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Contribution of capital, labor, and total factor productivity to economic growth and enterprise value-added: A case study of Ha Tinh province, Vietnam

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Abstract

The article focuses on researching and identifying the contribution of Capital, Labor, and Total Factor Productivity (TFP) to GRDP growth and the role of science, technology, and innovation in enhancing TFP in Ha Tinh province, Vietnam. The research results show that the role of TFP in the GRDP growth of Ha Tinh is increasingly important, particularly in the value-added (VA) of businesses, where TFP's impact is becoming more evident and contributes significantly to the increase in VA of enterprises. However, the contribution of science, technology, and innovation to TFP and the province's GRDP is showing a declining trend. This is due to a period of strong technological investment, during which businesses may have reached a saturation point where current technologies have fully exploited their potential. This could become a development barrier for the province, especially in the context of prolonged difficulties faced by enterprises, reduced investment in research and development (R&D), and challenges in attracting large technology companies to invest in the area. Based on these findings, the study proposes several indicators for science, technology, and innovation in the province by 2030, including enhancing the attraction and effective use of foreign capital in the field of science, technology, and innovation, and developing science and technology aimed at modern industry, comprehensive, and sustainable development in Ha Tinh province.

Keywords: GDP, Innovation, Science and Technology, TFP, Total Factor Productivity, Vietnam.

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1. Introduction

Total Factor Productivity (TFP) reflects the production outcomes achieved through improved efficiency in utilizing input factors. While the growth rates of capital and labor are limited, TFP serves as an unrestricted driver of economic growth. TFP growth is typically decomposed into three main components: (1) Growth driven by advancements in science and technology (S&T); (2) Growth resulting from production rationalization (through improved management, more efficient resource utilization, and a more favorable business environment); (3) Growth due to changes in the scale of production.

The corresponding terms for these three components are (1) technical change efficiency, also referred to as technological change efficiency; (2) technical efficiency; and (3) scale efficiency. Among these components, advancements in science and technology (S&T) can significantly accelerate TFP growth and enable the economy to achieve sustained long-term growth by expanding the economic efficiency frontier. In contrast, production rationalization and changes in scale can only enhance TFP by bringing the economy closer to the efficiency frontier. Without technological advancements, the efficiency frontier remains unchanged, meaning that production rationalization and scale adjustments can only drive short-term economic growth until the economy reaches its existing efficiency frontier. Therefore, the contribution of TFP to economic growth serves as a crucial indicator of growth quality. In particular, the contribution of technological change to TFP is a key factor in assessing whether an economy can sustain high growth over the long term.

To determine the contribution of TFP to the economic growth (GRDP) of Ha Tinh province, this study employs the Stochastic Frontier Analysis (SFA) method, integrating both provincial-level macroeconomic data and firm-level microeconomic data from the annual enterprise survey published by the General Statistics Office (GSO) [1]. This dataset provides insights into the factors driving technological progress/technical change (TC) and TFP growth in Ha Tinh province. The Translog or Cobb-Douglas production function will be applied; however, the inefficiency component u_{it} will be estimated as a function of government technology utilization indicators and the time trend variable *t*. In this context, changes in u_{it} resulting from variations in government technology utilization indicators will reveal the contribution of government science and technology (S&T) applications to economic growth. This approach is based on the assumption that government operations may cause the economy to perform below its potential production frontier, thereby creating an inefficiency gap. Government technology adoption influences this inefficiency level, subsequently contributing to TFP growth and economic growth in the province.

Based on this framework, the objective of this study is to quantify the contribution of TFP to GRDP growth and assess the impact of S&T on TFP improvement in Ha Tinh province during the 2011–2023 period, utilizing publicly available data from the General Statistics Office (GSO) [2] and the research team's calculations.

2. Research Methodology

2.1. Method for Calculating TFP from Macroeconomic Data

The Solow Residual Method is applied to estimate Total Factor Productivity (TFP) from macroeconomic data, following the approach established by Solow [3]. This method utilizes key economic indicators such as Gross Domestic Product (GDP) or Gross Regional Domestic Product (GRDP), capital stock (K), and labor (L).

The estimation is based on the Cobb-Douglas production function model, expressed as:

$$Y = AK^{\alpha}L^{1-\alpha} \quad (1)$$

Where: Y represents output (GDP or GRDP); A denotes Total Factor Productivity (TFP); K represents capital stock; L represents labor; α is the capital share in output.

TFP is calculated using the Solow Residual, expressed as:

$$A = \frac{Y}{K^{\alpha}L^{1-\alpha}} \quad (2)$$

2.2. Method for Calculating TFP from Enterprise Survey Data

For enterprise survey data, this study employs a semi-parametric approach. Following the methodology of Olley and Pakes [4], the firm's production function is represented as follows:

$$VA_{it}^{j} = \alpha + \beta_l l_{it}^{j} + \beta_m m_{it}^{j} + \beta_k k_{it}^{j} + \omega_{it}^{j} + \varepsilon_{it}^{j} \quad (3)$$

Where: VA_{it}^{j} is the logarithm of value-added output; l_{it}^{j} is the logarithm of labor input; m_{it}^{j} is the logarithm of materials (intermediate inputs); k_{it}^{j} is the logarithm of capital stock.

The error terms $\omega_{it}^{j}$and ε_{it}^{j}follow an independent and identically distributed (i.d.) normal distribution. The indices *i*, *j* and *t* represent firm *i*, industry *j*, and year *t*, respectively.

In Model (2), Total Factor Productivity (TFP) is determined by the two unobserved components, ω_{it}^{j} and ε_{it}^{j}, leading to the following equation: $TFP_{it} = \omega_{it} + \varepsilon_{it}$ [5].

Based on Model (2), TFP can be calculated as follows:

$$TFP_{it} = VA_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_k k_{it} \quad (4)$$

The estimation methods proposed by Olley and Pakes [4] and Levinsohn and Petrin [5] encounter several challenges in the estimation process [6]. For instance, in Model (3), labor is assumed to be optimally determined by firms. However, in practice, determining the optimal labor input is highly complex, as it is influenced by labor productivity, managerial capacity, and workers' ability to utilize machinery and equipment to generate value-added (VA). These factors are, in essence, components of Total Factor Productivity (TFP). As a result, Model (3) is susceptible to endogeneity issues, where independent variables may be correlated with the dependent variable. Accordingly, Wooldridge [6] developed a TFP estimation method that addresses endogeneity issues in the model using the Generalized Method of Moments (GMM). Additionally, this study incorporates one-year lagged exogenous variables or one-year lagged intermediate inputs as instrumental variables to mitigate endogeneity concerns and enhance the accuracy of the estimation.

Therefore, to calculate Total Factor Productivity (TFP), Model (3) is estimated using a semi-parametric approach incorporating Wooldridge's [6] correction for endogeneity. The values of the variables in Model (3) are adjusted to a constant base price (real terms) by deflating them using industry-specific deflators before estimation.

At this point, TFP is computed using Equation 4. Estimating Model (3) yields the coefficients $\hat{\beta}_l$, $\hat{\beta}_m$ and $\hat{\beta}_k$, which represent the impact of labor, intermediate inputs, and capital on firm output, respectively.

The contribution of TFP to value-added is calculated as follows:

$$\rho_{TFP} = \frac{TFP_{it}}{VA_{it}} * 100 \qquad (5)$$

The contribution of labor to value-added is calculated as follows:

$$\rho_l = \frac{\hat{\beta}_l l_{it}}{VA_{it}} * 100 \qquad (6)$$

In Model (3), intermediate inputs represent the intermediate costs incurred by firms to generate value-added (VA). To simplify the analysis, the research team combines the contributions of intermediate inputs (m) and capital (k) into a single measure, referred to as the contribution of capital to value-added.

Thus, the contribution of capital to value-added is calculated as follows:

$$\rho_k = 100 - \rho_{TFP} - \rho_l \qquad (7)$$

Equations 5, 6, and 7, respectively, represent the contributions of TFP, labor, and capital to value-added (VA). Since the variables in model (3) are expressed in logarithmic form, the contributions of TFP, labor, and capital to VA can be interpreted as the percentage contributions of these factors to the growth rate of value-added (VA) [4].

2.3. Method for Estimating the Contribution of Science and Technology (S&T)

According to the Stochastic Frontier Analysis (SFA) methodology, the standard production function, assuming firms operate at full efficiency, is expressed as follows:

$$\mathrm{Ln}(Y_{it}) = \beta_0 + \beta_1 ln(X_{it}) + \beta_2 t + v_{it} \qquad (8)$$

In the case where firms are assumed not to operate at full technical efficiency, the generalized model is formulated as follows:

$$\mathrm{Ln}(Y_{it}) = \beta_0 + \beta_1 ln(X_{it}) + \beta_2 t + v_{it} - u_{it} \qquad (9)$$
$$\text{with } u_{it} = \delta_0 + \delta Z_{it} + w_{it}$$

The research team employs either the Cobb-Douglas or Translog production function to determine technological efficiency. Specifically:

Cobb-Douglas production function:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln\left(L_{it}\right) + \beta_2 \ln\left(K_{it}\right) + \beta_3 t + v_{it} - u_{it} \qquad (10)$$

Translog production function:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + \beta_3 t + \beta_4 \ln(L_{it}^2) + \beta_5 \ln(K_{it}^2) + \beta_6 t^2 + \beta_7 \ln(L_{it}.K_{it}) + \beta_8 t_{it}.ln(L_{it}) + \beta_9 t_{it}.ln(K_{it}) + v_{it} - u_{it} \qquad (11)$$

Where: Y_{it} represents the output of firm *i* at time *t*; X_{it} includes input variables, such as physical capital K_{it} and labor L_{it} of firm iii at time *t; Z_{it}* represents exogenous variables affecting technical inefficiency; *t* is the time trend variable; *β* denotes the parameters to be estimated; v_{it} is the error term.

The random error term follows a normal distribution with a mean of zero and a variance σ_v^2, denoted as $N(0, \sigma_v^2)$. This characteristic is considered a significant distinction between the Stochastic Frontier Analysis (SFA) method and Data Envelopment Analysis (DEA), as it allows for the incorporation of random fluctuations that may affect a firm's production performance.

The term u_{it} represents the inefficiency component, which is incorporated into the production function to indicate that firms are operating below full efficiency. Full efficiency is understood as the level at which a firm cannot further increase output given the existing level of technology and available inputs.

Technical efficiency is estimated based on the conditional expectation and the assumptions of the model. Given the specifications in the generalized Equation 9, the technical efficiency of firm iii in year t is determined as follows:

$$TE_{it} = \frac{Y_{it}}{\widehat{Y_{it}}} = \frac{f(X_{it};\beta).\exp(v_{it}-u_{it})}{f(X_{it};\beta).\exp(v_{it})} = \exp(-u_{it}) = \exp(-\delta Z_{it} - w_{it}) \qquad (12)$$

TE_{it} is measured as the ratio of actual output Y_{it} to maximum potential output $\widehat{Y_{it}}$. Therefore, the technical efficiency score TE_{it} ranges from 0 to 1. A firm operating at full efficiency (or a firm following best practices) has a TE_{it} score of 1, while less efficient firms have TE_{it} scores below 1. The inefficiency component u_{it} is a non-negative random variable, assumed to be the primary factor causing technical inefficiency in production. It is considered independent and identically distributed, following a zero-truncated distribution. Depending on the model specification, it may follow various distributional assumptions, such as half-normal, truncated-normal, or others.

The estimated coefficients of the production function in the given expression do not provide direct economic interpretations. However, they can be used to derive the output elasticities with respect to each input, calculated as follows:

$$\varepsilon n_{it} = \frac{\partial Y_{it}}{\partial X n_{it}} \qquad (13)$$

The standard profit of scale elasticity is calculated as follows:

$$\varepsilon_{Tit} = \sum_{n=1}^{N} \varepsilon n_{it} \qquad (14)$$

Regarding the SFA approach, the study employs the Likelihood Ratio (LR) test to select the appropriate functional form for the dataset. The null hypothesis (*H0)* assumes that the Cobb-Douglas model (10) is valid, which excludes squared time coefficients, input interaction terms, and input-time interaction terms from the Translog model (11), i.e., ($\beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$),. The alternative hypothesis *H1* assumes that the Translog model is more appropriate. The log-likelihood test statistic is given by: $LR = -2(lnL_{CD} + \ln L_{TL})$. The null hypothesis *H0* is not rejected if the *LR* statistic is smaller than the chi-square χ^2 critical value, where the degrees of freedom correspond to the number of restricted parameters in the model. Once the appropriate production function is selected, the study proceeds with the estimation of TFP growth.

To measure TFP growth using the SFA approach, we follow Sari et al. [7], who decompose *TFP* into three indices: technical efficiency change (*TEC*), technological change or technological progress (*TC*), and scale efficiency change (*SEC*). The formulas for obtaining these components are presented below.

TC can be directly calculated from the estimated parameters in the generalized expressions (9), (10), or (11). It is based on the time coefficient, the squared time term, and the interaction of time with input factors. However, *TC* may vary for different input vectors if technological change is non-neutral. To compute $TC_{it,t-1}$ the first step is to calculate the partial derivative with respect to time at each data point, for firm iii in period ttt, as $\frac{\partial Y_{it}}{\partial t}$.

$$TC_{it,t-1} = \frac{1}{2}\,[(\frac{\partial y_{it-1}}{\partial t})+(\frac{\partial y_{it}}{\partial t})] \quad (15)$$

Based on Equation 6, technical efficiency change (TEC) is calculated as the ratio of the technical efficiency of firm *i* in period *t* to its technical efficiency in period *t−1*:

$$TEC_{it,t-1} = \frac{\mathrm{TE_{it}}}{TE_{it-1}} \quad (16)$$

The final component required to calculate *TFP* growth is scale efficiency change *(SEC). SEC* requires the computation of output elasticity for each input factor (*Scale Factors – SF*) at each data point. First, the scale impact coefficients are determined as follows:

$$SF_{it} = \frac{\varepsilon_{Tit}-1}{\varepsilon_{Tit}} \quad (17)$$

$SEC_{it,t-1}$ between periods *t* and *t−1* is calculated as the average sum of the scale factors of firm iii over the two periods, multiplied by the change in the corresponding input usage. It can be expressed as follows:

$$SEC_{it,t-1} = \frac{1}{2}\sum_{n=1}^{N}[(SF_{it}\varepsilon n_{it} + SF_{it-1}\varepsilon n_{it-1})(Xn_{it} - Xn_{it-1})] * 100 \quad (18)$$

Finally, the change or growth in TFP for each firm between any two periods is the sum of $TEC_{it,t-1}$,$SEC_{it,t-1}$ and $TC_{it,t-1}$. Therefore, TFP growth can be defined as follows:

$$TFPg_{it,t-1} = TEC_{it,t-1} + SEC_{it,t-1} + TC_{it,t-1} \quad (19)$$

Where $TFPg_{it,t-1}$ represents the *TFP* growth of firm *i* between periods *t* and *t-1.*

Additionally, a descriptive analysis of S&T applications across business sectors, households, and government institutions will be conducted to support forecasting and policy recommendations aimed at enhancing the contribution of science and technology (S&T) to improving total factor productivity (TFP)**.**

3. Research Results and Discussion

3.1. Contribution of TFP to GRDP Growth in Ha Tinh Province

The study uses statistical data on GRDP, capital, and labor published annually from 2011 to 2023 (GSO, 2024, 2024) to calculate the contribution of TFP using the Solow Residual Method. Data from the 2011–2023 period are utilized to ensure a sufficient data length and statistical reliability for the calculations. However, to align with the research objectives, this paper focuses more in-depth on the period 2016–2023.

Table 1 shows that the calculated contribution of TFP to GRDP growth in Ha Tinh province has shown a positive improvement trend. The role of TFP in Ha Tinh is becoming increasingly important in driving economic growth. This not only helps improve the efficiency of production factor utilization but also creates a solid foundation for the province's sustainable development in the future. With continuous improvements and innovations, Ha Tinh has made significant breakthroughs in enhancing the quality of economic growth. Specifically:

Table 1.
Contribution of Factors to GRDP in Ha Tinh Province.

	Total	The contribution to GRDP is calculated as a percentage (%)		
		Contribution of capital	**Contribution of labor**	**Contribution of TFP**
	Total= (1) + (2) + (3)	(1)	(2)	(3)
2011-2015	100	56.43	13.89	29.67
2016-2020	100	54.49	13.32	32.19
2021-2023	100	54.11	12.84	33.04
2016	100	55.54	13.78	30.68
2017	100	54.83	13.71	31.46
2018	100	54.48	13.15	32.36
2019	100	53.84	13.10	33.07
2020	100	53.75	12.85	33.40
2021	100	53.77	12.84	33.39
2022	100	54.14	12.88	32.97
2023	100	54.42	12.81	32.77

Source: Author's calculations based on data from the Ha Tinh Province Statistics Office.

(1) Contribution of TFP: The period from 2011 to 2015 shows that the contribution of capital **to** GRDP was 56.43%, while labor contributed 13.89%, and TFP accounted for 29.67%. This indicates that during this period, Ha Tinh Province was heavily reliant on capital investment to drive economic growth, while the efficiency of labor and technology was not yet a key factor. In the 2016–2020 period, although the contribution of capital decreased to 54.49% and labor slightly decreased to 13.32%, TFP increased significantly to 32.19%. This reflects improvements in the efficiency of production factor utilization and highlights the growing importance of technology and effective management in driving economic growth in Ha Tinh Province.

Notably, in the 2021–2023 period, the contribution of TFP continued to rise, reaching 33.04%, while the contributions of capital and labor decreased to 54.11% and 12.84%, respectively. This indicates that Ha Tinh Province has been shifting significantly toward enhancing the efficiency of production factor utilization through technological improvements and better management, rather than relying solely on increasing capital and labor investments. This is reflected in the annual contribution data, where in 2016, TFP contributed 30.68% to GRDP, but by 2020, this figure had increased to 33.40%. Similarly, from 2021 to 2023, the contribution of TFP fluctuated between 32.77% and 33.39%. The continuous growth of TFP during these years reflects the ongoing efforts of Ha Tinh Province in applying new technologies, improving production processes, and managing efficiently.

(2) Contribution of Capital: In the 2011–2015 period, the contribution of capital to GRDP was 56.43%. This indicates that Ha Tinh Province was heavily reliant on capital investment to drive economic growth. Large-scale projects, particularly in the industrial and infrastructure sectors, played a significant role in strengthening the province's production capacity. However, the reliance on capital gradually decreased in the subsequent periods. Specifically, the contribution of capital decreased to 54.49% in the 2016–2020 period and further declined to 54.11% in the 2021–2023 period. This reduction reflects Ha Tinh's shift from relying solely on capital investment to enhancing the efficiency of existing resources through technological improvements and better management.

(3) Contribution of Labor: The contribution of labor to GRDP in the 2011–2015 period was 13.89%. This indicates that labor still played a significant role in driving economic growth. However, this ratio slightly declined in the subsequent periods, reaching 13.32% in the 2016–2020 period and 12.84% in the 2021–2023 period. This decline may reflect changes in the labor structure and the application of new technologies that enhance labor productivity. Although the contribution of labor has decreased, its role cannot be overlooked. Investment in training and enhancing labor skills remains one of the key factors in improving productivity and production efficiency.

3.2. Contribution of S&T to Enhancing TFP in Ha Tinh Province

Table 2 shows the contribution of the components of TFP, including Scale Efficiency, Technological Change Efficiency, and Technical Efficiency, to Value Added (VA) from 2011 to 2023. Additionally, Table 2 also provides the average values for the periods 2011-2015, 2016-2020, and 2021-2023. Specifically:

Table 2.
Results of determining the contribution of TFP factors to the VA of enterprises in Ha Tinh province, 2011-2023 Period (Percentage points %) *

	TFP	Scale efficiency	Technological change efficiency	Technical efficiency
2011	30,29	1.10	24.88	4.30
2012	29,17	0.85	23.22	5.10
2013	29,81	0.35	23.60	5.86
2014	29,39	0.66	22.20	6.52
2015	29,70	0.77	21.29	7.65
2016	30,68	0.33	21.65	8.69
2017	31,46	2.77	18.67	10.02
2018	32,36	1.32	18.18	12.86
2019	33,07	3.05	15.20	14.82
2020	33,40	2.93	16.55	13.92
2021	33,39	2.32	16.60	14.47
2022	32,97	2.19	15.59	15.20
2023	32,77	1.92	14.89	15.96
Average value 2011-2015	29,67	0.75	23.04	5.89
Average value 2016-2020	32,19	2.08	18.05	12.06
Average value 2021-2023	33,04	2.14	15.69	15.21

Note: * VA - Value Added.
Source: Author's calculations from data provided by the Ha Tinh Province Statistics Bureau.

(1) Contribution of Scale Efficiency to VA. Scale efficiency shows significant fluctuations over the years. In 2011, the value was 1.10% and decreased to 0.35% in 2013. The period of 2014-2015 saw a slight increase, but it remained at a low level with values of 0.66% and 0.77%, respectively. The average contribution of scale efficiency to VA in the 2011-2015 period was 0.75%, indicating a low level of scale efficiency. From 2016 onwards, the contribution of scale efficiency to VA showed an upward trend, particularly in the years 2017 (2.77%) and 2019 (3.05%).

The calculation results show that the period of 2016-2020 saw improvement, with an average of 2.08%; the period of 2021-2023 continued to show improvement, with an average of 2.14%. This reflects a greater stability in scale efficiency. The positive change in scale efficiency reflects the increasingly effective changes in the production scale of enterprises in Ha Tinh province. The early years of the 2011-2015 period may have been a challenging time for expanding production scale. The gradual improvement in the subsequent periods indicates that businesses have found ways to optimize their production scale or have benefited from government policies that support the enhancement of production scale.

(2) Regarding the contribution of technological change efficiency to VA (Value Added). The technological change efficiency has shown a declining trend over the years. In 2011, the value of technological efficiency in TFP (Total Factor Productivity) contributed 24.88% to VA, and then gradually decreased over the years. From 2018, the efficiency of technological change declined sharply, reaching only 14.89% by 2023. On average, the efficiency of technological change during the 2011-2015 period was 23.04%, indicating a high level of effectiveness in technological transformation. However, the 2016-2020 period witnessed a decline, with the average dropping to 18.05%. Notably, the 2021-2023 period recorded the lowest level of efficiency, with an average of only 15.69%. The high efficiency of technological change during the 2011-2015 period may reflect strong investment in new technologies and production improvements. However, the subsequent decline could be attributed to several factors, such as technological saturation, financial difficulties or technology investment policies, and a lack of skilled human resources necessary to adopt and exploit new technologies.

Particularly, the 2021-2023 period showed very low efficiency in technological change, likely due to the impact of the COVID-19 pandemic, which disrupted supply chains, reduced investment in technology, and diverted resources to maintaining business operations. This is an important argument for the Government, local authorities, and businesses to carefully consider the influencing factors and develop appropriate strategies to improve production efficiency and invest in new technologies, while stabilizing production scale to achieve optimal productivity.

(3) Regarding the contribution of technical efficiency to VA (Value Added). The contribution of technical efficiency to VA has shown an increasing trend over the years. In 2011, this value was 4.30% and gradually increased, reaching a peak of 15.96% in 2023. On average, the contribution of technical efficiency to VA during the 2011-2015 period was 5.89%, which rose to 13.26% in the 2016-2020 period, reflecting a clear improvement, and further increased to 15.21% in the 2021-2023 period. These results indicate that businesses have focused on enhancing labor skills, improving production processes, and adopting more effective management measures.

Contribution of factors to TFP (Total Factor Productivity). Figure 1 shows that, in general, the factors contributing to TFP growth in Ha Tinh province vary, with labor remaining the primary factor contributing to the province's TFP.

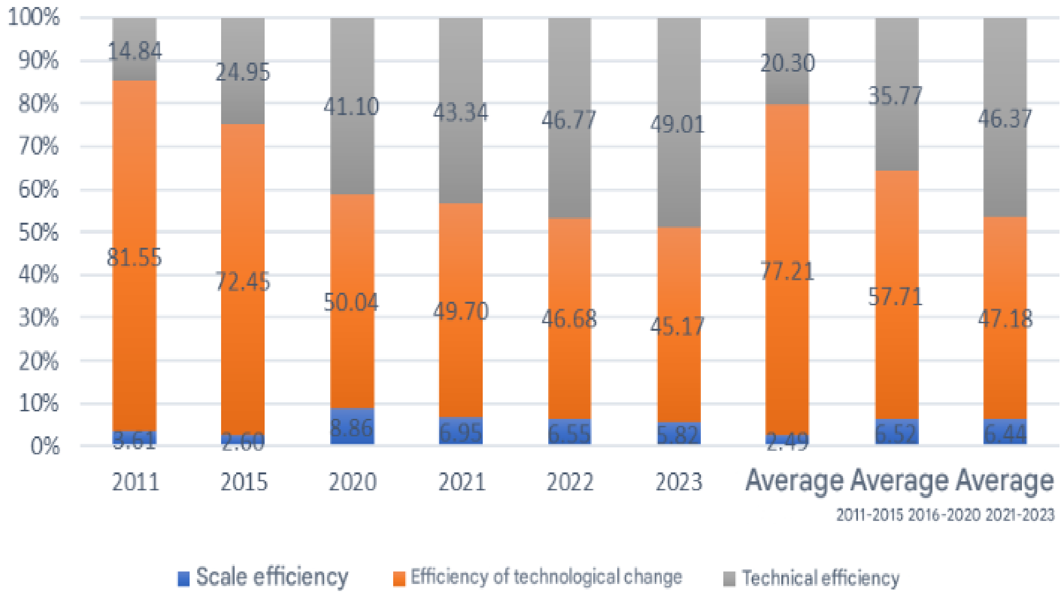

Figure 1.
The contribution rate of factors to TFP (%)
Source: Calculated by the author based on data from the Ha Tinh Province Statistics Office.

Regarding the contribution of scale efficiency to TFP (Total Factor Productivity). In 2011, the contribution value of scale efficiency to TFP was 3.61%, but it then sharply decreased to 1.2% in 2013. During the 2014-2015 period, there was a slight increase, but it remained at a low level with values of 2.23% and 2.6%, respectively. From 2016 onwards, scale efficiency showed an upward trend, particularly in 2017 (9.01%) and 2019 (9.42%). On average, the contribution of scale efficiency during the 2011-2015 period was 2.49%, and it improved to an average of 6.52% in the 2016-2020 period. The 2021-2023 period saw an average of 6.44%, indicating greater stability in scale efficiency. Scale efficiency reflects changes in the production scale of businesses. The gradual improvement in later periods suggests that businesses have found ways to optimize their production scale or have benefited from government support policies aimed at enhancing production scale.

Regarding the contribution of technological change efficiency to TFP (Total Factor Productivity). The efficiency of technological change has shown a declining trend over the years. In 2011, the contribution value of technological change efficiency reached 81.55% but gradually decreased in subsequent years. From 2018 onwards, technological change efficiency declined sharply, dropping to only 45.17% by 2023. On average, the contribution of technological change efficiency to VA during the 2011-2015 period was 77.21%; it decreased to 57.71% in the 2016-2020 period; and further dropped to 47.18% in the 2021-2023 period. The high efficiency of technological change during the 2011-2015 period may reflect strong investment in new technologies and production improvements. However, the subsequent decline could be attributed to several factors, such as technological saturation, financial difficulties or technology investment policies, and a lack of skilled human resources necessary to adopt and exploit new technologies. Particularly, the 2021-2023 period showed very low efficiency in technological change, likely due to the impact of the COVID-19 pandemic, which disrupted supply chains, reduced investment in technology, and diverted resources to maintaining business operations.

Regarding the contribution of technical efficiency to TFP (Total Factor Productivity). Technical efficiency has shown an increasing trend over the years. In 2011, the contribution value of technical efficiency was 14.84%, and it steadily increased, reaching a peak of 49.01% in 2023. On average, the contribution of technical efficiency during the 2011-2015 period was 20.3%, which rose to 35.77% in the 2016-2020 period, and further increased to 46.37% in the 2021-2023 period. Technical efficiency has shown continuous and stable improvement, particularly during the 2016-2020 and 2021-2023 periods. This improvement may be attributed to businesses focusing on enhancing labor skills, improving production processes, and adopting more effective management measures.

4. Conclusions and Recommendations

4.1. Conclusions

Based on the calculated results above, the following discussions can be drawn: *(1)* The role of TFP in GRDP growth is becoming increasingly important. By analyzing the contribution rate of factors to GRDP in Ha Tinh province, it is evident that TFP has shown an increasing trend across periods, rising from 29.67% (2011-2015) to 32.19% (2016-2020) and 33.04% (2021-2023). This indicates improvements in the efficiency of production factor utilization and highlights the growing importance of technology and effective management in driving the province's economic growth. *(2)* The contribution of science and technology (S&T) to TFP and GRDP is gradually declining. This decline may be due to several reasons, such as technological saturation and the impact of the COVID-19 pandemic. *3)* The role of TFP in the value added (VA) of businesses is becoming increasingly evident and significantly contributes to the increase in VA. This reflects improvements made by businesses, such as optimizing production processes, reducing waste, and enhancing work efficiency. *(4)* The contribution of S&T to TFP and VA of businesses has also shown a declining trend in recent years. This can be explained by the fact that after a period of strong investment in technology, businesses may have reached a saturation point where the potential of existing technologies has been fully exploited. Finding and adopting new technologies may become more challenging and costly. Additionally, investment in S&T requires significant capital. In the context of economic difficulties or fluctuations, businesses may reduce investments in research and development.

4.2. Recommendations

To enhance Total Factor Productivity (TFP) based on S&T and thereby drive GRDP growth in Ha Tinh Province, the article proposes the following recommendations.

(1) Strengthen the attraction and efficient utilization of foreign capital in the S&T sector. For FDI, continue improving the investment environment to create favorable conditions for international investors, aiming to attract capital, technology, and generate new job opportunities for local labor, as well as attract labor from outside the province. In the short term, it is necessary to focus on resolving the obstacles faced by foreign investors to bring the approved projects into operation. The foreign investment policy should target attracting companies with significant potential in capital and expertise in research and technology transfer.

(2) Develop S&T toward a modern, comprehensive, and sustainable industry. Ha Tinh Province has identified the goal of developing industry sustainably, making Ha Tinh one of the key industrial development centers in the region, focusing on the steel industry, supporting industries, steel fabrication, and power production. It aims to maintain high growth rates and continue being the main driver of economic growth. Specifically, *firstly,* enhance steel production technology. Invest in R&D for new technologies in the steelmaking process to improve product quality, increase productivity, and reduce harmful emissions. Additionally, promote the application of modern technologies such as automation and artificial intelligence to optimize production processes; *Secondly,* develop the supporting industries. Facilitate businesses that produce components and materials for the steelmaking industry, such as metals, alloys, and necessary equipment. Encourage collaboration and investment in high-tech companies to produce high-quality products and services; *Thirdly,* encourage the development of the post-steel manufacturing industry. Increase investment in R&D technologies to produce products processed after steelmaking, such as steel pipes, cables, and metal components. Promote collaboration between businesses in the supply chain to create higher added value.

Fourthly, invest in efficient power production technologies. Strengthen the development of renewable energy sources such as wind, solar, and hydropower to produce clean and efficient electricity. Simultaneously, promote the application of energy storage technologies and smart grid networks to optimize electricity use and reduce energy losses.

Fifthly, solutions related to enhancing training and developing human resources are key to ensuring the success of the above solutions. Train skilled workers and highly specialized engineers to meet the demands of modern industries. Collaborate with training and research institutions to improve the quality of education and vocational training, ensuring the workforce has the necessary skills and knowledge. Promoting international collaboration is an important strategy for accessing advanced technologies, management experience, and investment capital. Expanding cooperation with international partners and participating in international programs and projects will enhance the competitiveness of Ha Tinh's industrial sector in the global market while facilitating technology and knowledge transfer. Finally, building modern infrastructure is the foundation for industrial development. Invest in the development of transportation infrastructure, logistics, and modern industrial parks to support the growth of industries. Ensure the supply of electricity, water, and other basic services to create a favorable environment for business operations, helping businesses to develop sustainably.

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