment, i.e., the set of output-input combinations that are possible using the period $t$ meta-technology in a production environment characterized by $z$]. If outputs (inputs) are strongly disposable, then a suitable aggregator function is $Q(q) = D_O^{\bar{t}}(\bar{x}, q, \bar{z})$ $(X(x) = D_I^{\bar{t}}(x, \bar{q}, \bar{z}))$ where $\bar{t}$ is a representative time period, and $\bar{x}$, $\bar{q}$, and $\bar{z}$ are vectors of representative inputs, outputs, and environmental variables, respectively. By construction, the period-and-environment-specific output (input) distance is nonnegative and linearly homogeneous in outputs (inputs). The corresponding index that compares the TFP of province $i$ in year $t$ with the TFP of province $k$ in years can then be computed as the ratio of $TFP_{it}$ over $TFP_{ks}$:

$$TFPI_{ksit} = \frac{D_O^{\bar{t}}(\bar{x}, q_{it}, \bar{z})}{D_O^{\bar{t}}(\bar{x}, q_{ks}, \bar{z})} \frac{D_I^{\bar{t}}(x_{ks}, \bar{q}, \bar{z})}{D_I^{\bar{t}}(x_{it}, \bar{q}, \bar{z})}. \quad (6)$$

The use of $k$ and $s$ allows for changing the baseline in the comparison. In our empirical model, a province is compared with itself in 2002 to minimize the problem of sectoral changes among provinces, which is a known issue with variations in TFP. For example, the baseline for comparison is province $k = i$ in $s = 2002$. Different choices are possible regarding the distance function. For instance, the log-distance function can be the Cobb-Douglas function (Aigner et al., 1977)

$$\ln D_O^t(x_{it}, q_{it}, z_{it}) = \sum_{l=1}^{L} \gamma_l \ln q_{ilt} - \varphi_i - \lambda t - \sum_{j=1}^{J} \delta_j \ln z_{ijt} - \sum_{m=1}^{M} \beta_m \ln x_{imt}, \quad (7)$$

where $\varphi_i$ is a fixed effect capturing time-invariant features of the environment, such as topography, $\sum_{l=1}^{L} \gamma_l = 1$, and $\sum_{m=1}^{M} \beta_m = r$. It can then be shown that, in this case, the TFPI defined by equation (6) takes the form used by O'Donnell (2016):

$$TFPI_{ksit} = \prod_{l=1}^{L} \left(\frac{q_{lit}}{q_{lks}}\right)^{\gamma_l} \prod_{m=1}^{M} \left(\frac{x_{mks}}{x_{mit}}\right)^{\frac{\beta_m}{r}}. \quad (8)$$

Consider the case where production can be summarized using only one output such as GDP as in our application. Then, the index presented above is simplified to

$$TFPI_{ksit} = \frac{q_{lit}}{q_{lks}} \prod_{m=1}^{M} \left(\frac{x_{mks}}{x_{mit}}\right)^{\frac{\beta_m}{r}}. \quad (9)$$

Computing the index presented in Equation (7) involves estimating the $\beta_1, \cdots, \beta_M$ parameters. This can be achieved using SFA methods. Consider a sample of $N$ provinces followed during $t$ years for which the study observed the outputs, the inputs, and only $J^*$ environmental factors. The distance function defined by Eq. (10) is

$$\ln q_{it} = \varphi_i + \lambda t + \sum_{j=1}^{J^*} \delta_j \ln z_{ijt} + \sum_{m=1}^{M} \beta_m ln x_{imt} + u_{it} + v_{it}, \tag{10}$$

where $u_{it} = -LnD_O^t(x_{it}, q_{it}, z_{it})$ and $u_{it}$ can be interpreted as a nonnegative technical efficiency effect. The error term $v_{it}$ accounts for stochastic signals (the possibility that the distance function is not a Cobb-Douglas function) and omitted variables (notably, the possibility of $J^*$ and other sources of statistical noise like measurement errors). Additionally, $\lambda$ is a dummy variable that accounts for the rate of technical change, $\sum_{m=1}^{M} ln x_{imt}$ are conventional inputs, and $\sum_{j=1}^{J^*} ln z_{ijt}$ are environmental variables like weather. In equation (10), the study follows Greene's "true fixed effect" calculation (2005a, 2005b).

Equation (10) can be used to decompose TFP change into technological change, environmental change, efficiency change, and technical change:

$$TFPI_{lsit} = \underbrace{\frac{\exp(\lambda t)}{\exp(\lambda s)}}_{OTI} \underbrace{\frac{\exp(\emptyset_i)}{\exp(\emptyset_k)} \prod_{j=1}^{J^*} (\frac{z_{jit}}{z_{jks}})^{\delta_j}}_{OEI} \underbrace{\prod_{m=1}^{M} (\frac{x_{mit}}{x_{mks}})^{\beta_m (\frac{r-1}{r})}}_{OSEI} \underbrace{\frac{\exp(-u_{it})}{\exp(-u_{ks})}}_{OTE} \underbrace{\frac{\exp(v_{it})}{\exp(v_{ks})}}_{SNI}. \tag{11}$$

The following highlights the model's assumptions and future research directions related to calculating the TFP index and its components in Equation (11).

- OTI: The output-oriented technological index is a component that changes with trends over time. The OTI captures changes in technological progress, general policy changes, and variations in energy use (Tang et al., 2016), which can also be factors in improving or decreasing Vietnam's institutional factors. As noted, we assume that technological, institutional, and political factors change linearly over time.
- OEI: The output-oriented environmental index comprises external environmental factors capturing climate change, such as weather shocks, average temperature, and precipitation (Njuki et al., 2018). Future studies may consider more diverse effects of extreme environmental events on TFP using this component.
- OSEI: The output-oriented scale efficiency index captures the efficiency of input use (labor, capital, and natural capital like land area), excluding stochastic factors and technological progress (Thanh et al., 2019). Future research may alter the structure of the production function, modify assumptions about the production function's inputs, and add new types of inputs to this component.
- OTEI: The output-oriented technical efficiency index is a learning-by-doing skill. The present study uses FDI to capture OTEI fluctuation over time (Anwar and Nguyen, 2014). By declaring assumptions about the distribution of efficiency errors here, studies can change how technical efficiency is estimated.

- SNI: The statistical noise index captures changes in unobserved factors in the model and is estimated through SFA.

Finally, the present study considered SCTFP as an indicator of economic growth driven by sustainable internal capacity. SCTFP assumes that OTE reaches 100%. This indicator focuses on Vietnam's potential sustainable growth in the following period; mathematically, $SCTFP = OSEI \times OTI$. The present study uses panel data from 63 Vietnamese provinces and cities in the 2002–2019 period (Table 2).

**Table 2.** Data for Measuring TFP and Its Components

| Components | Proxy | Describe | Source |
|---|---|---|---|
| OTE | FDI | Implemented FDI | |
| OTI | Time-trend | Year dummy variables | |
| OSEI | Labor | Formal labor force over 15 years old | |
| | Capita | Capital stock for the economy including agriculture, industry, and service sectors, converted from investment data | *Statistical Yearbook* |
| | Natural Capital | Total land use for agriculture, industry, and service sectors | |
| OEI | Temperature | Average temperature | |
| | Rainfall | Average precipitation | |
| Outcomes | GRDP | Gross regional domestic product | |

The empirical application of data in Vietnam requires noting potential bias and errors. First, measurement errors like underestimation of labor data bias estimates; massive informal employment in large caused a TFP calculation higher than its actual value (+). Meanwhile, using investment data to estimate capital stock in equation (3) can entail measurement errors. Second, Vietnam's shadow economy is relatively large, and its potential economic growth rate is slower than its actual growth rate. Consequently, the TFP calculation was higher than the actual value (+). Third, Vietnam's General Statistics Office (GSO) only has official data on GDP, which is much lower than that of the whole economy and thus produced a lower TFP calculation (-).

To partly address measurement errors, the present study considers the TFP index and its components in relative terms, focusing more on trends over time and comparing a province with itself in 2002. The measurement errors from eliminating shadow economy data can be skipped because the interplay of the second (overestimated) and third (underestimated) causes can be assumed to be equal. Finally, we use the best data available.

## 4.2. Capital Structure

To assess the impact of capital structure on productivity, the study updates research by Thanh and Canh (2020) to generate the following Equation:

$$Y_{it} = \alpha + \beta_0 \ln(Cap_{it}) + \Sigma_{m=1}^{m} \delta_m Z_{mit} + \lambda t + \theta_i + \varepsilon_{it}, \quad (12)$$

where $Y$ is TFP/OTE, $Cap$ is the ratio of state capital to overall capital, $Z$ is the control variable, $\lambda$ is the time factor ($t = 1,2,\cdots,18$ from 2002 to 2019), $\theta$ captures differences in fixed effects ($i = 1,2,\cdots,63$ provinces and cities), and $\varepsilon$ is the error term. Control variables were selected based on previous research and include literacy, labor quality rate, urbanization rate, FDI flows, provincial competitiveness index, and private sector development (Fan et al., 2019).

The model may face simultaneity and potential dynamic endogeneity issues, which is the product of the capital structure in the past affecting the current term. Therefore, the study employs the two-step GMM estimator proposed by Blundell and Bond (1998) to solve this problem. However, GMM estimation easily produces fallacious estimates because of their complexity; it is thus necessary to have external exogenous variables to ensure the consistency of the coefficient in the model (Wintoki et al., 2012). Pursuing this argument, the study used two instrumental variables: average state capital ratio in a region by year ($mean\_sta\_cap$) (Fisman and Svensson, 2007) and a dummy variable of whether it is a Party Congress ($D\_D$) (HT Tran, 2019). Mathematically, we have

$$Cap_{ijt} = D\_D_t + CAP_{jt} + \eta_{ijt}, \quad (13)$$

where $CAP_j$ denotes the average capital rate typical of a location $j$, which is a function of the underlying characteristics inherent to that location, determining the extent to which a local government can retain a certain amount of investment. Meanwhile, $\eta_{ijt}$ denotes the idiosyncratic component. We assume that the local government's underlying politics and historical factors partly determine the region-specific part of the capital rate.

This component is exogenous to the provinces and cities when controlling for other factors (see Equation (12)) and thus uncorrelated with omitted variables. Therefore, this assumption implies that $cov(CAP, \varepsilon \mid X, Z) = 0$. In such a specification, using location averages as an instrument for provincial-level capital rates eliminates the bias. Furthermore, changes in party structure -through congresses- is also expected to change the development strategy of SOEs. The party structure is also reasonably expected to be exogenous and not part of the short-term productivity growth model; accordingly, the present study assumes that $cov(D\_D, \varepsilon \mid X, Z) = 0$.

Given this background, the GMM estimator is superior to the fixed effect estimator in accounting for simultaneity and potential dynamic endogeneity (Blundell and Bond, 1998; Wintoki et al., 2012), and the ratio of the state capital observations in Equation (12) is determined by the fitted values from the first-stage regression of the equation:

$$\ln(Cap_{ijt}) = f(D\_D_t, CAP_{jt}, Cap_{ijt-1}, Z_{ijkt}). \quad (12')$$

Details of the data are presented in Table 3.

**Table 3.** Descriptive Data

| | Units | 2002 | | 2012 | | 2019 | |
|---|---|---|---|---|---|---|---|
| | | MEAN | SD | MEAN | SD | MEAN | SD |
| Gross Domestic Product | Trillion VND | 19.11 | 38.91 | 47.45 | 85.01 | 81.50 | 142.29 |
| Labor | | 663.38 | 538.12 | 812.48 | 648.34 | 874.21 | 719.93 |
| Land | | 523.38 | 367.68 | 525.34 | 368.32 | 525.33 | 367.44 |
| Capital | Trillion VND | 49.25 | 103.15 | 136.85 | 220.81 | 289.31 | 454.93 |
| Temperature | $^0$C | 24.94 | 2.08 | 25.23 | 2.19 | 25.92 | 1.89 |
| Rain | mm | 1,751.02 | 508.87 | 1,767.36 | 407.53 | 1,683.83 | 575.02 |
| Literacy | % | . | . | 0.93 | 0.07 | 0.94 | 0.07 |
| Labor Quality rate | % | . | . | 14.79 | 6.29 | 19.64 | 7.79 |
| Industry Index | GSO calculation | . | . | 110.64 | 12.63 | 110.34 | 10.66 |
| Provincial Competitive Index | | . | . | 57.02 | 4.15 | 65.66 | 2.60 |
| Private sector development | [0,1] | . | . | 0.87 | 0.10 | 0.94 | 0.07 |
| Implemented FDI | Mill. USD | 41.22 | 120.04 | 146.56 | 299.46 | 247.60 | 438.93 |
| Urbanization rate | [0,1] | . | . | 0.27 | 0.17 | 0.30 | 0.18 |

*Source:* Authors' calculations. Note: Nominal prices converted to 2010 values. The "." indicates missing data.

## 5. RESULTS AND DISCUSSION

### 5.1. TFP and Economic Growth

Equation (10), determined through SFA with maximum likelihood estimation, is presented in Table 4. The coefficients in the regression results confirmed our expectations: input factors had a significant positive impact, weather factors had similar coefficients as in Njuki et al. (2018), and the effect of FDI on technical efficiency accorded with the results in Ni et al. (2017). The coefficient of time is an assumption that captures technological change and institutional factors like property rights and energy use efficiency.

The TFP calculation results are presented in Table 4. The study divides analytical periods by Party Congresses.[1] This division enables controlling for unobservable

[1] 2002–2006 under Prime Minister Phan Van Khai, 2006–2016 under Prime Minister Nguyen Tan Dung,

political factors. The five most notable results are as follows:

**Table 4.** Regression Results with Fixed Effect Model

| Variables | Estimates | Standard Errors | t-value |
|---|---|---|---|
| Time (λ) | 0.0510*** | 0.0010 | 57.0350 |
| Temperature ($\delta_1$) | -0.0150* | 0.0080 | -1.8870 |
| Precipitation ($\delta_2$) | 0.0000*** | 0.0000 | 3.0200 |
| Labor ($\beta_1$) | 0.1410*** | 0.0170 | 8.1280 |
| Land ($\beta_2$) | 0.2590*** | 0.0390 | 6.6790 |
| Capital Stock ($\beta_3$) | 0.3100*** | 0.0060 | 52.0110 |
| Constant ($\beta_0$) | -0.6540*** | 0.0460 | -14.2440 |
| FDI ($u_1$) | 0.0070*** | 0.0030 | 2.0700 |
| ID control ($\varphi_i$, i = [1,62]) | YES*** | | |
| sigma2 ($\sigma_1$) | 0.1080*** | 0.0060 | 18.5040 |
| Gamma ($\sigma_2$) | 1.0000*** | 0.0000 | 31,486,597.76 |
| Number of observations | 1134 | | |

*Source:* Authors' calculations. Note: Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

First, although average TFP growth between 2002 and 2019 was relatively high (3.7% annually, it decreased rapidly over time. The average TFP growth rates in the 2002-2006, 2007-2015, and 2016-2019 periods were 4.15%, 3.02%, and 2.57%, respectively. Given the TFP baseline in Table 1, Vietnam may have been losing sustainable growth momentum since late 2015 at a rate equivalent to about 3% of TFP growth per year.

Second, comparing the growth rate of TFP and SCTFP to identify TFP growth potential shows that Vietnam has been operating below potential since 2006; it could have achieved TFP growth rates of over 3% per year throughout the 2007-2019 period if the provinces and cities attained their highest performance.

Third, the growth path through improving the efficiency of allocating used inputs (i.e., labor, capital stock, and land) in Vietnam was not sustainable in subsequent years when the efficiency of inputs used, as represented by OSEI, decreased by an average of 1.46% per year from 2002 to 2019. This result accords with previous research (e.g., Barker and Üngör, 2019; Thanh et al., 2019) when the focus on growth solely through

and 2016–2020 under Prime Minister Nguyen Xuan Phuc.

capital accumulation entails short-term development incentives, such as subprime investment, ill-considered fiscal policy expansion, and lack of long-term policy linkages across provinces (Tu-Anh and Perkins, 2021). However, capital accumulation will continue to be an important driving force in economic growth in the early stages of development (Storm and Naastepad, 2005).

Fourth, Vietnam's OTI and OTEI show concerning trends: OTI growth was only about 3.93% annually from 2016 to 2019, compared to 4.67% annually between 2007 and 2015. Annual OTEI decreased by about 0.1% and by 0.29% in the 2007-2015 and 2016-2019 periods, respectively. This implies that the learning-by-doing capacity of the provinces has not improved, which may be due to ineffective central competitive incentives.

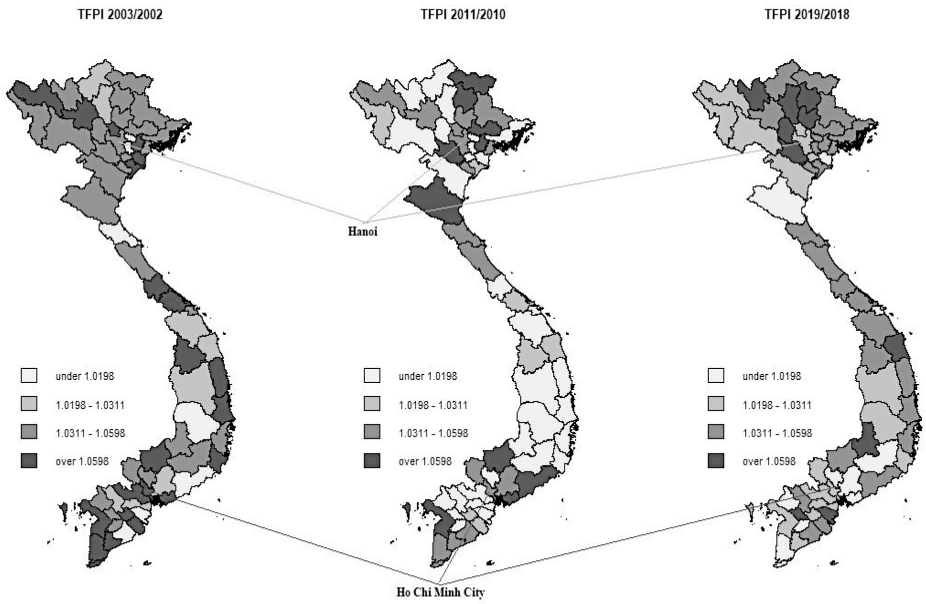
Fifth, Vietnam needs to be more careful about environmental impacts on the economy. Considering only the effect of average temperature and rainfall change, the damage caused by OEI averaged 0.02% and 0.04% per year in the 2007-2015 and 2016-2019 periods, respectively. These impacts could be even more extensive when capturing fluctuations of environmental shocks like extreme weather and risks if the thresholds are reached. In addition, FDI has a positive effect on TFP growth through the channel of increasing technical efficiency, but the coefficient is small (Ni et al., 2017). In other words, FDI can be a source of growth capital for short-term purposes but not for long-term growth.

**Table 5.** Vietnamese TFP and Its Components, 2002-2019

| $TFPI = OTI \times OSEI \times OTEI \times OEI$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $TFPI$ | $OTI$ | $OSEI$ | $SCTFP$ | $OTEI$ | $OEI$ | GRDP growth |
| Annual growth rate (%) | 3.6962 | 4.9688 | -1.4643 | 3.4318 | 0.2656 | -0.0095 | 6.5094 |
| AGR in 2002-2006 (%) | 4.1542 | 4.1933 | -1.2425 | 2.8987 | 1.2294 | -0.0080 | 7.3505 |
| AGR in 2007-2015 (%) | 3.0216 | 4.6701 | -1.4554 | 3.1467 | -0.1008 | -0.0200 | 5.8808 |
| AGR In 2016-2019 (%) | 2.5700 | 3.9256 | -0.9797 | 2.9074 | -0.2863 | -0.0400 | 6.9684 |
| | $OTEI = FDI \times Other$ | | | $OEI = Temp \times Precipitation$ | | | |
| | $OTEI$ | $FDII$ | $Other$ | $OEI$ | $Temp.$ | $Precip.$ | GDP per capita growth |
| Annual growth rate (%) | 0.2656 | 0.0723 | 0.1931 | -0.0095 | -0.0083 | -0.0011 | 5.4613 |
| AGR in 2002-2006 (%) | 1.2294 | 0.1038 | 1.1244 | -0.0080 | -0.0060 | -0.0040 | 6.3589 |
| AGR in 2007-2015 (%) | -0.1008 | -0.0033 | -0.0975 | -0.0200 | -0.0145 | -0.0056 | 4.8070 |
| AGR In 2016-2019 (%) | -0.2863 | 0.0099 | -0.2962 | -0.0400 | -0.0150 | -0.0250 | 5.9151 |

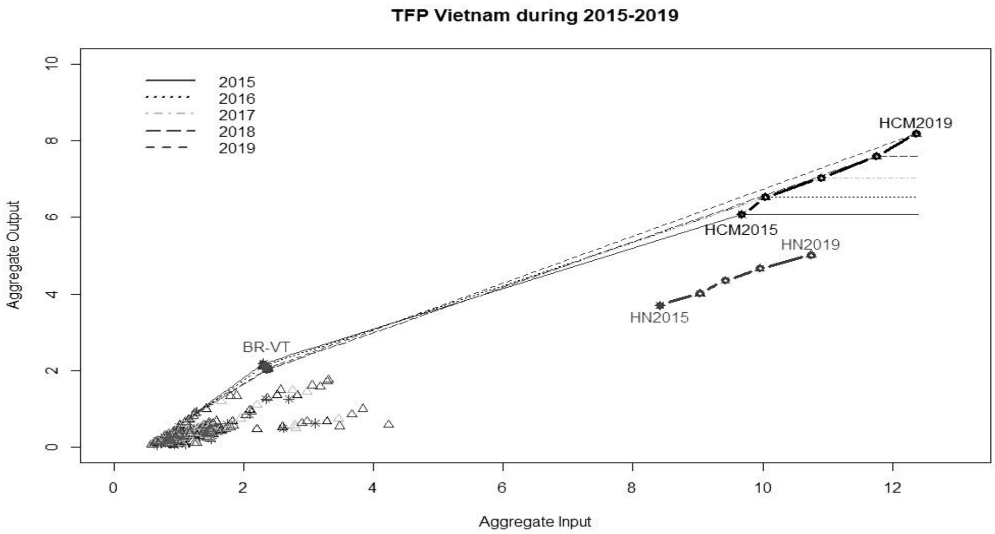
*Source*: Authors' calculations.

*Note*: AGR = annual growth rate




*Source:* Authors.

**Figure 2.** Evolution of TFP, 2002–2019




*Note:* The provinces/cities mentioned in the figure are Ba Ria-Vung Tau (BR-VT), Hanoi (HN), and Ho Chi Minh City (HCM).

**Figure 3.** Vietnam's Production Possibility Frontier, 2015-2019

The evolution of TFP from 2002 to 2019 is illustrated in Figure 2. The color shift visually demonstrates the decline of economic regions in Vietnam, especially the southeast and the Mekong Delta (see Appendix 3 for details). Some large cities have also lost sustainable growth momentum since 2019.

To investigate the dominant growth motivation of the economy, the present study examines the production possibility frontier (PPF) of Vietnam from 2015 to 2019. Vietnam's PPF curve, demonstrated in Figure 3, shows that Ho Chi Minh City (HCMC) is the central driving force of the economy and has an improving trend, represented through the outward expansion of the PPF. The input size of Hanoi in 2018 caught up with HCMC's in 2015, but the aggregate outputs of Hanoi are only about 85% of HCMC's.

### 5.2. Capital structure

The correlation between capital structure and productivity indicators in Appendix 4 shows a negative influence of the state capital ratio on TFPI (OTEI). The present study examines this relationship through ordinary least squares (OLS) and fixed-effects estimators in columns (1), (2), (4), and (5) in Table 6. A significant negative coefficient of state investment rate reflects the expectation in Appendix 1. Accordingly, the public sector has an inefficient use of resources due to inflexibility and less competition. Baccini et al. (2019) also showed that the state sector distorts competition in the context of globalization.

**Table 6.** Regression Results with Two-Step System GMM

| Dependent variables | Total Factor Productivity Index (TFPI) | | | Output-oriented Technical Efficiency Index (OTEI) | | |
|---|---|---|---|---|---|---|
| | OLS | FEM | GMM | OLS | FE | GMM |
| State Investment Rate | -0.305 | -0.249*** | -1.201* | -0.237* | -0.124*** | -1.011* |
| | (0.207) | (0.094) | (0.711) | (0.128) | (0.046) | (0.560) |
| Other control variables in Table 3 | YES | YES | YES | YES | YES | YES |
| Year dummies | YES | YES | YES | YES | YES | YES |
| Constant | 0.615 | -1.112 | -7.833 | 0.288 | 0.135 | -4.412 |
| | (2.691) | (1.626) | (13.221) | (1.454) | (0.796) | (7.404) |
| Observations | 305 | 305 | 305 | 305 | 305 | 305 |
| R-squared | 0.121 | 0.582 | | 0.097 | 0.161 | |
| Number of panels | | 62 | 62 | | 62 | 62 |
| AR (1) test (p-value) | | | 0.072 | | | 0.096 |
| AR (2) test (p-value) | | | 0.432 | | | 0.572 |
| Hansen test of overidentification (Chi2) | | | 45.52 | | | 50.74 |
| Diff-in-Hansen tests of exogeneity (Chi2) | | | 23.71 | | | 16.09 |

*Note:* Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. There are only 305 observations because the State Investment Rate has only been collected since 2015.

The coefficients of OLS and fixed-effects estimators may be biased because of endogeneity and potential dynamic endogeneity. Therefore, the study employed the two-step system GMM estimator proposed by Blundell and Bond (1998) to strengthen this finding. The results and tests -the AR (1), AR (2), and the Hansen and Diff-in-Hansen tests- also validated our hypothesis that the state capital is less effective than private capital (Baccini et al., 2019). The results in columns (3) and (6) in Table 6 confirm that, for every 1% in capital shift from the public to the private sector, there will be an average improvement of more than 28.75% of HCMC's TFP,[2] ceteris paribus.

## 6. CONCLUDING REMARKS

Using an SFA-FP index that enables decomposing TFP into several components, the present study examines the driving factors of Vietnam's TFP growth by conducting an empirical analysis on provincial data for 2002 to 2019.

The main results are as follows. First, despite the potential to reach a high TFP growth level, Vietnam has diverged from a sustainable growth path since 2015. The country's economy has been operating below its potential, and the trend is declining. The result shows that the failure to coordinate and sharing resources among provinces and cities had serious consequences, with annual TFP growth below 2.6% from 2015 to 2019.

Second, inefficient allocation of capital between the public and private sectors decreases Vietnam's TFP. The results reveal the unproductive use of capital in the public sector compared to the private sector: 28.75% on average, with HCMC as the baseline (see Table A3 in the Appendix). Therefore, a reform in capital use from low to high efficiency by enhancing competition is critical to improving TFP. To do so, the government should eliminate barriers to capital for the private sector, ensure transparency of information, support small- and medium-sized enterprises, and speed up the equitization process. From an international perspective, the balance of power between the private sector and the state is decisive in a country's success or failure (Acemoglu and Robinson, 2019). When the government sector dominates most economic activities, as was formerly the case in Vietnam, the economy tends to become dictatorial, whereas with the superiority of the private sector in a country (as with Chile in the past), the disorder is avoidable.

Third, growth through capital accumulation in Vietnam is unsustainable. Indeed, empirical research has found that input use efficiency represented through OSEI declined continuously throughout the 2002–2019 period. Therefore, in the context of limited resources, Vietnam needs to focus on training human resources for key industries closely linked with technological progress, rather than spreading investment around.

[2] HCMC's 2019 TFPI is 4.178.

Moreover, the higher education system must be a regular source of skilled labor, so improving the higher education system is a central task.

Finally, the effects of environmental factors on Vietnam's sustainable growth need to be examined. The present study shows that the damage from weather – considering only changes in average temperature and rainfall -harmed productivity in Vietnam by about 0.04% annually between 2016 and 2019. If environmental issues emerge, the effect on productivity growth will be much more serious.

This study could be a baseline for further research to assess the impact of the COVID-19 pandemic on various aspects of the economy and the effectiveness of the government's intervention policies. The COVID-19 pandemic is an exogenous event that profoundly affected many areas of the economies of Vietnam and countries the world over. Therefore, examining the impact of COVID-19 on TFP using indicators like the number of infections, the number of deaths, and the level of government lockdown measures would be valuable. At the moment, data related to that topic are insufficient for a meaningful study, but as they become available, that will be a worthwhile option.

## APPENDIX

**Table A1.** The Structure of Vietnam's Age Group in 1979-2019

| | | Million people | | | Ratio (%) | | |
|---|---|---|---|---|---|---|---|
| | Population | 0-14 | 15-59 | 60+ | 0-14 | 15-59 | 60+ |
| 1979 | 53.74 | 23.40 | 26.63 | 3.71 | 41.80 | 51.30 | 6.90 |
| 1989 | 64.38 | 24.98 | 34.76 | 4.64 | 39.20 | 53.60 | 7.20 |
| 1999 | 76.33 | 25.56 | 44.58 | 6.19 | 33.00 | 58.90 | 8.10 |
| 2009 | 85.79 | 21.45 | 56.62 | 7.72 | 25.00 | 66.00 | 9.00 |
| 2019 | 96.21 | 23.37 | 63.07 | 9.77 | 24.29 | 65.56 | 10.15 |

*Source:* Authors synthesized from the 1979-2019 Census.

**Table A2.** Return on Assets (ROA), Return on Equity (ROE), and Velocity of Vietnam's Enterprises

| Velocity | 2011-2015 | 2017 | 2018 |
|---|---|---|---|
| Overall | 0.7 | 0.7 | 0.6 |
| State Enterprises | 0.5 | 0.3 | 0.4 |
| Domestics Private Enterprises | 0.7 | 0.7 | 0.7 |
| Multinational Private Enterprises | 1.1 | 1.0 | 1.0 |
| ROA/ROE | 2011-2015 | 2017 | 2018 |
| Overall | 2.6/8.2 | 2.9/10.0 | 2.4/7.6 |
| State Enterprises | 3.0/12.1 | 2.2/11.4 | 2.0/8.9 |
| Domestics Private Enterprises | 1.2/3.4 | 1.8/6.0 | 1.6/4.5 |
| Multinational Private Enterprises | 5.8/15.1 | 7.0/18.1 | 5.8/15.4 |

*Source:* Ministry of Planning and Investment - MPI (2020).

**Table A3.** TFP and Its Components at Province Level

| Provinces | Group | TFPI | OTI | SCTFP | OEI | OSEI | OTEI | FDII |
|---|---|---|---|---|---|---|---|---|
| | | | | Medium-small size in GRDP | | | | |
| Lai Chau | 1 | **4.2749** | 4.9688 | 2.9492 | -0.0050 | -1.9240 | 1.2927 | 0.0000 |
| Lao Cai | 1 | **3.5306** | 4.9688 | 2.8387 | -0.0273 | -2.0293 | 0.6996 | -0.0597 |
| Ha Giang | 1 | 0.6101 | 4.9688 | 2.5830 | -0.0217 | -2.2729 | -1.9017 | 0.0000 |
| Cao Bang | 1 | 1.8239 | 4.9688 | **3.3030** | -0.0011 | -1.5870 | -1.4309 | 0.0189 |
| Son La | 1 | **5.4383** | 4.9688 | **3.3236** | -0.0228 | -1.5673 | 2.0704 | -0.0357 |
| Yen Bai | 1 | **6.2451** | 4.9688 | **4.0457** | -0.0178 | -0.8794 | 2.1324 | 0.1248 |
| Tuyen Quang | 1 | **4.5696** | 4.9688 | **3.7079** | -0.0095 | -1.2013 | 0.8405 | 0.0454 |
| Lang Son | 1 | 2.9655 | 4.9688 | **3.5439** | -0.0106 | -1.3575 | -0.5488 | -0.0682 |
| Quang Ninh | 1 | **5.2487** | 4.9688 | **3.5659** | -0.0184 | -1.3365 | 1.6434 | 0.0762 |
| Hoa Binh | 1 | **3.4118** | 4.9688 | **4.0294** | -0.0111 | -0.8949 | -0.5824 | -0.0946 |
| Ninh Binh | 1 | **4.7504** | 4.9688 | **3.2415** | -0.0122 | -1.6456 | 1.4735 | 0.1865 |
| Thai Binh | 1 | **3.7225** | 4.9688 | **3.4914** | -0.0362 | -1.4075 | 0.2597 | 0.0503 |
| Thanh Hoa | 1 | 2.3777 | 4.9688 | 2.9427 | -0.0044 | -1.9302 | -0.5445 | 0.1199 |
| Nghe An | 1 | **3.2048** | 4.9688 | **3.5644** | -0.0078 | -1.3379 | -0.3396 | 0.1595 |
| Ha Tinh | 1 | 0.8554 | 4.9688 | 2.2516 | 0.0028 | -2.5886 | -1.3680 | 0.2063 |
| Quang Binh | 1 | **5.1614** | 4.9688 | **4.2155** | -0.0111 | -0.7177 | 0.9190 | 0.2192 |
| Quang Tri | 1 | 2.5951 | 4.9688 | **3.3791** | -0.0050 | -1.5145 | -0.7530 | 0.1035 |
| Thua Thien - Hue | 1 | **4.9290** | 4.9688 | **3.7954** | -0.0284 | -1.1179 | 1.1210 | 0.0926 |
| Quang Nam | 1 | **5.6927** | 4.9688 | **3.5483** | -0.0078 | -1.3533 | 2.0790 | -0.0345 |
| Kon Tum | 1 | 2.1669 | 4.9688 | 2.7655 | -0.0156 | -2.0990 | -0.5671 | 0.0000 |
| Quang Ngai | 1 | **5.4437** | 4.9688 | **3.4818** | -0.0128 | -1.4167 | 1.9091 | 0.2096 |
| Gia Lai | 1 | **4.4414** | 4.9688 | **3.5798** | 0.0011 | -1.3233 | 0.8304 | 0.0000 |
| Binh Dinh | 1 | 2.7575 | 4.9688 | **3.6003** | -0.0061 | -1.3038 | -0.8076 | 0.1784 |
| Phu Yen | 1 | **4.8174** | 4.9688 | **3.7358** | -0.0111 | -1.1747 | 1.0539 | 0.0000 |
| Dak Lak | 1 | 2.0097 | 4.9688 | **3.4706** | 0.0017 | -1.4273 | -1.4139 | 0.0000 |
| Khanh Hoa | 1 | 1.9468 | 4.9688 | **3.4602** | -0.0379 | -1.4373 | -1.4252 | 0.0635 |
| Lam Dong | 1 | **4.1521** | 4.9688 | 2.9864 | 0.0161 | -1.8886 | 1.1150 | 0.1068 |
| Ninh Thuan | 1 | **3.1101** | 4.9688 | **3.4684** | -0.0083 | -1.4295 | -0.3379 | 0.2053 |
| Tay Ninh | 1 | **5.5324** | 4.9688 | **3.3753** | -0.0006 | -1.5181 | 2.0873 | 0.1525 |
| Dong Nai | 1 | **4.3086** | 4.9688 | **3.6648** | -0.0167 | -1.2423 | 0.6381 | 0.0211 |
| Binh Thuan | 1 | **4.2774** | 4.9688 | **3.3776** | -0.0095 | -1.5160 | 0.8799 | 0.0261 |
| Long An | 1 | **4.2481** | 4.9688 | **3.5681** | 0.0022 | -1.3344 | 0.6545 | 0.0569 |
| An Giang | 1 | **3.5244** | 4.9688 | **4.2181** | 0.0078 | -0.7152 | -0.6733 | 0.0000 |
| Dong Thap | 1 | **4.7223** | 4.9688 | **3.7742** | 0.0044 | -1.1381 | 0.9090 | 0.0778 |
| Tien Giang | 1 | **3.5343** | 4.9688 | **3.6720** | 0.0033 | -1.2355 | -0.1360 | 0.1535 |
| Kien Giang | 1 | **3.3092** | 4.9688 | **3.4250** | 0.0061 | -1.4708 | -0.1184 | -0.0150 |
| Vinh Long | 1 | **4.1660** | 4.9688 | **3.8781** | -0.0017 | -1.0391 | 0.2788 | 0.0564 |
| Ben Tre | 1 | 2.8595 | 4.9688 | **3.6475** | -0.0145 | -1.2588 | -0.7460 | 0.1177 |
| Tra Vinh | 1 | **3.7201** | 4.9688 | **3.0935** | 0.0044 | -1.7865 | 0.6036 | 0.0448 |
| Soc Trang | 1 | **3.8740** | 4.9688 | 3.7628 | -0.0145 | -1.1490 | 0.1215 | 0.0233 |
| Bac Kan | 1 | **3.6241** | 4.9688 | 3.7365 | -0.0061 | -1.1740 | -0.1020 | 0.0454 |
| Bac Giang | 1 | 2.7774 | 4.9688 | 2.9961 | -0.0083 | -1.8794 | -0.2041 | 0.1816 |
| Bac Lieu | 1 | 0.8096 | 4.9688 | 3.2167 | 0.0061 | -1.6692 | -2.3382 | -0.0251 |
| Bac Ninh | 1 | **6.1189** | 4.9688 | 2.9305 | -0.0178 | -1.9418 | 3.1161 | 0.2550 |

*Note:* The bold numbers present the annual growth of TFPI higher 3%

**Table A3.** TFP and Its Components at Province Level (cont')

| Provinces | Group | TFPI | OTI | SCTFP | OEI | OSEI | OTEI | FDII |
|---|---|---|---|---|---|---|---|---|
| Medium-small size in GRDP | | | | | | | | |
| Binh Phuoc | 1 | **5.1918** | 4.9688 | 3.3692 | 0.0083 | -1.5239 | 1.7548 | 0.0089 |
| Ca Mau | 1 | **3.6314** | 4.9688 | 3.6039 | -0.0067 | -1.3003 | 0.0332 | 0.1270 |
| Hai Duong | 1 | **3.0153** | 4.9688 | 3.4198 | -0.0184 | -1.4758 | -0.3727 | 0.1681 |
| Ha Nam | 1 | **3.8700** | 4.9688 | 2.9338 | -0.0067 | -1.9387 | 0.9162 | 0.2240 |
| Hung Yen | 1 | **4.5003** | 4.9688 | **3.4922** | -0.0044 | -1.4068 | 0.9786 | 0.0855 |
| Nam Dinh | 1 | 2.5140 | 4.9688 | **3.6756** | -0.0318 | -1.2320 | -1.0891 | -0.0050 |
| Phu Tho | 1 | **3.7727** | 4.9688 | **3.7322** | -0.0161 | -1.1781 | 0.0547 | 0.1530 |
| Thai Nguyen | 1 | **5.0121** | 4.9688 | **3.1212** | -0.0078 | -1.7602 | 1.8414 | 0.1692 |
| Vinh Phuc | 1 | **5.3061** | 4.9688 | **3.4325** | -0.0122 | -1.4636 | 1.8239 | 0.0696 |
| Dien Bien | 1 | **3.2291** | 4.9688 | **3.5188** | -0.0184 | -1.3814 | -0.2619 | 0.0000 |
| Dak Nong | 1 | **4.4845** | 4.9688 | **3.1589** | -0.0139 | -1.7242 | 1.2989 | 0.0547 |
| Hau Giang | 1 | 2.1476 | 4.9688 | **3.4818** | -0.0095 | -1.4167 | -1.2796 | 0.0000 |
| Can Tho | 1 | **4.5124** | 4.9688 | 2.9695 | -0.0145 | -1.9047 | 1.5132 | 0.0404 |
| Hai Phong | 1 | **5.4547** | 4.9688 | **3.4579** | -0.0044 | -1.4394 | 1.9348 | 0.0970 |
| Medium-large size in GRDP | | | | | | | | |
| Binh Duong | 2 | **5.1491** | 4.9688 | **3.4235** | -0.0117 | -1.4722 | 1.6804 | 0.0277 |
| Ba Ria - Vung Tau | 2 | 0.4440 | 4.9688 | **4.8784** | -0.0145 | -0.0862 | -4.2142 | 0.1259 |
| Da Nang | 1 | 0.4830 | 4.9688 | **2.4293** | -0.0234 | -2.4193 | -1.8771 | -0.0017 |
| Large size in GRDP | | | | | | | | |
| Ha Noi | 3 | 2.8962 | 4.9688 | **3.4040** | -0.0044 | -1.4908 | -0.4869 | 0.1079 |
| HCMC | 3 | **4.1784** | 4.9688 | **3.5365** | -0.0078 | -1.3645 | 0.6276 | 0.0712 |

*Note:* The bold numbers present the annual growth of TFPI higher 3%

**Table A4.** Correlation between Capital Structure and Productivity

| | State Investment rate | Domestic private Investment rate | Multinational Investment rate |
|---|---|---|---|
| TFPI | -0.177 | 0.055 | 0.088 |
| OTI | -0.198 | 0.213 | -0.041 |
| OEI | -0.093 | -0.026 | 0.096 |
| OSEI | 0.106 | 0.004 | -0.087 |
| OTEI | -0.139 | -0.056 | 0.160 |
| SCTFP | -0.096 | 0.203 | -0.112 |

*Source:* Authors' calculation.

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