# TFP Convergence, Environmental friendliness and Innovation

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**Abstract**

This paper aims to revisit the Porter hypothesis associated with TFP convergence using a panel data set of manufacturing SMEs in Vietnam covering 2005 - 2015. It contributes to the literature by giving more deeply understanding about TFP convergence of SMEs. Especially, this is the first one examining the link between environmental practices and TFP convergence. We apply the stochastic method developed by Levinsohn and Petrin (2003) to estimate stochastic TFP. The theory of $\sigma$- and $\beta$-convergence developed by Barro and Sala-i Martin (1995) and Sala-i Martin (1996) is used to establish empirical framework and test its convergence/divergence. We showed an existence a steady-state of productivity between enterprises. However, we found no significant evidence to support the 'Strong version' of the Porter hypothesis. Interestingly, cluster proximity has significantly negative impact on productivity growth.

*Keywords: $\sigma$- and $\beta$-convergence, Porter hypothesis, TFP stochastic, Environmental regulation, Innovation, cluster proximity*

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# 1 Introduction

Productivity is one of the most important issues of any firms. As Paul Krugman states: "Productivity is not everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its capacity to raise its output per worker".[1] Wherein, the concept of productivity convergence is mentioned as a long-term process. Generally, there are two types of convergences: (i) Basing on the Solow model, the $\beta$-convergence supposes a lower productivity entity (country, industry/region, or firm) getting faster growth than higher ones; while, (ii) the $\sigma$-convergence implies a decreasing of gap in productivity over time (Barro and Sala-i Martin, 1992, 1997).

Although there is a wide literature on productivity convergence, most of the existing studies, however, relate to a $\beta$- and/or $\sigma-$convergence of labor productivity at country and/or industry level (Barro et al., 1991, Baumol, 1986, Bernard and Jones, 1996c, Wang and Szirmai, 2013). For instance, Rodrik (2012) studies unconditional convergence in manufacturing in 118 countries and Frantzen (2004a) examines the link between international technological diffusion and productivity convergence. Ben-David and Loewy (1998) claims that all strong traded countries' steady-state growth can be influenced positively by diffusion of liberalization and knowledge. While, Ben-David (1993, 1996) found the strong link between trade reform and income convergence between countries.

It should be noteworthy that evidence for firms' TFP convergence and its determinants are little studied. For example, productivity convergence in Spanish manufacturing sector has been existed and varied by technological differences (Pascual and Westermann, 2002); it has also been affected by business cycles through recession and expansion periods (Escribano and Stucchi, 2014a). For the case of China, Bas and Causa (2013) prove that reform in product, trade and financial market could increase the convergence speed.

These studies mainly research on developed countries. For the case of US from 1963 - 1989, labor productivity convergence has existed in manufacturing and mining industries, but not for all industries (Bernard and Jones, 1996d). This evidence is similar to the case study of European countries (Pascual and Westermann, 2002). On another aspect, Wolff (1991) shows that the convergence is likely to be influenced positively by improving capital intensity in developed countries (G7) and for OECD countries, TFP convergence is proved exist (Frantzen,

[1]Paul Krugman, The Age of Diminishing Expectations (1994)

2004b) and affected positively by capital intensity (Gouyette and Perelman, 1997).

Meanwhile, studies on developing countries are still limited. Typically, Rodrik (2013) find that there is exist $\sigma$-convergence between countries in a small sample and be strongly within manufacturing in low-income countries. Kumar and Managi (2012) point out the negative sign of $\beta$ coefficient that implies convergence possibility of productivity growth among states in India. For the cases of China, labor productivity convergence and technical efficiency of regions were varied regarding the significant control covariates of GDP per capita, capital intensity, technical efficiency and value added per worker (Wang and Szirmai, 2013); speed of the convergence could also be affected by reforming in product, trade, and financial market (Bas and Causa, 2013).

Besides, the literature reveals an existence of the significant link between environmental regulation and productivity. The conventional view proposes Those stringent environmental standards might cause adverse effects on firms' competitiveness (Simpson and Bradford III, 1996). This finding can be explained by the fact that these regulations may increase production cost, leading to a reduce in investment in other profitable opportunities; as a result, profitability may be reduced (Rubashkina et al., 2015a). Whereas, Porter and Van der Linde (1995a) challenged this view by argument that well-designed environmental standards can improve firms' performance, that known as "Porter hypothesis" (hereafter, PH).[2] In fact, appropriate environmental policies can help to recheck resource using efficiency in the production process, improve facilities; promote innovation; that might help to reduce material cost as well as compliance cost in the future. Then, productivity and competitiveness could be enhanced. However, we have found none of the existing works examining firms' TFP convergence and its determinants related to environmental issues.

Therefore, the question raised is that whether environmental regulation and its related variables like innovation, cluster proximity have significant impacts on productivity growth rate or heterogeneity of TFP between enterprises. We do suspect of existing phenomenon of $\beta$- and/or $\sigma$-convergence/divergence and significant links between these convergences and environmental regulations associated with other indicators as innovation or cluster proximity of manufacturing SMEs in Vietnam. The present research is focusing on indicators of TFP convergence of manufacturing SMEs. We are going to investigate the hypotheses of existing the $\beta/\sigma$- the convergence of TFP and its determinants. In which impacts of environmental compliance and its related variables like innovation and cluster proximity are core explanatory

[2]see Wagner, 2003; Brännlund and Lundgren, 2009; Ambec and Barla, 2002 for a survey

variables that we aim to explore.

For this objective, we first estimate TFP; but, unlike, many previous studies that calculated TFP by the deterministic method, we estimate stochastic TFP by applying the method and mathematical procedure of Levinsohn and Petrin (2003). Second, productivity growth rate will be calculated, and then, the phenomenon of TFP $\beta/\sigma$-convergence will be tested. Finally, these convergences will be used as the dependent variables to analyze impacts of the interesting environmental related-variables (as mentioned above). In other words, we would like to test the Porter hypothesis associated with TFP convergence, but we just focus on the 'Strong version'.

# 2 Theoretical background and hypotheses

## 2.1 TFP Convergence

There is a significant number of studies on TFP convergence; however, most of these have examined about countries, regions, or industries. For example, investigating 13 advantaged economies in the period of 1963 - 1982, Dollar and Wolff (1988) explore that productivity convergence appeared in every manufacturing sector and can be affected by capital intensity.This finding is not consistent with Bernard and Jones (1996a) which studied impacts of sectors on convergence for 14 OECD countries in the period 1970 - 1987 and shows marginal findings for convergence of both labor productivity and multifactor productivity. Effectively, it finds no significant evidence of convergence for manufacturing sectors. Unlikely other studies, the authors propose a new method of multi-factor productivity to enhance the robustness of estimation.

For the case of manufacturing in European countries, Pascual and Westermann (2002) find the convergence existed in some manufacturing sub-sectors and likely to varied by technological differences. Studying OECD countries, Bernard and Jones (1996e) show that convergence among countries can be affected significantly by differences in technologies; this rate was decreased from 0.171 to 0.134 (Gouyette and Perelman, 1997). Besides, the convergence is not always appeared in all industries in US (Bernard and Jones, 1996d) and the convergence speed in manufacturing is likely weaker than that in service sectors (Bernard and Jones, 1996b).

As been seen, the studies on productivity convergence mostly focus on regional or national levels. Indeed, works on this field on micro-level is likely to scare. Escribano and Stucchi (2014b) posit that the convergence is likely to be motivated in recession periods for the case of Spanish manufacturing sector in the period 1991 and 2005. Bas and Causa (2013) concern impacts of regulations in upstream industries on firm performance in downstream manufacturing in China and prove that reform in product, trade and financial market could increase the convergence speed. For Japan, Nishimura et al. (2005) find existing of productivity convergence in both manufacturing and non-manufacturing sector. Further, Álvarez and Molero (2005) show that TFP convergence could be affected by business cycles.

For the case of Vietnam, studies on TFP convergence are still limited. At provincial level, for instance, Khac Minh et al. (2015) investigate labor's productivity convergence in Vietnam regionally and indicate that without lag variable and using OLS in estimation could bias convergence speed of indicators like trade relation, knowledge spillover. Minh and Van Khanh (2013) show that lacking of infrastructure and unfair distribution can slow productivity growth rate, and convergence speed is varied among provinces. On another perspective, Coxhead and Phan (2006) reveal the impact of immigration on income convergence at the provincial level in Vietnam and Dollar (2002) examine convergence in Vietnam concerning on link with reform and growth with claiming that Vietnam has to take further reform to keep high growth rate, if not it will be slow down.

Moreover, studies on productivity convergence at the firm level in Vietnam are more really scare. Minh et al. (2014) investigate the impact of FDI on firms' efficiency convergence by applying stochastic production frontier and using panel data set of manufacturing firms covering 2000-2011; as a result, this impact is negative. Besides, Minh et al. (2015) research the link between technological spillovers and income convergence of enterprises. It points out that technological diffusion can stimulate speed of conditional convergence faster than that of unconditional one.

In our research, manufacturing SMEs vary through wide-dimension in term of firm-size (on both revenue and total employee); hence, it is likely to exist heterogeneity in productivity growth among firms. Also, in recent years, market competition has been more pushed significantly, and the number of exited firms has increased rapidly. As Krugman said in long-term productivity is vital for firm's development. Therefore, catching-up the market's steady-state growth of new entries as well as smaller companies can help them increase survivability; then sustainability and equality for the business environment could be created. Then, we expect that small firms could catch-up larger firms in term of productivity growth and suppose the first hypothesis as below:

**Hypothesis 1.** *There is evidence for $\beta-$convergence of TFP among SMEs.*

## 2.2 Productivity and Environmental regulation

The literature on the link between environmental regulations and productivity is abundant and known as a "Strong version" of PH. Porter and Van der Linde (1995b) effectively argue that environmental stringency can make firms more efficient and thus improve their productivity. The empirical evidence supporting the 'Strong version' of PH is found in many countries. Hamamoto (2006) and Yang et al. (2012a), Piot-Lepetit and Le Moing (2007) and (Berman and Bui, 2001 find a positive link between the stringency of environmental regulation and R&D that may increase TFP. These results imply that it is possible to reach "win-win" position in of PH, that means a stringent environmental policy framework could help enhance both - profitability of firms and environmental quality.

Furthermore, TFP could be affected by environmental regulation directly through exporting participating. Empirically, firms' export capacity may be influenced by environmental policies (Costantini et al., 2013; Costantini and Mazzanti, 2012) because these policies can help firms approach international market by following environmentally proactive international standards by obtaining certificates (ISO14001, for example). Then, innovation might be also stimulated through this process and as a result, firms' productivity and competitiveness will be enhanced (Porter and Van der Linde, 1995b; Prakash and Potoski, 2006; Bigliardi et al., 2012). Additionally, environmental regulations can positively push firms to invest more in technology, human resource, R&D. That can help firms increase competitiveness, especially in the international market. For instance, with more stringent environmental regulations, some countries can become surplus exporters of new technologies that are friendly to environment (Costantini and Crespi, 2008).

Whereas, Jaffe et al. (1995), Shadbegian and Gray (2005), Lanoie et al. (2008), Greenstone et al. (2012), Koźluk and Zipperer (2013) find negative impact of stringent environmental regulations on productivity. Barbera and McConnell (1990) point out a small negative effect of environmental regulation on TFP growth. Meanwhile, Becker (2011) finds no statistically significant impact on productivity in a country having higher environmental compliance costs. While, Leeuwen and Mohnen (2013) and Becker (2011) posit no any significant evidence to support 'Strong version' of PH. Besides, spending more on pollution abatement, plants tend to be inefficient in both production and emissions (Shadbegian and Gray, 2006; Färe et al., 2007). Most recently, Rubashkina et al. (2015a) also has not succeed in finding any support for the

‘Strong version’ of PH.

Additionally, for the case of Vietnam, due to lacking of capital and human resource, SMEs frequently have the lower ability of technology integrating to update new production process and enhance productivity. Hence, the capacity of technology integrating to improve the productivity of them is low and their efforts to increase investment to improve technological facilities proactive environment often are not voluntarily. Further, Tuân (2012) point out a view that environmental regulations of Vietnam have mainly based on “end of pipe” solution to meet waste disposal appropriate standards. Enterprises frequently do compliance to deal with these inspections and whenever the inspections implemented. Because of lacking of capital and skill, they are rarely set up treatment process to comply regulations voluntarily. It can be seen that the relationship between environmental regulation and firm’s productivity is still ambiguous. For examining this issue in Vietnam, we should find evidence for Hypothesis 2 below:

**Hypothesis 2.** *Stringency of environmental regulations leads to a higher speed of TFP convergence.*

## 2.3 Productivity and innovation

Productivity growth can be affected by innovation enhanced by R&D and technology transfer which can be stimulated by international trade (Cameron et al., 2005). Further, it also points out that the convergence of productivity is examined by lots of research that mostly are at country level, in which conditional convergence investigated by including more control variables can be dependent on the capacity to absorb of the economy. In fact, only a few of works investigate the issue relating to firms’ productivity convergence. Fung (2005) finds that convergence is likely to be supported by R&D involvement, the intensity of spillovers among industries. However, with applying simple ordinary - least - square regressions (OLS), the result could be biased and inefficient because the variables dropped may relate with time variance. We suspect that innovation has positive effect on TFP and suppose the following hypothesis is formed as follows:

**Hypothesis 3.** *Firms with innovation experience have higher TFP growth rate.*

Firm’s productivity can be indirectly improved by environmental induced innovation, and this is considered as the “Strong version” of PH in the literature. Concretely, a rise in environmental stringency may incite firms to innovate, and in turn, this boosts their performance.

Hamamoto (2006) and Yang et al. (2012a) find the positive impact of stringent environment on innovation. This result can be explained that innovation could be stimulated through improving technological capacities or knowledge capital (Horbach, 2008). Besides, these regulations also encourage firms to improve production process such that resource waste would be mitigated. Then innovation capacity could be strengthened, leading to an increase in productivity (Hamamoto, 2006). This finding may because the flexible environmental mechanism is more incentive for firms innovative activities (Jaffe and Palmer, 1997). While Eiadat et al. (2008) point out that the link between the adaptation of innovation strategy and businesses' performance can be influenced by environmental regulation. Further, it may help to reduce unexpected outputs and stimulate adoption of new energy-saving technology; as a result, TFP can be improved (Zhang et al., 2011) and firm's market value could also be highly appreciated (Dowell et al., 2000). Studying seven European countries by using energy tax to proxy stringency, Franco and Marin (2014) reveal that stringency plays a major role on affects directly to innovation and productivity. However, Rennings and Rammer (2011) find that in term of profit, there is no significant evidence to confirm the performance of environmental innovation is lower than other innovations.

Bigliardi et al. (2012) study impact of eco-innovation and non-eco-innovation on firm performance by using data from 2000 Irish enterprises and indicate that the role of the first is more significant than that of the later. According to Worrell et al. (2001), appearing new environmental problems could be affected by technical innovations. Therefore, technological innovation should be used carefully with much more attentions to the environment because it may give adverse effects (Lewis, 2007). Effectively, the link between harsh environment and eco - innovation is bi-directional relations. In fact, environment plays a major role in reducing toxic emission in the US, and, in turn, strict environmental management can stimulate firm's innovation ability (Carrión-Flores and Innes, 2010). However, innovation can also be affected by companies' characteristics. For instance, Conceição et al. (2006) studied the case of Portugal and show that environmentally induced innovation associated positively with the firm's size and export shares, but negatively with its technological capacity.

For the case of Vietnam, studies on this issue are still limited. Lin et al. (2013) researching on four motorcycle foreign companies and find that market demand is positively associated with green product innovation and the positive impact of this innovation on firm performance. That shows evidence that conducting green innovation in production can help firms take advantage and enhance product's market value. Besides, Dieu (2006) finds that SMEs are normal lacking of capital and human resource to invest as well as set up and update a new production process. Therefore, we suspect that environmental compliance is not likely to result in any significant impacts on the link between innovation and firms' productivity, especially to SMEs. However, we still also prefer to re-test the 'Strong hypothesis' and expect to find evidence supporting for:

**Hypothesis 4.** *Environmental stringency positively impacts firm's innovation and the latter, in turn, contributes to firm's TFP convergence.*

# 3 Data

The panel data used in this research is originally from the biannual survey series carried out in collaboration between the Institute of Labour Studies and Social Affairs (ILSSA) in the Ministry of Labour, Invalids and Social Affairs (MOLISA) of Vietnam and Department of Economics, the University of Copenhagen with funding from DANIDA. The survey focuses on collecting data of Vietnamese SMEs. As presented above, it is a rich data set of over 2,500 firms interviewed in several waves (2005, 2007, 2009, 2011, 2013 and 2015). These different waves can be gathered to constitute a panel data set. The data include non-state firms, both registered and non-official (not registered), under the various forms of ownership (household, private, cooperative, limited liability, and join-stock).

Data surveyed in 10 provinces cover information on firm characteristics, production, inputs, economic performance, bureaucracy and informality, trade, etc. Information regarding environmental questions covers environmental-friendly practices, the existence of environmental standards certificates and environmental regulations (law, compliance inspections), firm's localization decisions. We focused on firms in manufacturing sectors and divided into two groups: the first is urban-city (proxied by $Location = 1$) including firms located in the first-ranked cities in Vietnam (Hanoi, HCMC, Haiphong) and the second is province containing firms located in other provinces ($Location = 0$).[3] We categorize firms having main production facility located in industrial Industrial Park/zone (IZ), High-Tech Park/Zone (HTZ), and Export processing park/zone (EPZ) into one group ('$Cluster' = 1$); and otherwise. Finally, because its dimension is too large (from 1 to 300 employees), we group observation into three categories: Microen-

[3] In Vietnam, there are fives first-ranked cities: Hanoi, Haiphong, Danang, Hochiminh City (HCMC), and Cantho.

terprises (less than 10), small enterprises (10 to 49 ), and medium-size enterprises (50 to 300 employees).[4]. The variable description is presented detail in Appendix A

## 3.1 Descriptive statistics in the period 2007 to 2015

Descriptive statistics figures in Appendix B show that rate of firms having the Environmental Standard Certificate (ESC) fluctuate in the interval of 9% and 20% over years, and the average rate is 14.43%. While, the rate having innovation activities is higher; although decreased slightly over years, the rate having products improved is highest, 35.57% in average; introducing new products and new production process are lower, around 13.31% and 14.03%, respectively (Table 3)[5].

Regarding the purposes of obtaining ESC and treating the environment, as statistical descriptive in Table 10, firms have been asked what the most important standard they feel most difficult when complying environment and majority of them (58.28%) said they do that because of asking from officials. Meanwhile, 2.24%, 5.91%, and 26.14% answered due to purposes related to economic motivations like reducing cost, attracting customers, and improving working respectively. Especially, the personal reason of environmental responsibility is too low, around 6.17% in average, implying that just small number of them consider environmental protection issue. Likewise, the reasons for doing environmental treatment are mainly because of requiring from the government, say 32% and 52.67% firms answered due to improving working conditions; yet only a little, 3.40% and 1.5%, concerning to significant economic reasons like reducing cost and attracting customers. Particularly, the treatment reason because of environmental responsibility is also relatively small, 6.77% in average.

Finally, Table 16 shows that added value is not significant changed, around the mean value, 346.88 million VND[6] per year.[7] Especially, total physical assets were sharply increased in 2015, reach 5340 million VND, compared to 2111 million VND in average. Total labor and investment are not significant changed, fluctuating from 13.61 to 17.45 employees and 1124 to 1612 million, respectively.

[4]According to Decree 90/2001/$ND-CP$

[5]See detail in Appendix B

[6]Vietnam Dong

[7]Real Value are calculated basing on the base price of the year 1994

# 4 Methodology

## 4.1 TFP estimation specification

We base on the Cobb-Douglass production function:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta} \tag{1}$$

where $Y_{it}$ is output of firm $i(i = 1, ..., N)$ at period $t\,(t = 1, ..., T)$, $A_{it}$, $K_{it}$, $L_{it}$ are total factor productivity (TFP), capital stock and labour, respectively. We take log (1):

$$lnY_{it} = lnA_{it} + \beta_k lnK_{it} + \beta_l lnL_{it} + \varepsilon_{it} \tag{2}$$

Supposing $A_{it} = A_0 exp(\omega_{it})$, then we have

$$lnY_{it} = lnA_0 + \omega_{it} + \beta_k lnK_{it} + \beta_l lnL_{it} + \varepsilon_{it} \tag{3}$$

or

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it} \tag{4}$$

If we use traditional methods, in particular, the OLS, the panel fixed effects or random effects estimators, then the estimators may be biased due to the presence of the unobserved and stochastic part in $\varepsilon_{it}$. This issue can be solved by the method of Olley and Pakes (1996) (henceforth, OP), in which investment is used as an appropriate instrument for inputs. However, investment information, sometimes, is not available in some of the points in the data source. Therefore, Levinsohn and Petrin (2003) develop an alternative by using material cost as an intermediate input demand function to invert out $\omega_{it}$, then the production function can be derived as below:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_{it} + \varepsilon_{it} \tag{5}$$

where $m_{it}$ is supposed as a set of intermediate inputs measured by materials cost; $\omega_{it} = lnTFP - \beta_0$ that is considered as the stochastic productivity.

## 4.2 Estimate for convergence/divergence of firm TFP

Basing on aforementioned productivity growth framework, we will estimate nature of TFP convergence. Specifically, the mathematics process is derived as follows: or

$$\left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1(\omega_{i,t}) + \theta H_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \tag{6}$$

where $\omega$ is log of the firm's TFP and $H$ captures environmental regulations and/or innovation's variables. $X$ is a group of control variables whose are divided into two groups:

(i) Firm characteristics including firm size and its investment level.

The first variable contains three elements: micro firm, small firm, and medium firm. Investment is then proxied for firm's intensity to improve its competitiveness. It should be noted that the willingness of SMEs to invest in new technology is low. As a consequence, resources firms invest in new technology or (R&D, Human capital, and Patent) are limited; while investments urban cities on physical investments like land, building, equipment; that may capture firms from the incentive of innovations.

(ii) Firm industrial characteristics including Cluster and Capital intensity and Industrial dummy.

Using Equation (6), unconditional convergence is first estimated (no control variable is taken into account) (Model 1). Second, environmental practices' variables are added in the baseline model (Model 2). Then, firm characteristics and its industrial characteristics are respectively controlled for (Model 3 and 4). Industrial dummies are lastly added (Model 5) to capture unobserved sectoral effects. Consistently with numerous empirical studies on the topic (Frantzen, 2004a; Rodrik, 2012; Escribano and Stucchi, 2014a), the fixed effect method is applied for all specifications.

If the coefficient $\hat{\beta}_1$ estimated in Equation (6) takes a positive value, then there is a divergence in terms of TFP between firms. Otherwise, if that value is negative, convergence is found. As a consequence, the associated speed of convergence ($\beta-$convergence) can be computed as follows:

$$\beta = -\frac{\ln(1+\hat{\beta}_1)}{T} \tag{7}$$

from where, the half-life time ($hl$) can be calculated as:

$$hl = \frac{\ln 2}{\beta} \tag{8}$$

The half-life time is "the time it takes for half the initial gap to be eliminated" (Barro and Sala-i Martin, 1995). In this research, it is the necessary time for firm' TFP in the associated year to be half way between the initial and the steady-state values.

Furthermore, basing on definition from Sala-i Martin (1996) about relationship between $\beta$-convergence and $\sigma$-convergence, we construct the formula to estimate $\sigma$-convergence for firms as follows:

$$\omega_{it} = \alpha + (1+\beta_2)\omega_{i,t-1} + u_{it} \tag{9}$$

where as in Equation (6) above, the condition $\beta_2$ implies the existence of $\beta-$convergence.

From Equation (9), the evolution of $\sigma_t$ (i.e., the cross-sectional of TFP) overtime can be driven as:

$$\sigma_t^2 \cong (1+\beta_2)^2\sigma_{t-1}^2 + \sigma_u^2 \tag{10}$$

It should be noted that if no evidence for $\beta-$convergence is found, the cross-sectional variance increases over time implying a non-existence of $\sigma-$convergence. In other words, the existence of $\beta-$convergence is a necessary condition for $\sigma-$convergence. If it is the case, the value of $\sigma_t^2$ can be computed as:

$$\sigma_t^2 = (\sigma^*)^2 + (1+\beta_2)^2\left[\sigma_{t-1}^2 - (\sigma^*)^2\right] \tag{11}$$

where $(\sigma^*)^2$ is the steady-state value of $(\sigma^*)^2$ and calculated by:

$$(\sigma^*)^2 = \frac{\sigma_u^2}{1+(1+\beta_1)^2}$$

It is noteworthy that the existence of $\beta-$convergence is not a sufficient condition for $\sigma-$convergence. As we can see in Equation (11), although the value of $\beta_2$ is negative, $\sigma_t^2$ can increase or decrease toward its steady-state $(\sigma^*)^2$ once the latter is lower or higher than the initial value of $\sigma^2$.

# 5 Estimate Findings

## 5.1 Environmental regulation and TFP convergence: the 'Strong version' of PH

The present subsection aims at examining the 'Strong version' of PH. Estimates based on Equation (6) are reported in Table 1. $H_{i,t}$ includes environmental practices containing PACE (Pollution Abatement and Control Expenditure), ESC (Environmental Standard Certificate), and ISO Certificate (ISO 9002 or ISO 14001). As in the literature (Yang et al., 2012b; Sanchez-Vargas et al., 2013; Rubashkina et al., 2015b, among others), PACE is used as a proxy for stringent environmental regulations. Also, the two dummy variables ESC and ISO Certificate are considered as the proxies for firm voluntary to improve environmental quality.

Table 1: Determinants of TFP convergence

Dependent Variable: $d \log TFP_t$

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| $\ln TFP_{t-1}$ | -0.547*** | -0.548*** | -0.551*** | -0.555*** |
| | (0.006) | (0.012) | (0.012) | (0.012) |
| **Environmental practices** | | | | |
| $PACE_{t-1}$ | | 0.012 | 0.013 | 0.012 |
| | | (0.010) | (0.010) | (0.010) |
| $ESC_{t-1}$ | | 0.011 | 0.013 | -0.011 |
| | | (0.016) | (0.016) | (0.016) |
| $ISO\ Certificate_{t-1}$ | | -0.013 | -0.009 | -0.013 |
| | | (0.025) | (0.025) | (0.025) |
| **Firm characteristics** | | | | |
| *Firm size (reference: micro firm)* | | | | |
| Small firm | | | 0.057*** | 0.059*** |
| | | | (0.016) | (0.015) |
| Medium firm | | | 0.122** | 0.123** |
| | | | (0.039) | (0.039) |
| $Investment_{t-1}$ | | | 0.005+ | 0.007* |
| | | | (0.003) | (0.003) |
| **Industrial characteristics** | | | | |
| *Cluster* | | | | -0.062*** |
| | | | | (0.011) |
| $Capital\ intensity_{t-1}$ | | | | 0.055*** |
| | | | | (0.005) |
| Constant | 2.403*** | 2.403*** | 2.390*** | 2.185*** |
| | (0.026) | (0.050) | (0.049) | (0.056) |
| Observations | 24,699 | 24,699 | 24,699 | 24,657 |
| R-squared | 0.295 | 0.295 | 0.296 | 0.300 |
| Number of id | 4,913 | 4,913 | 4,913 | 4,907 |

*continued next page*

Table 1: Determinants of TFP convergence - Full sample (continued)

Dependent Variable: dLog TFP

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Ficher test | 8271.93*** | 625.78*** | 405.84*** | 353.96*** |
| Beta-convergence (%) | 7.2 | 7.2 | 7.3 | 7.4 |
| Half-life time (years) | 9.6 | 9.6 | 9.5 | 9.4 |

Robust standard errors in parentheses.

Significant levels : $^{***}p < 0.1\%$, $^{**}p < 1\%$, $^{*}p < 5\%$, $^{+}p < 10\%$.

Model 1 representing the unconditional convergence shows a significant and negative coefficient of $lnTFP$. It implies that there is an unconditional convergence, or in other words *absolute* as mentioned in Fung (2005), beta-convergence for Vietnamese SMEs during the period 2003-2014. The respected speed is 7.2%) corresponding a half-life time of 9.6 years. The result highly supports Hypothesis 1.

Model 2 then represents the role of Environmental practices on TFP growth rate and beta-convergence. All related variables are statistically insignificant. The strong PH (Hypothesis 2) is not supported. It means that stringent regulations have the negligent effect on firm's TFP growth. As a result, Model 2 reports a similar coefficient of $lnTFP$ as that in Model 1 showing a quasi-no impact of environmental practices on convergence.

The finding is thus consistent to Rubashkina et al. (2015b). By investigating the role of environmental regulations, the authors find no evidence of significant impact of PACE neither on factor productivity nor sectoral TFP growth in 17 European countries.[8] Further, Leeuwen and Mohnen (2013) find no significant evidence to support the 'Strong version' because environmental regulations have not impacted directly to TFP. Otherwise, it is in contrast with Hamamoto (2006) and Yang et al. (2012b) since the authors argue the positive impact of environmental regulations' stringency on TFP growth at sectoral level in Japan and Taiwan, respectively.

In Model 3, the firm characteristics are controlled. On one hand, firm size positively affects its TFP growth rate. Compared to micro firms, TFP growth rate of small businesses

[8] Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Hungary, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK.

and medium firms is respectively 5.7% and 12.2% higher. On the other hand, firm's investment level positively contributes to its TFP growth rate, but the impact is marginal. An increase of 10% in investment last year leads to an increase of 0.05% in TFP growth rate in the current year. Importantly, it is likely that firm characteristics have a small contribution to its TFP convergence because the parameter associated with variable $lnTFP$ slowly increases from -0.548 in Model 2 to -0.551 in Model 3. Consequently, the associated speed slightly grows from 9.6% to 9.5%.

In Models 4, firms' industrial characteristics are taken into account. Astonishingly, the parameter associated with *Cluster* is statistically significant but negative. It follows that Cluster proximity has a negative influence on firms' TFP growth rate. By locating in a cluster (Industrial, Export, or Processing Zone), firms are experienced by a 6.2% lower regarding TFP growth rate than their counterparts locating outside a cluster. This finding is not really in line with Costantini et al. (2013) that posit that spillover of technological change or innovation may depend on particular sectors in specific regions, that is not only due to geographical economics but also of cognitive proximity. Furthermore, the scale of region and sector may also affect to performance of environment and innovation (Costantini et al., 2013). For instance, in China, impacts of environmental regulations on productivity measured are different via economic zones; the highest changed growth rate of TFP is in the Southern Coastal area, say 7.06%; whereas, this rate is negative in the Southwest economic zone, approximately 1.03% (Zhang et al., 2011).

One possibility explaining this surprising result is that firms located in a cluster have higher TFP than their compared counterparts followed by a lower growth of the former. As for the role of industrial capital intensity, it positively impacts the growth rate. A 10% increase in that intensity results in an improvement of 0.55% in TFP growth rate of firms located in the industry in question. However, it should be noteworthy that the values of the parameter related to $\ln TFP$ are little changed compared to that of Model 3 implying weak impacts of industrial characteristics on the convergence.

Overall, all specifications, from Model 1 to Model 4, show the existence of beta-convergence for Vietnamese SMEs over the period 2004-2014. However, all controlled covariates appear to have marginal or no contribution to firms' TFP convergence implying that evidence for absolute convergence is much clearer than that for conditional one. Following Fung (2005), this finding suggests that companies converge to an average steady-state growth rate rather than their one. This evidence may be explained by following arguments.

First, the no-impact of Environmental practices raise a question related to the amount of PACE. We are thinking of a threshold of investment that is likely to be existed and play a crucial role in determining whether these environmental investments have negative or positive effects on TFP growth or not. The theory of optimal growth can help us investigate this ambiguous more deeply. According to Bruno et al. (2008); Le Van et al. (2010), the level of investment should exceed a threshold such that it has a significant impact on the economy. Hence, in the case of Vietnamese SMEs, it could be possible that firms' expenditures in treating environmental pollution are not sufficiently high to have a non-negligible impact on its TFP growth. Effectively, more than 75% of firm-observations in this study exhibited a null-value of PACE. Also, firms having positive PACE have average real expenditures are 5.5 million VND, i.e. only 0.2% of their average real revenue.

Another possibility that could explain the insignificant impact of PACE is associated with the duration such that the latter could matter firm TFP. The estimates reported in Table 1 represent impacts of one-year lag of PACE (and other variables) on firm TFP growth in the current year. Following Yang et al. (2012b); Rubashkina et al. (2015b), two-years lag's variables including PACE should be used because firms need sufficient time to feel the pressure, discover and adopt new technology, and state impacts on productivity. We will discuss this in deep in the next version of this research.

Second, the positive but marginal contribution of firm size occurs another question about the linearity of the convergence. More precisely, do micro, small, and medium firms display the same convergence speed? That we are not going to discuss in this version, instead in the later version wherein we will run quantile by classifying firm's size.

Third, it is possible that environmental stringency does not directly improve firm's TFP but indirectly through its incentive to innovate. This result prompts us to find evidence for the role of innovation and the 'weak version' of PH in the following subsection.

## 5.2 Innovation and TFP convergence

Table 2 allows to examine the impact of innovation on TFP convergence and then investigate the weak PH. Estimates are based on Equation (6) with $H_{i,t}$ now including innovation and interaction between innovation and environmental practice variables.

Table 2: Determinants of TFP convergence - Innovation and Environmental practice

Dependent Variable: $d \log TFP_t$

| Variables | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| $\ln TFP_{t-1}$ | -0.547*** | -0.548*** | -0.551*** | -0.555*** | -0.555*** |
| | (0.011) | (0.011) | (0.011) | (0.012) | (0.012) |
| **Innovation and Environmental practices** | | | | | |
| *Innovation*$_{t-1}$ | 0.002 | -0.001 | -0.006 | 0.012 | 0.012 |
| | (0.007) | (0.008) | (0.008) | (0.008) | (0.008) |
| *Innov*ESC*$_{t-1}$ | | 0.026 | 0.025 | -0.001 | -0.000 |
| | | (0.019) | (0.019) | (0.019) | (0.019) |
| *Innov*ISO Certificate*$_{t-1}$ | | 0.004 | 0.010 | -0.001 | -0.001 |
| | | (0.031) | (0.032) | (0.032) | (0.032) |
| **Firm characteristics** | | | | | |
| *Firm size (reference: micro firm)* | | | | | |
| Small firm | | | 0.057*** | 0.059*** | 0.060*** |
| | | | (0.016) | (0.015) | (0.015) |
| Medium firm | | | 0.122** | 0.123** | 0.123** |
| | | | (0.039) | (0.039) | (0.039) |
| *Investment*$_{t-1}$ | | | 0.005+ | 0.006* | 0.006* |
| | | | (0.003) | (0.003) | (0.003) |
| **Industrial characteristics** | | | | | |
| *Cluster* | | | | -0.055*** | -0.042** |
| | | | | (0.012) | (0.016) |
| *Capital intensity*$_{t-1}$ | | | | 0.055*** | 0.056*** |
| | | | | (0.005) | (0.005) |
| *Industrial fixed effects* | No | No | No | No | Yes |
| Constant | 2.403*** | 2.404*** | 2.393*** | 2.185*** | 2.153*** |
| | (0.050) | (0.050) | (0.049) | (0.056) | (0.064) |
| Observations | 24,697 | 24,697 | 24,697 | 24,655 | 24,655 |
| R-squared | 0.295 | 0.295 | 0.296 | 0.300 | 0.301 |
| Number of id | 4,913 | 4,913 | 4,913 | 4,907 | |

*continued next page*

Table 2: Determinants of TFP convergence - Innovation and Environmental practice (continued)

Dependent Variable: dLog TFP

| Variables | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Ficher test | 1154.54*** | 578.85*** | 384.60*** | 277.52***1 | 119.55*** |
| Beta-convergence (%) | 7.2 | 7.2 | 7.3 | 7.4 | 7.4 |
| Half-life time (years) | 9.6 | 9.6 | 9.5 | 9.4 | 9.4 |

Robust standard errors in parentheses.

Significant levels : $^{***}p < 0.1\%$, $^{**}p < 1\%$, $^{*}p < 5\%$, $^{+}p < 10\%$.

In Model 1, only variable *innovation* is considered. The estimate shows a positive but insignificant impact of this variable on firm's TFP convergence. Also, the estimated coefficient associated with $\ln TFP$ appears to be the same as that in Model 1 of Table 1. Hence, it seems that innovation directly does not help firms to improve their speed of TFP convergence and Hypothesis 3 can not be supported in the case of Vietnamese SMEs over the period 2003-2014. This finding is likely to be in contrast with Fung (2005) since the author, by examining the case of U.K. firms, observes a positive impact of R&D expenditure on firms' TFP convergence.

In Model 2, interaction variables between innovation and environmental practice are added in the estimation. The main purpose is to examine whether environmental regulation indirectly matters the convergence through the innovation, and thus find evidence for the weak PH. The results, unfortunately, display that neither $Innov * ESC$ nor $Innov * ISOCertificate$ is statistically significant. Therefore, in this case, we could not give any convincing conclusion about the extended 'Strong version' of the PH, and Hypothesis 4 is not supported.

These results are, on the one hand, consistent partially with Frondel et al. (2008)study German manufacturing and find no significant impact of environmental management system on innovation. The authors also suggest that we should use correlation concept to explain this link, rather than causal association. On the other hand, these findings are in contrast with Eiadat et al. (2008) which find that environmental innovation is associated with firm's performance and this link may be affected by environmental regulations. Similarly, Hamamoto (2006) asserts that more stringent environmental regulations might stimulate firm invest in new technology environmental proactive that first due to enhancing productivity, but in turn, it will benefit to environmental quality also. Also, it is consistent to Yang et al. (2012a) that find that the striker environmental regulations may pressure firms increase investment in R&D as well as abatement cost. Besides, Leeuwen and Mohnen (2013) point out that environmental regulations by government or market pressure all affect positively not only on environmental innovation but also on the production process.

Further, it can be seen that condition of PH is more stringent but well-designed environmental policies. These results raise the question that whether two conditions are appropriate in Vietnam. First, we can see that it may not be stringent because local authority may be the lack of ability to supervise and control environmental activities of firms. Second, environmental policy may not be well-designed (see Lanoie et al. (2010)).

Besides, as mentioned in Frondel et al. (2008), complementing ISO 14001 can be considered as voluntary environmental compliance with auditing from a third-party. In fact, owning ISO certificate has become one of the principal aims of enterprises because it could help them increase name-label and extent market share in either domestic and foreign markets. For obtaining these certificates, firms have to follow their requirements to assure the quality of products, and environmental quality in some cases. However, this process takes time, human and financial resources. Meanwhile, the majority of enterprises in the data are small companies, so that they may do not need or lack the ability to achieve this certificate. Therefore, Data indicator may be biased in this estimation because there are several types of criteria and certificate relating to the environment. Consequently, the coefficients relating to ISO are not significant.

When firm characteristics, industrial identities, and sector dummies are respectively taken into account (Models 3, 4, and 5) nothing is significantly changed, and businesses always experience the speed of convergence in TFP around 7.3%. It follows that their TFP converges to the same steady state rather than their one.

To sum up, it occurs that in the case of Vietnamese SMEs, no evidence of the role innovation is found, whatever the related specification. Such proof could be explained that in the case of Vietnam, obtaining ESC is not likely a discipline. It is just the voluntary behavior of firms, and local authorities may not be able to supervise environmental compliance level of enterprises. Consequently, firms may do that because authorities ask them to do so; but actually, environmental issues are not important to them. The another reason may be that the majority of enterprises are small firms; hence, the level of environmental investment is not enough to generate actual effectiveness.

# 6 Conclusions

Our research tests the existence TFP divergence/convergence of manufacturing SMEs in Vietnam. The method of Levinsohn and Petrin (2003) is applied to estimate the stochastic TFP; we calculate TFP growth rate and test its convergence. Then, we investigate the link between TFP convergence and environmental practices, innovation, and other interesting control variables like firm size, cluster, capital intensity. This research is based on the firm-level panel of manufacturing SMEs in Vietnam, that has been carried out by the Institute of Labour Studies and Social Affairs (ILSSA) in the Ministry of Labour, Invalids and Social Affairs (MOLISA) of Vietnam and Department of Economics, the University of Copenhagen with funding from DANIDA.

We found some significant results. First, we found the existence of TFP convergence. Second, complying environmental protection has no any significant effects on TFP convergence; hence the extended 'Strong version' as well as 'Weak version' of PH associated with TFP convergence are not supported. Third, the cluster has significant negative impact on this convergence. It means that TFP growth rate of firms having main production facilities located in urban cities are likely slower than that located in other provinces.

We found some significant results. First, we found the existence of TFP convergence. Second, complying environmental protection has no any significant effects on TFP convergence, hence the extended 'Strong version' of PH associated with TFP convergence are not supported. Third, the cluster has significant negative impact on this convergence. It means that TFP growth rate of firms having main production facilities located in urban cities are likely slower than that located in other provinces.

However, the present research is also containing some limitations such as lacking of the robustness test, quintile regression to mitigate bias ability from the wide dimension of firm size has not been conducted yet. We are going to solve these weak points in the next version.

## Appendix A: Variable description

**Revenue** is measured by real added value or real production output. Data are in VND 1,000,000 (1994 price).

**Physical asset**: Capital stock measured by real total physical fixed asset. Data are in VND 1,000,000 (1994 price).

**Material cost**: Real intermediate material cost. Data are in VND 1,000,000 (1994 price)

**Investment**: Real investment spending in last-two years from the previous survey. Data are in VND 1,000,000 (1994 price)

**Total labours**: Number of full-time employees.

**PACE**: Pollution Abatement and Control Expenditure. Data are in VND 1,000,000 (1994 price).

**ESC**: Environmental Standards Certificate; Dummy coded 1 if firm has Environmental standard certificate.

**ISO** Certificate: Internationally quality certificate; Dummy coded 1 if firms have ISO 9000 or ISO14001 or others.

**General innovation**: Dummy coded 1 if firm has at least one of three types of Product innovation or Process innovation in last two years.

**Capital intensity**: Physical capital per capita. Data are in VND 1,000,000 (1994 price)

**Cluster**: Cluster. Dummy coded 1 if firm located in industrial zone, or processing zone, or economic special zone.

**Firm size** Micro enterprises (less than 10), Small enterprises (10 to 49 ), and Medium-size enterprises (50 to 300 employees).

Table 3: Descriptive statistics of dummy variables

| Indicators | **2005** | **2007** | **2009** | **2011** | **2013** | **2015** | **Total** |
|---|---|---|---|---|---|---|---|
| ESC (%) | . | 9.12 | 13.53 | 16.17 | 19.58 | 13.56 | 14.34 |
| Standard error (%) | . | 28.80 | 34.21 | 36.83 | 39.69 | 34.24 | 35.05 |
| | . | . | . | 24.94 | 26.16 | 19.16 | 23.61 |
| New product | 40.16 | 5.17 | 2.86 | 4.36 | 0.71 | 23.90 | 13.31 |
| | 49.03 | 22.14 | 16.68 | 20.42 | 08.38 | 42.66 | 33.97 |
| Improve product | 59.38 | 43.56 | 40.62 | 37.93 | 16.48 | 13.33 | 35.57 |
| | 49.12 | 49.59 | 49.12 | 37.93 | 48.53 | 13.33 | 35.57 |
| New process | 29.35 | 15.43 | 13.87 | 13.00 | 6.32 | 4.87 | 14.03 |
| | 4555 | 3613 | 3457 | 3364 | 2433 | 2153 | 3473 |
| Export | 6.42 | 5.70 | 5.84 | 5.99 | 6.27 | 7.07 | 6.22 |
| | 24.51 | 23.19 | 23.45 | 23.73 | 24.24 | 25.64 | 24.15 |
| Investment | 62.42 | 42.72 | 60.72 | 56.03 | 46.76 | 48.98 | 53.07 |
| Standard error | 48.44 | 49.48 | 48.85 | 49.64 | 49.90 | 50.00 | 49.91 |
| Total(N) | 2,821 | 2,631 | 2,654 | 2,523 | 2,549 | 2,648 | 15,826 |

*Source:* Calculating from data set SMEs

Table 4: Environmental perceptions

| Indicators | 2011 | 2013 | 2015 | Total | 2011 | 2013 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|
| | **ESC*** | | | | **Treatment*** | | | |
| Cost reducing | 7 | 7 | 11 | 25 | 26 | 63 | 11 | 100 |
| | 1.72 | 1.99 | 3.06 | 2.24 | 2.17 | 4.38 | 3.62 | 3.40 |
| Customer attract | 19 | 27 | 20 | 66 | 8 | 18 | 5 | 31 |
| | 4.67 | 2.69 | 5.57 | 5.91 | 0.67 | 1.25 | 1.64 | 1.05 |
| Officials | 257 | 237 | 157 | 651 | 460 | 342 | 128 | 930 |
| | 63.14 | 67.53 | 43.73 | 58.28 | 38.40 | 23.80 | 42.11 | 31.64 |
| Responsibility | 32 | 26 | 12 | 70 | 89 | 87 | 23 | 199 |
| | 7.86 | 7.41 | 3.34 | 6.27 | 7.43 | 6.05 | 7.57 | 6.77 |
| Working condition | 85 | 54 | 153 | 292 | 579 | 845 | 124 | 1,548 |
| | 20.88 | 15.38 | 42.62 | 26.14 | 48.33 | 58.80 | 40.79 | 52.67 |
| Other | 7 | 0 | 6 | 13 | 36 | 82 | 13 | 131 |
| | 1.72 | 0.00 | 1.67 | 1.16 | 3.01 | 5.71 | 4.28 | 4.46 |
| Total | 407 | 351 | 359 | 1,117 | 1,198 | 1,437 | 304 | 2,939 |

*Source:* Calculating from data set SMEs

*Note: Reasons of obtaining ESC (Environmental standards certificate) and environmental treatment*

Table 5: Knowledge levels about environmental law

| **Indicators** | 2005 | **2007** | **2009** | **2011** | **2013** | **2015** |
|---|---|---|---|---|---|---|
| Good (%) | 7.37 | 3.91 | 3.65 | 3.49 | 2.35 | 2.23 |
| Average | 26.73 | 15.32 | 15.79 | 17.95 | 16.48 | 14.69 |
| Poor | 23.04 | 27.10 | 30.56 | 26.71 | 29.08 | 29.27 |
| No/Not of my interest | 42.86 | 53.67 | 50.00 | 51.84 | 52.08 | 53.81 |
| **Total**(N) | 2,821 | 2,631 | 2,654 | 2,523 | 2,549 | 2,648 |

*Source:* Calculating from data set SMEs

Table 6: The most difficult standard in environmental compliance

| **Indicators** | 2007 | **2009** | **2011** | **2013** | **2015** | **Total** |
|---|---|---|---|---|---|---|
| Air quality (%) | 43.33 | 28.21 | 31.97 | 27.41 | 23.72 | 29.52 |
| Fire | 11.11 | 15.79 | 26.48 | 27.91 | 32.43 | 22.36 |
| Heat | 12.50 | 22.06 | 12.08 | 17.48 | 15.02 | 17.45 |
| Lighting | 0.83 | 2.56 | 2.62 | 2.26 | 1.50 | 2.35 |
| Noise | 18.33 | 16.81 | 12.81 | 14.67 | 9.01 | 14.92 |
| Waste disposal | 3.33 | 5.74 | 5.55 | 3.75 | 6.31 | 5.04 |
| Water pollution | 8.61 | 7.53 | 7.50 | 5.57 | 9.61 | 7.15 |
| Soil degradation/poll | 0.56 | 0.53 | 0.92 | 0.83 | 2.40 | 0.80 |
| Others | 1.39 | 0.77 | 0.06 | 0.11 | 0.00 | 0.41 |
| Total: N responded | 360 | 2,457 | 1,639 | 1,813 | 333 | 6,602 |

*Source:* Calculating from data set SMEs

Table 7: The most costly standard in environmental compliance

| **Indicators** | **2007** | **2009** | **2011** | **2013** | **2015** | **Total** |
|---|---|---|---|---|---|---|
| Air quality (%) | 61.73 | 44.70 | 45.45 | 32.07 | 18.40 | 41.07 |
| Fire | 20.39 | 16.75 | 22.21 | 26.16 | 31.60 | 21.61 |
| Heat | 10.34 | 16.54 | 14.03 | 15.17 | 15.34 | 15.14 |
| Lighting | 0.00 | 1.67 | 1.40 | 2.12 | 4.29 | 1.77 |
| Noise | 4.75 | 10.51 | 6.10 | 12.72 | 7.98 | 9.57 |
| Waste disposal | 0.84 | 4.40 | 4.27 | 4.57 | 7.67 | 4.38 |
| Water pollution | 1.40 | 4.24 | 5.25 | 6.19 | 11.04 | 5.21 |
| Soil degradation/poll | 0.56 | 0.65 | 1.28 | 0.95 | 3.68 | 1.04 |
| Others | 0.00 | 0.53 | 0.00 | 0.06 | 0.00 | 0.21 |
| **Total** | 358 | 2,454 | 1,639 | 1,793 | 326 | 6,570 |

*Source:* Calculating from data set SMEs

Table 8: Main purposes of investment

| **Main purposes of investment** | **2005** | **2007** | **2009** | **2011** | **2013** | **2015** | **Total** |
|---|---|---|---|---|---|---|---|
| Add to capacity (n) | 1,079 | 616 | 1,047 | 817 | 751 | 853 | 5,163 |
| (%) | 61.24 | 54.80 | 65.19 | 58.07 | 64.02 | 65.77 | 61.69 |
| Replace old equipment | 310 | 253 | 209 | 182 | 176 | 170 | 1,300 |
| | 17.59 | 22.51 | 13.01 | 12.94 | 15.00 | 13.11 | 15.53 |
| Improve productivity | 199 | 70 | 116 | 118 | 88 | 109 | 700 |
| | 11.29 | 6.23 | 7.22 | 8.39 | 7.50 | 8.40 | 8.36 |
| Improve product quality | 51 | 43 | 47 | 45 | 33 | 28 | 247 |
| | 2.89 | 3.83 | 2.93 | 3.20 | 2.81 | 2.16 | 2.95 |
| Produce a new output | 65 | 36 | 54 | 40 | 50 | 20 | 265 |
| | 3.69 | 3.20 | 3.36 | 2.84 | 4.26 | 1.54 | 3.17 |
| Safety | 17 | 14 | 8 | 70 | 15 | 21 | 145 |
| | 0.96 | 1.25 | 0.50 | 4.98 | 1.28 | 1.62 | 1.73 |
| Environmental require | 13 | 11 | 14 | 9 | 11 | 16 | 74 |
| | 0.74 | 0.98 | 0.87 | 0.64 | 0.94 | 1.23 | 0.88 |
| Other purpose | 28 | 81 | 111 | 126 | 49 | 80 | 475 |
| | 1.59 | 7.21 | 6.91 | 8.96 | 4.18 | 6.17 | 5.68 |
| **Total** | 1,762 | 1,124 | 1,606 | 1,407 | 1,173 | 1,297 | 8,369 |

*Source:* Calculating from data set SMEs

Table 9: Descriptive statistics in quantile of key indicators, Unit: million VND

| **Year** | **Variable** | **N** | **mean** | **p25** | **p50** | **p75** |
|---|---|---|---|---|---|---|
| 2007 | Added value | 2590 | 335.12 | 25.68 | 67.08 | 199.13 |
| | Total physical asset | 2618 | 1420.99 | 58.95 | 272.93 | 924.89 |
| | Total labor | 2630 | 17.45 | 3.00 | 6.00 | 14.00 |
| | Investment capital | 1124 | 295.12 | 2.82 | 20.17 | 121.02 |
| 2009 | Added value | 2535 | 327.73 | 24.13 | 70.35 | 223.41 |
| | Total physical asset | 2549 | 1145.97 | 65.43 | 291.02 | 994.37 |
| | Total labor | 2654 | 14.81 | 3.00 | 6.00 | 13.00 |
| | Investment capital | 1612 | 334.95 | 8.15 | 37.63 | 188.15 |
| 2011 | Added value | 2438 | 398.64 | 29.72 | 83.09 | 250.27 |
| | Total physical asset | 2472 | 1518.39 | 116.88 | 402.08 | 1207.67 |
| | Total labor | 2511 | 14.08 | 3.00 | 5.00 | 12.00 |
| | Investment capital | 1412 | 225.40 | 4.81 | 26.74 | 120.50 |
| 2013 | Added value | 2429 | 318.45 | 27.51 | 73.46 | 209.11 |
| | Total physical asset | 2493 | 981.84 | 75.60 | 287.07 | 901.60 |
| | Total labor | 2530 | 13.61 | 2.00 | 5.00 | 10.00 |
| | Investment capital | 1191 | 272.54 | 6.35 | 25.41 | 127.03 |
| 2015 | Added value | 2603 | 355.29 | 25.95 | 71.43 | 207.46 |
| | Total physical asset | 2648 | 5339.68 | 285.00 | 1087.50 | 3754.00 |
| | Total labor | 2642 | 14.07 | 2.00 | 4.00 | 10.00 |
| | Investment capital | 1297 | 216.88 | 6.31 | 21.04 | 108.35 |
| **Total** | Added value | 12595 | 346.88 | 26.44 | 72.75 | 216.34 |
| | Total physical asset | 12780 | 2111.26 | 95.45 | 387.46 | 1332.41 |
| | Total labor | 12967 | 14.82 | 3.00 | 5.00 | 12.00 |
| | Investment capital | 6636 | 270.61 | 5.36 | 27.52 | 141.19 |

*Source:* Calculating from data set SMEs

Table 10: **Statistics of key indicators by sector in 2015, Unit: million VND**

| **Sector** | **Variable** | **N** | **mean** | **p25** | **p50** | **p75** |
|---|---|---|---|---|---|---|
| Food-beverage | Added value | 836 | 175.98 | 14.13 | 32.34 | 84.67 |
| | Total physical asset | 838 | 3155.17 | 131.80 | 467.20 | 2132.00 |
| | Total labor | 837 | 7.24 | 2 | 3 | 5 |
| | Investment capital | 342 | 123.19 | 2.52 | 10.20 | 42.08 |
| Textiles | Added value | 86 | 323.05 | 28.47 | 99.36 | 241.43 |
| | Total physical asset | 86 | 3880.58 | 570.00 | 1707.00 | 5933.55 |
| | Total labor | 86 | 14.88 | 3 | 7 | 15 |
| | Investment capital | 38 | 201.19 | 6.31 | 87.10 | 273.50 |
| Apparel | Added value | 141 | 740.04 | 61.33 | 178.86 | 576.74 |
| | Total physical asset | 141 | 5389.01 | 760.00 | 2524.00 | 5517.69 |
| | Total labor | 140 | 39.68 | 4 | 10 | 34 |
| | Investment capital | 51 | 160.96 | 7.15 | 63.12 | 210.38 |
| Leather | Added value | 61 | 391.37 | 20.10 | 79.32 | 259.83 |
| | Total physical asset | 61 | 3733.59 | 300.00 | 1155.00 | 3350.00 |
| | Total labor | 61 | 21.13 | 2 | 5 | 18 |
| | I Investment capital | 28 | 431.75 | 3.68 | 10.52 | 31.56 |
| Wood | Added value | 291 | 191.18 | 26.12 | 61.35 | 152.01 |
| | Total physical asset | 291 | 2265.99 | 295.00 | 760.00 | 2150.00 |
| | Total labor | 290 | 10.28 | 2 | 4 | 9 |
| | Investment capital | 170 | 134.58 | 6.31 | 21.04 | 63.12 |
| Rubber | Added value | 158 | 1004.61 | 89.49 | 205.39 | 556.28 |
| | Total physical asset | 159 | 9128.70 | 1620.00 | 4071.00 | 8260.50 |
| | Total labor | 159 | 28 | 5 | 8 | 25 |
| | Investment capital | 68 | 394.76 | 31.56 | 105.19 | 420.77 |
| Non-metallic | Added value | 98 | 488.51 | 50.56 | 137.21 | 413.90 |
| | Total physical asset | 98 | 8013.76 | 790.00 | 1984.69 | 5930.00 |
| | Total labor | 98 | 21.45 | 4 | 8 | 20 |
| | Investment capital | 58 | 213.11 | 10.52 | 43.55 | 193.72 |
| Fabricated metal | Added value | 449 | 239.64 | 31.69 | 68.54 | 152.54 |
| | Total physical asset | 450 | 2849.70 | 281.20 | 892.20 | 2890.00 |
| | Total labor | 450 | 9.58 | 2 | 4 | 7 |
| | Investment capital | 239 | 87.69 | 6.31 | 14.73 | 71.53 |
| Furniture, jewel | Added value | 163 | 297.40 | 34.98 | 77.45 | 191.70 |

Table 11: Environment, Innovation, and Export participating by sector in 2015

| | **ESC** | | **NP** | | **IP** | | **PP** | | **Ex** | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sector** | N | Y | N | Y | N | Y | N | Y | N | Y | |
| 01 (Firm) | 752 | 86 | 663 | 175 | 769 | 69 | 798 | 40 | 811 | 26 | 838 |
| (%) | 32.87 | 24.02 | 32.94 | 27.65 | 33.54 | 19.55 | 31.70 | 31.01 | 33.39 | 14.05 | 31.67 |
| 03 | 74 | 12 | 68 | 18 | 76 | 10 | 82 | 4 | 71 | 13 | 86 |
| | 3.23 | 3.35 | 3.38 | 2.84 | 3.31 | 2.83 | 3.26 | 3.10 | 2.92 | 7.03 | 3.25 |
| 04 | 119 | 22 | 115 | 26 | 104 | 37 | 135 | 6 | 105 | 36 | 141 |
| | 5.20 | 6.15 | 5.71 | 4.11 | 4.54 | 10.48 | 5.36 | 4.65 | 4.32 | 19.46 | 5.33 |
| 05 | 54 | 7 | 46 | 15 | 54 | 7 | 57 | 4 | 55 | 5 | 61 |
| | 2.36 | 1.96 | 2.29 | 2.37 | 2.35 | 1.98 | 2.26 | 3.10 | 2.26 | 2.70 | 2.31 |
| 06 | 278 | 13 | 199 | 92 | 249 | 42 | 282 | 9 | 259 | 30 | 291 |
| | 12.15 | 3.63 | 9.89 | 14.53 | 10.86 | 11.90 | 11.20 | 6.98 | 10.66 | 16.22 | 11.00 |
| 07 | 38 | 21 | 40 | 19 | 46 | 13 | 53 | 6 | 53 | 6 | 59 |
| | 1.66 | 5.87 | 1.99 | 3.00 | 2.01 | 3.68 | 2.11 | 4.65 | 2.18 | 3.24 | 2.23 |
| 08 | 72 | 14 | 70 | 16 | 70 | 16 | 83 | 3 | 80 | 5 | 86 |
| | 3.15 | 3.91 | 3.48 | 2.53 | 3.05 | 4.53 | 3.30 | 2.33 | 3.29 | 2.70 | 3.25 |
| 10 | 30 | 23 | 46 | 7 | 41 | 12 | 47 | 6 | 47 | 6 | 53 |
| | 1.31 | 6.42 | 2.29 | 1.11 | 1.79 | 3.40 | 1.87 | 4.65 | 1.93 | 3.24 | 2.00 |
| 11 | 115 | 44 | 140 | 19 | 132 | 27 | 144 | 15 | 46 | 13 | 159 |
| | 5.03 | 12.29 | 6.95 | 3.00 | 5.76 | 7.65 | 5.72 | 11.63 | 6.01 | 7.03 | 6.01 |
| 12 | 75 | 23 | 73 | 25 | 85 | 13 | 92 | 6 | 89 | 9 | 98 |
| | 3.28 | 6.42 | 3.63 | 3.95 | 3.71 | 3.68 | 3.66 | 4.65 | 3.66 | 4.86 | 3.70 |
| 13 | 21 | 7 | 16 | 12 | 24 | 4 | 26 | 2 | 27 | 1 | 28 |
| | 0.92 | 1.96 | 0.79 | 1.90 | 1.05 | 1.13 | 1.03 | 1.55 | 1.11 | 0.54 | 1.06 |
| 14 | 411 | 39 | 322 | 128 | 393 | 57 | 429 | 21 | 435 | 15 | 450 |
| | 17.96 | 10.89 | 16.00 | 20.22 | 17.14 | 16.15 | 17.04 | 16.28 | 17.91 | 8.11 | 17.01 |
| 15 | 48 | 11 | 44 | 15 | 47 | 12 | 55 | 4 | 49 | 10 | 59 |
| | 2.10 | 3.07 | 2.19 | 2.37 | 2.05 | 3.40 | 2.19 | 3.10 | 2.02 | 5.41 | 2.23 |
| 18 | 146 | 18 | 133 | 31 | 137 | 27 | 161 | 3 | 157 | 7 | 164 |
| | 6.38 | 5.03 | 6.61 | 4.90 | 5.97 | 7.65 | 6.40 | 2.33 | 6.46 | 3.78 | 6.20 |
| **Total** | 2,288 | 358 | 2,013 | 633 | 2,293 | 353 | 2,517 | 129 | 2,429 | 185 | 2,646 |

*Source:* Calculating from data set SMEs, *Y: yes, N: no

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