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Productivity Growth, Technological Progress, and Efficiency Change in Vietnamese Manufacturing Industries: A Stochastic Frontier Approach*

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ABSTRACT

This study applies a stochastic frontier production approach to decompose the sources of total productivity (TFP) growth into technical progress and changes in technical efficiency of 8057 firms in Vietnamese manufacturing industries during 2003-2007. Using both total manufacturing industry and sub-manufacturing industrial regressions, the analysis focuses on the trend of technological progress (TP) and technical efficiency change (TEC), and the role of productivity change in economic growth. According to the estimated results, the annual technical progress for the manufacturing industry and sub-manufacturing industries are calculated directly from the estimated parameters of the translog stochastic frontier production function by taking a partial derivative of output with respect to time *t*. The average technical changes in manufacturing industry and sub-manufacturing industries are positive, with an average technical change about 5.2%, 5.8%, 5.4%, 11.8%, 4.6%, 4.1%, 7.3%, 4.8%, 4.8% and 4.8% for total sample, food products & beverages, textile & wearing apparel, footwear, paper & products, industrial chemicals, rubber & plastic products, nonmetallic mineral, basic & fabricated metal and other sub-industries, respectively. Total TFP in the manufacturing sector has grown at the annual rate of 0.052, although the rate of growth decreased continuously during the sample period. For the sub-industry estimates during the sample period, TFP grew fastest in the footwear sub-industry, with annual average growth rate of 11.8%, followed by the rubber & plastic products with a rate of 7.3%, and the food products & beverages with a rate of 5.8% per annum.

Keywords: Total Factor Productivity; Technical Efficiency Change; Technological Progress; Stochastic Frontier Approach; Vietnamese Manufacturing Industry

1. Introduction

In the “Solow residual approach”, technical progress is usually considered to be the unique source of TFP growth. TFP growth can be defined as the residual of output growth after the contribution of labor and capital inputs and subtracted from total output growth. This approach is based on the assumption that the economies are producing along the production possibility frontier with full technical efficiency (it does not allow inefficiency).

The concept of the efficiency frontier has been used to present inefficiencies.

A varies of methods have been used to measure efficiency and decomposition total factor productivity (TFP) into technical progress, changes in technical efficiency.

These methods differ to the assumptions on the outer bound of the frontier, which deterministic or stochastic frontier production function, and to the method of measurement parametric or non-parametric.

For nonparametric method, such as data envelopment analysis (DEA). This method cannot separate deviation from the frontier technology into their systematic and random components. However, this method has the advantage of imposing no restrictions on the underlying technology and have an advantage in dealing with disaggregated inputs and multiple output technologies.

An alternative method is called a stochastic frontier production function approach. The most important difference between the stochastic frontier production function approach and the Solow residual approach to productivity growth analysis lies in one assumption that firms do not fully utilize existing technology since vari-

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ous factors that lead to inevitable technical inefficiencies in production.

The stochastic frontier production function approach allows decomposing TFP into efficiency change (TE) and technical progress (TP). From a policy perspective, the decomposition of TFP into efficiency changes and technical changes provides useful information in productivity analysis.

Since Nishimizu and Page [1] first proposed the decomposition of TFP into efficiency changes and technical changes, researchers have applied this approach to various datasets in order to investigate productivity growth. Bauer [2] estimated a translog cost frontier using data on the US airline industry to decompose TFP growth into efficiency, technical progress, and scale components. Sangho Kim and Gwangho Han [3] applied a stochastic frontier production model to Korean manufacturing industries to decompose the sources of total productivity (TFP) growth into technical progress, changes in technical efficiency, and changes in allocative efficiency, and scale effects. Empirical results based on data from 1980-1994 showed that productivity growth was driven mainly by technical progress, that changes in technical efficiency had a significant positive effect, and that allocative efficiency had a negative effect. They suggested that specific guidelines are required to promote productivity in each industry, and provided additional insights into understanding the recent debate about TFP growth in Korean manufacturing.

Hailin Liao *et al.* [4] applied a stochastic frontier approach to sector-level data within manufacturing and examined total factor productivity (TFP) growth for eight East Asian economies during 1963-1998, using both single country and cross-country regression. The analysis focuses on the trend of technological progress (TP) and technical efficiency change (TEC), and the role of productivity change in economic growth. The empirical results reveal that although input factor accumulation is still the main source for East Asian economies' growth, TFP growth is accounting for an increasing and important proportion of output growth, among which the improved TEC plays a crucial role in productivity growth.

Nguyen Khac Minh *et al.* [5] applied a non-parametric approach method to decompose the sources of total productivity (TFP) growth of three sectors of Vietnamese economy into technical progress and changes in technical efficiency.

This study develops the study of Nguyen Khac Minh *et al.* [6] "A decomposition of total factor productivity growth in Vietnamese industries—a stochastic frontier approach" to decompose TFP growth in Vietnamese manufacturing industries from 2003-2007. We attempt to decompose TFP growth in Vietnamese manufacturing using a stochastic frontier production model, and provide additional insights into understanding on TFP growth of Vietnamese sub-manufacturing industries.

This paper is organized as follows. Section 2 presents a decomposition of TFP and presents the functional form of the estimation model. Section 3 discusses the data and estimation results. Section 4 contains the conclusions.

2. Decomposition and Functional Form

2.1. Decomposition of TFP

A stochastic frontier production function can be defined by

$$y_{it} = f\left(x_{it}, t\right)\exp\left(-u_{it}\right) \tag{1}$$

where y_{it} is the output of the *i*th firm $\left(i = 1, \cdots, N\right)$ in the *t*th time period $\left(t = 1, \cdots, T\right)$; $f\left(\cdot\right)$ is the production frontier; χ is an input vector, t is a time trend index that serves as a proxy for technical change; and u (non-negative) is the output-oriented technical inefficiency.

Taking total differentials $f\left(x_{it}, t\right)$ with respect to time to get

$$\begin{aligned}\frac{\mathrm{d}\ln f\left(x,t\right)}{\mathrm{d}t} &= \frac{\partial \ln f\left(x,t\right)}{\partial t} + \sum_j \frac{\partial \ln f\left(x,t\right)}{\partial x_j}\frac{\mathrm{d}x_j}{\mathrm{d}t} \\ &= \mathrm{TP} + \sum_j \varepsilon_j \dot{x}_j\end{aligned} \tag{2}$$

whereas the first and second terms on the right-hand side are the output elasticity of frontier out put with respect to time, defined as TP, the second term measures the input growth weighted by output elasticities with respect to input j, $\varepsilon_j = \partial \ln f / \partial \ln x_j$. A dot over a variable indicates its rate change.

The derivative of the logarithm of (1) with respect to time t and using (3) is given by:

$$\dot{y} = \mathrm{TP} + \sum_j \varepsilon_j \dot{x}_j - \frac{\mathrm{d}u}{\mathrm{d}t} \tag{3}$$

from Equation (3), TFP growth can be defined technical change (TP) and technical efficiency change.

2.2. Model Specification

In our empirical study, we employ the stochastic frontier approach. The output of the manufacturing industry (or sub-industries) is assumed to be a function of two inputs, namely capital and labor. The components of productivity change can be estimated within a stochastic frontier approach, and the time-varying production frontier can be specified in translog form as:

$$\begin{aligned}\ln y_{it} &= \alpha_o + \sum_j \alpha_j \ln x_{jit} + \alpha_t t \\ &\quad + \frac{1}{2}\sum_j \sum_l \beta_{jl} \ln x_{lit} \ln x_{jit} + \frac{1}{2}\beta_{tt} t^2 \\ &\quad + \sum_j \beta_{tj} t \ln x_{jt} + v_{it} - u_{it}, \quad j,l = L,K\end{aligned} \tag{4}$$

In Equation (4), y_{it} is the observed output, t is the time variable and x variables are inputs, subscripts j and l index inputs. The efficiency error, u, accounting for production loss due to unit-specific technical inefficiency, is always greater than or equal to zero and assumed to be independent of the random error, v, which is assumed to have the usual properties $\left(\sim iid\ N\left(0,\sigma_v^2\right)\right)$. Equation (4) can be rewritten as the following form:

1) Specification model for whole manufacturing industry

$$\begin{aligned}Lny_{it}^j &= \alpha_0+\alpha_L\ln L_{it}^j+\alpha_K\ln K_{it}^j+\frac{1}{2}\beta_{LL}\left(\ln L_{it}^j\right)^2\\&+\frac{1}{2}\beta_{KK}\left(\ln K_{it}^j\right)^2+\beta_{LK}\left(\ln L_{it}^j\right)\left(\ln K_{it}^j\right)+\beta_{tL}\left(\ln L_{it}^j\right)t\\&+\beta_{tK}\left(\ln K_{it}^j\right)t+\alpha_t t+\frac{1}{2}\beta_{tt}t^2+\left(v_{it}-u_{it}\right)\end{aligned}$$

where y_{it}^j is the firm's output. The subscripts i represent the ith firm for $i=1,2,\cdots,N$. N is equal to 8057 for the total sample. t represents year for $t=1,2,\cdots,T$ and so T is equal to 5. The subscripts j represent the jth industry for $j=1,2,\cdots,H$, K_{it}^j and L_{it}^j represent capital and labor, respectively. The $\alpha's$ and $\beta's$ are unknown parameters to be estimated.

2) Specification model for each industry

$$\begin{aligned}Lny_{it} &= \alpha_0+\alpha_L\ln L_{it}+\alpha_K\ln K_{it}+\frac{1}{2}\beta_{LL}\left(\ln L_{it}\right)^2\\&+\frac{1}{2}\beta_{KK}\left(\ln K_{it}\right)^2+\beta_{LK}\left(\ln L_{it}\right)\left(\ln K_{it}\right)+\beta_{tL}\left(\ln L_{it}\right)t\\&+\beta_{tK}\left(\ln K_{it}\right)t\ \ \alpha_t t+\frac{1}{2}\beta_{tt}t^2+\left(v_{it}-u_{it}\right)\end{aligned}\quad (5)$$

The distribution of technical inefficiency effects, u_{it}, is taken to be the non-negative truncation of the normal distribution $N\left(\mu,\sigma_u^2\right)$, following Battese & Coelli [7], to take the form as

$$u_{it}=\eta_t u_i=u_i\exp\left(-\eta\left[t-T\right]\right),\quad t\in\tau(i) \quad (6)$$

Here, the unknown parameter η represents the rate of change in technical inefficiency, and the non-negative random variable ui, is the technical inefficiency effect for the ith firm in the last year for the data set. That is, the technical inefficiency effects in earlier periods are a deterministic exponential function of the inefficiency effects for the corresponding forms in the final period (*i.e.*) $u_{iT}=u_i$ given that data for the ith firm are available in period t). $\tau(i)$ is the set of T time periods. A firm with a positive η is likely to improve its level of efficiency over time and vice-verse. A value of $\eta=0$ implies no time-effect.

Since the estimates of technical efficiency are sensitive to the choice of distribution assumptions, we consider truncated normal distribution for general specifications for one-sided error u_{it}, and half-normal distribution can be tested by LR test.

Given the estimates of parameters in Equations (5) and (6), the technical efficiency level of a firm at time t is defined as

$$\mathrm{TE}_{it}=\exp\left(-u_{it}\right) \quad (7)$$

and TEC is the change in TE, and the rate of technical progress is defined by,

$$\mathrm{TP}_{it}=\frac{\partial\ln f\left(x_{it,t}\right)}{\partial t}=\alpha_t+\beta_{tt}+\beta_{tL}\left(\ln L_i\right)+\beta_{tK}\left(\ln K_i\right) \quad (8)$$

If technical change is non-neutral then this technical change may vary for different input vectors. Hence, we use the geometric mean between adjacent periods as a proxy,

$$\mathrm{TP}_{it}=\left[\left(1+\frac{\partial\ln f\left(x_{it,j}\right)}{\partial t}\right)\times\left(1+\frac{\partial\ln f\left(x_{it+1,t+1}\right)}{\partial\left(t+1\right)}\right)\right]^{1/2}-1 \quad (9)$$

Both TE_{it} and TP_{it} vary over time and across the firms.

The output elasticities of input K and L are

$$\varepsilon_K=\frac{\partial\ln Y}{\partial\ln K}=\alpha_K+\beta_{KK}\ln K+\beta_{KL}\ln L+\beta_{Kt}t$$

$$\varepsilon_L=\frac{\partial\ln Y}{\partial\ln L}=\alpha_L+\beta_{KL}\ln K+\beta_{LL}\ln L+\beta_{Lt}t$$

The above equations indicate the percentage change in output due to a 1% change in inputs. They can be used to obtain an estimate of aggregate return to scale. The elasticity of scale is defined as e: $e=\varepsilon_K+\varepsilon_L$.

The elasticity of scale (e) measures how output varies as a particular input bundle is augmented by a scalar. If the scale elasticity is unity, then the technology exhibits constant returns to scale.

3. Data and Empirical Results

3.1. Data Issues

The panel data of Vietnamese manufacturing sectors' annual time-series during 2003-2007 are used in estimating production functions. The sectors and their SIC classification numbers are listed in **Table 1**.

The sample consists of 8057 firms in Vietnamese manufacturing industries. Data for these firms have been taken for 5 years from 2003 to 2007. All these firms that are selected at least 5 workers.

The basic data for the analysis have been drawn the Database, 2007 version from General Statistics Office (GSO). It contains information for about characterized enterprises. The coverage includes public, private, and

Table 1. Manufacturing sectors.

1) Manufacturing sector (Total sample)	6) Industrial chemicals
2) Food products and beverages	7) Rubber and plastic products
3) Textile and wearing apparel	8) Non-metallic mineral
4) Footwear	9) Basic & fabricated metal products
5) Paper & products	10) Other manufacturing industries

joint sector companies. The coverage of this database is total manufacturing firms that existed from 2003 to 2007 with number of workers greater than 5.

The available Information includes data from the enterprises' profit, balance sheets. Key variables on which data were collected for this study include gross fixed assets, wages, revenue, gross output and foreign equity.

3.2. Variables for the Estimation of the Model

As discussed above, a two-input production function framework is used to estimate technical efficiency. This requires, for each firm, data on output, labor input and capital input.

Deflated revenue has been taken as the measure of output. For this purpose, the products of each enterprise were matched with the wholesale price indices classification, and the best available price series was chosen for deflation.

Total number of employees connected to the production has been taken as the measure of labor input for each firm in our sample.

Gross fixed capital stock at constant prices (at year 2000) has been taken as the measure of capital input.

4. Empirical Results

The estimation of parameters in the stochastic frontier mode given by Equations (8) and (9) are carried out via maximum-likelihood method, using the program FRONTIER 4.1. Two kinds of panel are constructed. Individual sub-Industry panel is used in the single regression, consisting of total sample and 9 sub-manufacturing sectors and 5 years' observations; panel data is used in the regression. Instead of directly estimating σ_v^2 and σ_u^2, FRONTIER 4.1 seeks estimates of

$$\gamma = \sigma_u^2 / \sigma^2 , \quad \sigma^2 = \sigma_u^2 + \sigma_v^2 \qquad (10)$$

which are also reported in the result table. These are associated with the variances of the stochastic term in the production function, v_{it} and the inefficiency term v_{it}. The parameter γ must lie between zero and one. If the hypothesis $\gamma = 0$ is accepted, this would indicate that σ_u^2 is zero and thus the efficiency error term, v_{it} should be remove from the model, leaving a specification with parameters that can be consistently estimated by OLS. Conversely, if the value of γ is one, we have the full-frontier model, where the stochastic term is not present in the model.

4.1. Hypotheses Tests and Preferred Model Chosen

We performed a number of *LR* test to identify the adequate functional form and presence of inefficiency. We examine various hypotheses, such as non-presence of technical inefficiency effects, which can be tested by using the generalized likelihood ratio statistics λ, given by:

$$\lambda = -2\left[\ln\left\{L\left(H_0\right)\right\} - \ln\left\{L\left(H_1\right)\right\}\right]$$

where $L(H_0)$ is the value of the likelihood function for the frontier model in which the parameter restrictions specified by the null hypothesis H_0 are imposed and $L(H_1)$ is the value of the likelihood function for the general frontier model. If the null hypothesis is true, then λ has approximately a mixed Chi-Squared distribution with degrees of freedom equal to the difference between the numbers of parameters estimated under H_1 and H_0, respectively.

4.2. Hypotheses Tests for Aggregated Samples

Table 2 presents the test results of various null hypotheses on the total sample.

1) The first null hypothesis that the technology in Vietnamese manufacturing is a Cobb-Douglas $\left(H_o : \beta_{LL} = \beta_{KK} = \beta_{KL} = \beta_{tt} = 0\right)$, is rejected for the total sample and all aggregated-samples. Thus, the Cobb-Douglas production function is not an adequate specification for the Vietnamese manufacturing sector, given the assumptions of the translog stochastic frontier production function model, implying that the translog production function better describes the technology for Vietnamese manufacturing industries.

2) The second null hypothesis, that there is no technical change $\left(H_o : \alpha_t = \beta_{tK} = \beta_{tL} = \beta_{tt} = 0\right)$ is strongly rejected by the data in all cases. It implies that the existence of technical progress, given the specified production model.

3) The third null hypothesis, that technical progress is neutral $\left(H_o : \beta_{tK} = \beta_{tL} = 0\right)$.

Not that the translog parameterization of this stochastic frontier model allows for non-neutral TP. TP is neutral if all β_{tj} s are equal to zero. Total sample, food & beverages, footwear, paper & products, Industrial chemicals, non-metallic mineral, basic & fabricated metal and other manufacturing industries cannot reject the hypothe-

Table 2. Generalized likelihood ratio of hypotheses for parameters of the SFPF for Vietnamese manufacturing industries.

Hypothesis	Log-likelihood value	Test statistics	Critical value		Decision
			1%	5%	
Cobb-Douglas production function, H_0: all β_s are equal to zero (df = 6)					
Total sample	–48319.83	21475.94	16.81	12.59	reject
Food products & beverages	–7559.98	31.65	16.81	12.59	reject
Textile & wearing apparel	–4781.91	41.92	16.81	12.59	reject
Footwear	–1007.15	29.69	16.81	12.59	reject
Paper & products	–2731.46	25.00	16.81	12.59	reject
Industrial chemicals	–1604.32	21.13	16.81	12.59	reject
Rubber & plastic products	–2238.63	50.15	16.81	12.59	reject
Non-metallic mineral	–3394.03	107.98	16.81	12.59	reject
Basic & fabricated metal	–10757.17	94.99	16.81	12.59	reject
Others	–9754.55	86.46	16.81	12.59	reject
No technical change, $H_0: \alpha_t = \beta_{tL} = \beta_{tK} = \beta_{tt} = 0$ (df = 4)					
Total sample	–38319.59	1475.40	13.28	9.49	reject
Food products & beverages	–7700.38	312.45	13.28	9.49	reject
Textile & wearing apparel	–4871.20	220.51	13.28	9.49	reject
Footwear	–1038.66	92.71	13.28	9.49	reject
Paper & products	–2786.94	135.95	13.28	9.49	reject
Industrial chemicals	–1622.30	57.08	13.28	9.49	reject
Rubber & plastic products	–2339.36	51.61	13.28	9.49	reject
Non-metallic mineral	–3408.05	136.03	13.28	9.49	reject
Basic & fabricated metal	–10900.30	381.25	13.28	9.49	reject
Others	–9871.85	32.06	13.28	9.49	reject
Neutral technical progress : $H_0: \beta_{tL} = \beta_{tK} = 0$ (df = 2)					
Total sample	–37582.35	0.99	9.21	5.99	accept
Food products & beverages	–7551.48	14.65	9.21	5.99	reject
Textile & wearing apparel	–4765.83	9.77	9.21	5.99	reject
Footwear	–992.42	0.23	9.21	5.99	accept
Paper & products	–2719.95	1.98	9.21	5.99	accept
Industrial chemicals	–1595.48	3.44	9.21	5.99	accept
Rubber & plastic products	–2216.81	6.49	9.21	5.99	reject at 5%
Non-metallic mineral	–3340.88	1.68	9.21	5.99	accept
Basic & fabricated metal	–10709.84	0.33	9.21	5.99	accept
Others	–9712.29	1.93	9.21	5.99	accept
No technical inefficiency, $H_0: \mu = \eta = \gamma = 0$ (df = 3)					
Total sample	–48321.28	21477.84	10.501	7.045	reject
Food products & beverages	–9464.15	3839.99	10.501	7.045	reject
Textile & wearing apparel	–5977.24	2432.59	10.501	7.045	reject
Footwear	–1277.32	569.79	10.501	7.045	reject
Paper & products	–3658.84	1877.77	10.501	7.045	reject
Industrial chemicals	–2113.51	1036.06	10.501	7.045	reject
Rubber & plastic products	–3076.49	1725.86	10.501	7.045	reject
Non-metallic mineral	–4358.00	2035.93	10.501	7.045	reject

Continued

Basic & fabricated metal	–13321.73	5223.78	10.501	7.045	reject
Others	–12002.09	4579.61	10.501	7.045	reject
	Half-normal distribution of technical inefficiency, $H_0: \mu = 0$ (df = 1)				
Total sample	–37582.35	837.03	6.63	3.84	reject
Food products & beverages	–7544.15	96.11	6.63	3.84	reject
Textile & wearing apparel	–4760.95	169.35	6.63	3.84	reject
Footwear	–992.42	32.43	6.63	3.84	reject
Paper & products	–2719.95	91.22	6.63	3.84	reject
Industrial chemicals	–1595.48	12.31	6.63	3.84	reject
Rubber & plastic products	–2213.56	25.55	6.63	3.84	reject
Non-metallic mineral	–3340.88	162.24	6.63	3.84	reject
Basic & fabricated metal	–10709.84	191.64	6.63	3.84	reject
Others	–9712.29	229.34	6.63	3.84	reject
	Time invariant technical inefficiency, $H_0: \eta = 0$ (df = 1)				
Total sample	–37115.2	97.27	6.63	3.84	reject
Food products & beverages	–7496.09	12.46	6.63	3.84	reject
Textile & wearing apparel	–4676.28	32	6.63	3.84	reject
Footwear	–976.21	33.96	6.63	3.84	reject
Paper & products	–2674.30	32.97	6.63	3.84	reject
Industrial chemicals	–1589.31	0.16	6.63	3.84	accept
Rubber & plastic products	–2199.78	43.45	6.63	3.84	reject
Non-metallic mineral	–3258.92	4.01	6.63	3.84	reject at 5%
Basic & fabricated metal	–10614.02	21.32	6.63	3.84	reject
Others	–9597.62	8.81	6.63	3.84	reject

The critical value for this test involving $\gamma = 0$ is obtained from **Table 1** of Kodde and Palm (1986).

sis. Then, the existence of neutral technical progress in the data set of these industries. In the case of food products & beverages, textile & wearing apparel and rubber & plastic products, the hypothesis is rejected it implies that the existence of non-neutral technical progress in the data set of these industries.

4) Given the specification of stochastic frontier model, there is a particular interest in testing the hypothesis of the non-existence of sector-level inefficiency, expressed by $H_0: \gamma = \mu = \eta = 0$ The first null hypothesis is strongly rejected at the 1% significance level for all samples, suggesting that the average production function is an inadequate representation of the aggregated models for all cases and will underestimate the actual frontier because of the manufacturing sector for all cases and will underestimate the actual frontier because of the existence of technical inefficiency effects.

5) The fifth null hypothesis, specifying that technical inefficiency effects have half-normal distribution $(H_0: \mu = 0)$ against truncated normal distribution, is rejected at the 1% significance level for the total sample and all sub-samples.

6) The last null hypothesis, that technical inefficiency is time-invariant $(H_0: \eta = 0)$ is rejected for total sample, food products and beverages, textile and wearing apparel, footwear, paper & products, rubber and plastic products, non-metallic mineral, basic & Fabricated metal products and Other manufacturing industries at least the 5% significance level. The industrial chemicals are only the case that cannot reject the hypothesis.

4.3. Estimation of Stochastic Production Functions

Given the specifications of translog frontier with time-varying inefficiency effects the results of statistical tests of the estimated parameters, the preferred frontier models are chosen and the estimates of their parameters are given in **Tables 3** and **4**.

To estimate production frontier for the total sample and aggregated samples, the maximum—likelihood estimates of the parameters in the translog stochastic frontier production function, defined by Equations (4) and (5), are employed in this study.

Moreover, since there may exist some uncontrollable

Table 3. Panel estimation of stochastic frontier production and technical inefficiency model.

		Total sample	Food	Textiles	Footwear	Paper
Variable		Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Const	α_t	2.928*** (0.076)	2.2214*** (0.171)	3.6363*** (0.250)	3.272*** (0.477)	4.1904*** (0.256)
ln*K*	β_K	0.497*** (0.019)	0.659*** (0.042)	0.5172*** (0.059)	0.403*** (0.124)	0.3306*** (0.070)
ln*L*	β_L	0.555*** (0.022)	0.4891*** (0.056)	0.3559*** (0.059)	0.526*** (0.117)	0.4411*** (0.091)
T	β_t	0.13*** (0.01)	0.0968*** (0.029)	–0.017*** (0.038)	0.047 (0.062)	0.0816 (0.025)***
*t*ln*K*	β_{LK}		0.0092** (0.004)	0.0088** (0.004)		
*t*ln*L*	β_{tL}		–0.017*** (0.005)	0.0055 (0.004)		
ln*K*ln*L*	β_{KL}	–0.01*** (0.004)	0.0099 (0.011)	–0.0219** (0.009)	–0.086*** (0.024)	0.0011 (0.021)
ln*K*2	β_{KK}	0.005*** (0.002)	–0.0214** (0.005)	0.0008 (0.005)	0.033** (0.013)	0.0055 (0.008)
ln*L*2	β_{LL}	0.005 (0.003)	0.0154 (0.009)	0.0364*** (0.007)	0.066*** (0.016)	0.0226 (0.017)
*t*2	β_{tt}	–0.017*** (0.001)	–0.0198*** (0.004)	–0.0133*** (0.004)	–0.015* (0.008)	–0.0144*** (0.004)
	σ^2	0.71*** (0.014)	0.7608*** (0.034)	0.6756*** (0.037)	0.465*** (0.045)	0.4413*** (0.028)
	γ	0.676*** (0.006)	0.6524 (0.018)***	0.6782 (0.012)***	0.578 (0.042)***	0.6434 (0.021)***
	μ	1.254 (0.032)***	1.155*** (0.086)	1.3537*** (0.061)	1.003*** (0.14)	1.0657*** (0.067)
	η	0.027*** (0.003)	0.0254*** (0.007)	0.0426*** (0.008)	0.103*** (0.018)	0.0493*** (0.008)
log-likelihood function		–37111.57	–7489.87	–4660.92	–959.229	–2657.86

Source: Authors' estimates from the data source; Note: 1) standard errors are given in the parenthesis; 2) */**/***Denotes statically significant at the 10, 5 and 1 per cent levels, respectively.

stochastic shocks, such as changes of government policies or other conditions affecting firms' production efficiency, a stochastic frontier production approach is applied. Concerning productivity, there are two indices to indicate whether firms in Vietnamese manufacturing industry have a high or low production efficiency: σ^2 represents total variance of output, containing a random error term $\left(\sigma_v^2\right)$ and a technical inefficiency term $\left(\sigma_u^2\right)$. However large value of σ^2 does not necessary mean a less efficient way of production since it includes two types of production variation.

The estimates of η are positive (or at least zero) in the cases, except for the non-metallic mineral sub-industry.

Almost coefficients of variables in all equations are statistically significant. A significant γ along with a positive and significant η implies the existence of technical inefficiency that declines over the years, except for the Industry Non-metallic Mineral.

Table 5 presents the average technical efficiency (TE) for Vietnamese manufacturing industries for time period during 2003-2007. Estimates of TE vary considerably, both across manufacturing industries, and cross time periods. The average TE is 0.309 for the total sample. The industrial chemical and rubber and plastics industries have the highest and second highest estimates, 0.417 and 3.91, respectively. and the textile & wearing apparel and non-metal mineral industries have the lowest and second lowest estimates, 0.267 and 0.290, respectively. The other industries have estimates the range from 0.300 to 0.342.

The average TE for all industries improves throughout

Table 4. Panel estimation of stochastic frontier production and technical inefficiency model.

		Chemical	Rubber	Non-metal	Basic-metal	Others
Variable		coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Const	α_t	1.6381*** (0.396)	3.3089*** (0.338)	2.079*** (0.22)	3.2191*** (0.152)	3.2944*** (0.152)
ln*K*	β_K	0.6885*** (0.107)	0.5934*** (0.089)	0.352*** (0.058)	0.3717*** (0.039)	0.4251*** (0.040)
ln*L*	β_L	0.7403*** (0.123)	0.2795 (0.104)**	0.982*** (0.077)	0.6142*** (0.047)	0.4482*** (0.045)
t	β_t	0.1212*** (0.037)	0.0796 (0.047)*	0.138*** (0.028)	0.1571*** (0.019)	0.1733*** (0.020)
*t*ln*K*	β_{tK}		0.0111* (0.006)			
*t*ln*L*	β_{tL}		0.0037 (0.008)			
ln*K*ln*L*	β_{KL}	–0.0783*** (0.024)	0.0174 (0.020)	–0.114 (0.012)	0.0026*** (0.010)	0.0252** (0.008)
ln*K*2	β_{KK}	0.0087 (0.01)	–0.0104 (0.009)	0.041*** (0.005)	0.0084* (0.004)	–0.0003 (0.004)
ln*L*2	β_{LL}	0.0648*** (0.020)	0.0073 (0.015)	0.063*** (0.012)	–0.0103 (0.008)	–0.0125* (0.007)
*t*2	β_{tt}	–0.0114* (0.006)	–0.0283 (0.005)***	–0.012** (0.004)	–0.0218*** (0.003)	–0.0224*** (0.003)
	σ^2	0.8327*** (0.108)	0.6324*** (0.057)	0.654*** (0.049)	0.6342*** (0.023)	0.6758*** (0.026)
	γ	0.7665*** (0.031)	0.7142 (0.026)	0.72*** (0.012)	0.617*** (0.014)	0.6288*** (0.014)
	μ	0.8437*** (0.145)	0.8421*** (0.087)	1.372*** (0.06)	1.1383*** (0.063)	1.3038*** (0.053)
	η	0	0.0682 (0.010)	–0.004 (0.008)	0.028*** (0.006)	0.016** (0.006)
log-likelihood function		–1589.33	–2178.06	–3256.91	–10603.4	–9593.2

Source: Authors' estimates from the data source; Note: 1) standard errors are given in the parenthesis; 2) */**/***Denotes statically significant at the 10, 5 and 1 per cent levels, respectively.

Table 5. The average technical efficiency (TE) for Vietnamese manufacturing industries.

	Eff 2003	Eff 2004	Eff 2005	Eff 2006	Eff 2007	Average
Total sample	0.293	0.301	0.309	0.318	0.326	0.309
Food products & beverages	0.319	0.327	0.334	0.342	0.35	0.334
Textile & wearing apparel	0.242	0.254	0.267	0.279	0.292	0.267
Footwear	0.27	0.3	0.332	0.365	0.398	0.333
Paper & products	0.311	0.326	0.342	0.358	0.374	0.342
Industrial chemicals	0.417	0.417	0.417	0.417	0.417	0.417
Rubber & plastic products	0.349	0.37	0.391	0.412	0.433	0.391
Non-metallic mineral	0.293	0.292	0.29	0.289	0.288	0.290
Basic & fabricated metal	0.321	0.33	0.339	0.347	0.356	0.339
Others	0.291	0.296	0.301	0.306	0.31	0.301

Source: Authors' estimates from the data source.

the sample period, and this trend of steady improvement is also observed in the food, textiles, footwear, paper, rubber and plastics, basic-metal and other industries. The average TE unchanging through the years in chemical and non-metal industries.

Table 6 presents return to scale (RTS) for Vietnamese manufacturing industries for time period during 2003-2007. For the total sample, food products & beverages, textile & wearing apparel, footwear, paper & products, industrial chemicals, rubber & plastic products, non-metallic mineral, basic & fabricated metal and other sub-industries, the estimates of RTS are more than unity. RTSs are remaining more than unity. For textile & wearing apparel and rubber & plastic products, the estimates of RTS are 0.976 and 0.984 in 2003, respectively but continuously increases more than one during the sample period.

Table 7 shows the means of estimated technical effi-

Table 6. The average RTS for Vietnamese manufacturing industries.

	TRS 2003	RTS 2004	RTS 2005	RTS 2006	RTS 2007
Total sample	1.052	1.052	1.052	1.052	1.052
Food products & beverages	1.148	1.14	1.131	1.122	1.114
Textile & wearing apparel	0.976	0.993	1.008	1.023	1.033
Footwear	1.026	1.027	1.028	1.028	1.026
Paper & products	1.024	1.027	1.029	1.029	1.031
Industrial chemicals	1.131	1.127	1.125	1.123	1.116
Rubber & plastic products	0.984	1.001	1.016	1.031	1.045
Non-metallic mineral	1.15	1.148	1.148	1.146	1.146
Basic & fabricated metal	1.065	1.066	1.067	1.067	1.069
Others	1.115	1.12	1.121	1.122	1.125

Source: Authors' estimates from the data source.

Table 7. Mean technical efficiency in Vietnamese manufacturing firms, 2003-2007, by ownership category.

		2003	2004	2005	2006	2007	Obs
Total sample	Foreign	0.332	0.341	0.349	0.357	0.366	1325
	Domestic	0.285	0.293	0.302	0.310	0.318	6732
Food products & beverages	Foreign	0.406	0.414	0.421	0.428	0.436	135
	Domestic	0.311	0.318	0.326	0.334	0.342	1401
Textile & wearing apparel	Foreign	0.277	0.290	0.303	0.316	0.329	288
	Domestic	0.228	0.240	0.252	0.265	0.278	726
Footwear	Foreign	0.329	0.360	0.391	0.423	0.455	71
	Domestic	0.243	0.274	0.306	0.339	0.372	158
Paper & products	Foreign	0.350	0.365	0.380	0.395	0.410	50
	Domestic	0.308	0.323	0.339	0.355	0.371	671
Industrial chemicals	Foreign	0.535	0.535	0.535	0.535	0.535	82
	Domestic	0.384	0.384	0.384	0.384	0.384	297
Rubber & plastic products	Foreign	0.359	0.379	0.400	0.420	0.441	111
	Domestic	0.347	0.367	0.388	0.409	0.430	425
Non-metallic mineral	Foreign	0.462	0.460	0.459	0.458	0.457	51
	Domestic	0.281	0.280	0.279	0.278	0.276	732
Basic & fabricated metal	Foreign	0.354	0.362	0.371	0.380	0.389	481
	Domestic	0.313	0.321	0.330	0.339	0.348	1810
Others	Foreign	0.331	0.336	0.341	0.346	0.351	431
	Domestic	0.280	0.285	0.290	0.295	0.300	1591

Source: Authors' estimates from the data source.

ciency for the foreign owned firms, domestically owned (including private sector firms and public sector firms for different years during the period, 2003 to 2007).

It is evident from the comparison presented in **Table 5** that the mean technical efficiency of foreign firms was higher than that of domestically owned firms each year of the period under study. For the five-year period, 2003 to 2007, on an average, technical efficiency of foreign firms in total sample and sub-samples were higher technical efficiency than domestically owned firms. The average technical efficiency levels of foreign firms for industrial chemicals, non-metallic mineral, footwear over period 2003-2007 are 0.535, 0.457, 0.455 about, 39, 66 and 22.3 percent higher than that for domestic firms, respectively.

The estimates of the average annual rate of change in efficiency for the manufacturing industries and some sub-manufacturing industries are presented in **Table 8**.

We calculated these efficiency changes using Equation (2) ($\text{Technical change} = \text{TE}_{it}/\text{TE}_{st}$). The rate of growth in efficiency is an indicator of an industries' performance.

The estimate of the average rate of growth in efficiency in Vietnamese manufacturing industries suggests that the level efficiency has increased over the whole period (except Non-metallic mineral industry). For example the sub-industry, with average rate of growth in efficiency about 8.2% (highest rate) is footwear, following by rubber & plastic products (about 6.3%) and textile & wearing apparel (about 5.4%).

The annual technical progress change estimates for the manufacturing industry and submanufacturing industries are presented in **Table 9**. The technical progress change index between any two adjacent periods s and t were calculated directly from the estimated parameters of the translog stochastic frontier production function by taking a partial derivative of output with respect to time t. Then, we calculated technical change for each sub-industry, and given period by using Equation (3).

Table 10 shows that average technical changes in manufacturing industry and sub-manufacturing industries are positive, with an average technical change about 5.2%,

Table 8. Technical efficiency change in Vietnamese manufacturing firms, 2003-2007.

TEC	2003-2004	2004-2005	2005-2006	2006-2007	2003-2007
Total sample	0.039	0.04	0.037	0.036	0.030
Food products & beverages	0.034	0.03	0.032	0.031	0.025
Textile & wearing apparel	0.071	0.07	0.065	0.062	0.054
Footwear	0.111	0.11	0.099	0.09	0.082
Paper & products	0.065	0.06	0.059	0.056	0.048
Industrial chemicals	0	0	0	0	0.000
Rubber & plastic products	0.087	0.08	0.076	0.07	0.063
Non-metallic mineral	–0.006	–0.01	–0.006	–0.006	–0.006
Basic & fabricated metal	0.036	0.04	0.034	0.033	0.029
Others	0.022	0.02	0.022	0.021	0.017

Source: Authors' estimates from the data source.

Table 9. Technical progress change in Vietnamese manufacturing firms, 2003-2007.

TPC	2003-2004	2004-2005	2005-2006	2006-2007	2003-2007
Total sample	0.079	0.05	0.011	–0.023	0.023
Food products & beverages	0.071	0.05	0.032	0.012	0.033
Textile & wearing apparel	0.041	0.02	–0.011	–0.038	0.002
Footwear	0.047	0.05	0.047	0.047	0.038
Paper & products	0.04	0.01	–0.016	–0.044	–0.002
Industrial chemicals	0.087	0.06	0.041	0.019	0.041
Rubber & plastic products	0.097	0.04	–0.015	–0.071	0.010
Non-metallic mineral	0.102	0.08	0.054	0.03	0.053
Basic & fabricated metal	0.091	0.05	0.004	–0.039	0.021
Others	0.106	0.06	0.016	–0.029	0.031

Source: Authors' estimates from the data source.

Table 10. TFP change in Vietnamese manufacturing firms, 2003-2007.

TFP	2003-2004	2004-2005	2005-2006	2006-2007	2003-2007
Total sample	0.118	0.08	0.048	0.013	0.052
Food products & beverages	0.104	0.08	0.064	0.043	0.058
Textile & wearing apparel	0.112	0.08	0.054	0.025	0.054
Footwear	0.158	0.15	0.146	0.137	0.118
Paper & products	0.105	0.07	0.043	0.012	0.046
Industrial chemicals	0.087	0.06	0.041	0.019	0.041
Rubber & plastic products	0.184	0.12	0.061	0	0.073
Non-metallic mineral	0.096	0.07	0.048	0.024	0.048
Basic & fabricated metal	0.128	0.08	0.039	–0.006	0.048
Others	0.128	0.08	0.038	–0.007	0.048

Source: Authors' estimates from the data source.

5.8%, 5.4%, 11.8%, 4.6%, 4.1%, 7.3%, 4.8%, 4.8% and 4.8% for total sample, food products & beverages, textile & wearing apparel, footwear, paper & products, industrial chemicals, rubber & plastic products, non-metallic mineral, basic & fabricated metal and other sub-industries, respectively.

4.4. Total Factor Productivity Change

The total factor productivity (TFP) growth is simply the sum of efficiency and technical change. These two changes constitute the TFP change index. The decomposition of TFP change into technical efficient change (TEC) and technical progress change (TPC) makes it possible to understand whether the manufacturing industry and sub-industries have improved their productivity levels simply through a more efficient use of existing technology or through technical progress. **Table 8** shows the average annual TFP growth for manufacturing industry and for each sub-industry.

As can be seen TFP growth rates of total sample, food products & beverages, textile & wearing apparel, footwear, industrial chemicals, rubber & plastic products, basic & fabricated metal and other sub-industries, have positive due to increase in both TEC and TPC during 2003-2007. While TFP growth rate of paper & products has positive due to technical change and TFP growth rate of non-metallic mineral has positive due to TPC.

5. Conclusions

We applied a stochastic frontier production model to Vietnamese manufacturing industries, to decompose the sources of total productivity (TFP) growth into technical progress, changes in technical efficiency during 2003-2007. In terms of efficiency estimations, the average annual technical change in Vietnamese industries is positive and less than 1%, except non-metallic mineral (–0.006). The most important estimate though is that total factor productivity growth. This study estimates a rate of productivity growth of 5.2%. The estimated results show that TFP grew fastest in the footwear sub-industry, with annual average growth rate of 11.8%, followed by the rubber & plastic products with a rate of 7.3%.

The estimated results of our study show that although productivity growth was driven mainly by technical progress, changes in technical efficiency had a positive effect on productivity growth.

REFERENCES

[1] M. Nishimizu and J. M. Page, "Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1965-1978," *Economic Journal*, Vol. 92, No. 368, 1982, pp. 920-936. doi:10.2307/2232675

[2] P. W. Bauer, "Decomposing TFP Growth in the Presence of Cost Inefficiency, Nonconstant Returns to Scale, and Technological Progress," *Journal of Productivity Analysis*, Vol. 1, No. 4, 1990, pp. 287-299. doi:10.1007/BF00160047

[3] S. Kim and G. Han, "A Decomposition of Total Factor Productivity Growth in Korean Manufacturing Industries: A Stochastic Frontier Approach," *Journal of Productivity Analysis*, Vol. 16, No. 3, 2001, pp. 269-281. doi:10.1023/A:1012566812232

[4] H. Liao, M. Holmes, T. W. Jones and D. Llewellyn, "Productivity Growth of East Asia Economies' Manufacturing: A Decomposition Analysis," *Journal of Development Studies*, Vol. 43, No. 4, 2007, pp. 649-674. doi:10.1080/00220380701259723

[5] N. K. Minh and G. T. Long, "Factor Productivity and Efficiency of the Vietnamese Economy in Transition," *Asia-Pacific Development Journal*, Vol. 15, No. 1, 2008, pp. 93-117.

[6] N. K. Minh, N. T. Minh and G. T. Long, "A Decomposi-

tion of Total Factor Productivity Growth in Vietnamese Manufacturing Industries: A Stochastic Frontier Approach," *Proceedings of the DEA Symposium*, Taiwan, 19-21 January 2010, pp. 164-168.

[7] G. E. Battese and T. J. Coelli, "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India," *Journal of Productivity Analysis*, Vol. 3, No. 1-2, 1992, pp. 153-169. doi:10.1007/BF00158774

