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The role of environmental regulations and innovation in TFP convergence

Evidence from manufacturing SMEs in Viet Nam

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Abstract: This is a pioneer study investigating the relationship between environmental compliance and TFP convergence for SMEs. It examines the impacts of environmental compliance, and its combination with innovation, on TFP convergence of manufacturing SMEs. We applied the dynamic panel regression method to estimate stochastic TFP. We find evidence of a β-convergence but a σ-divergence. Impacts of environmental practices of firms—pollution abatement and control expenditure, and environmental treatment—are only significant through their interaction with innovation. The β-convergence in firms' TFP is influenced by their industrial identity, while firms' size and investment have marginal impacts.

Keywords: environmental practices, innovation, σ- and β-convergence, TFP stochastic
JEL classification: D24, O3, Q55

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1 Introduction

The trade-off between economic growth and environmental quality has recently become one of the most important global issues. In this circumstance, balancing the two sides—economic growth and environmental quality—is considered as one of most important priorities in order to achieve sustainable development. From this perspective, despite being a small emerging economy, Viet Nam might be regarded as a typical case. In fact, since the 'Doi Moi', the Vietnamese economy has achieved remarkable economic growth, in which small and medium enterprises (SMEs) play a crucial role, especially in terms of contributing to gross domestic product (GDP) and creating employment. For instance, SMEs accounted for nearly 97 per cent of total enterprises, contributed more than 40 per cent of GDP, and used approximately 51 per cent of the labour force (Phan et al. 2015). However, most of them have been facing tremendous difficulties, such as a lack of capital and managerial skills, and low technology. In addition, they are considered the main polluters that could make worsen environmental degradation. An explanation might be that, with limited financial, human, and technological resources, their first priority is how to survive[1] and increase profitability, rather than worry about environmental issues. Furthermore, a considerable number of SMEs are household businesses, using low technology and located in residential areas (Dieu 2006; Phan et al. 2015; Tuan et al. 2013).

In the context of intense global competition, the Vietnamese government has been formulating supportive policies to help SMEs to survive, and enhance their productivity and competitiveness. These policies are part of a long-term strategy for sustainable development and aim at encouraging firms' involvement with green innovation, pro-environmental business, and environmentally friendly production. Arguably, the policies should thus ensure harmony between the aim of environmental quality and the aim of firms' profitability; they should also ensure fair opportunities among enterprises. Therefore, adequately understanding the nature of productivity growth and its determinants, such as environmental practices and innovation, is worth investigating empirically.

Understanding the nature of productivity convergence might help us take a closer look at the spillovers of technology among enterprises, which are often from large enterprises to smaller ones. This is important for small firms and new entrants because they can learn and save costs from the innovation and operational experience of larger firms (Nishimura et al. 2005). Consequently, they could increase their ability to catch up with higher productivity firms. Policy makers could then form appropriate supportive policies to help those in need. As Paul Krugman (1994: 13) 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.' In this way, entities like countries, regions, industries, or enterprises with lower productivity could catch up those which have higher productivity, a process called β-convergence. In addition, if dispersion of deviation or standard variance of productivity among entities is likely to be mitigated, then σ-convergence occurs (Barro and Sala-i Martin 1992, 1997).

β-convergence is mainly based on 'the transitional growth process of the neo-classical model'.[2] In this model, supposing that an economy achieves a steady state, then denote x_i as the steady-state per capita growth rate; $\hat{y}_{it}$ as output per effective worker, and $\hat{y}_i$ as the steady-state level of output per effective worker. Then, β illustrates the rate such that $\hat{y}_{it}$ is able to converge with $\hat{y}_i$. This rate

[1] Recently, the number of enterprises going bankrupt has increased considerably, for example, 54,277 SMEs shut in 2012, 60,737 in 2013, and 67,800 in year 2014 (Hoang and Nguyen 2015).

[2] $\log \frac{y_{it}}{y_{i,t-T}} = x_i^* + \log \frac{\hat{y}_i^*}{\hat{y}_{it-T}} \left(\frac{1-e^{-\beta T}}{T}\right) + u_{it}$ (Barro et al. 1991a).

may be affected by conditional variables, in which case this convergence can be called 'conditional convergence' (Barro et al. 1991). Concerning the issue of convergence speed, and the extent to which firms catch up with average productivity growth across firms, the β-convergence is worth considering. In addition, another version of convergence which shows the possibility of productivity gap mitigation is σ-convergence. It is defined as the cross-sectional standard deviation of log(y_{it}). Under the existence of productivity heterogeneity, σ-convergence is taking place if the dispersion of deviation between $\log y_{it}$ and $\log y_i^*$, or variance, is narrowed down over time. There is a close relationship between β- and σ-convergence; it is worth noting, however, that the existence of β-convergence is not necessary to confirm the existence of σ-convergence (Barro et al. 1991).

The literature on productivity convergence has been expanding considerably. However, most of the existing studies mention β- and/or σ-convergence of labour productivity at country and/or industry level, or example in Barro et al. (1991), Baumol (1986), Bernard and Jones (1996a), and Wang and Szirmai (2013). These studies also mainly focus on the context of developed countries as can be illustrated by research such as that of Bernard and Jones (1996b), Pascual and Westermann (2002), Wolff (1991), Frantzen (2004), and Gouyette and Perelman (1997). Meanwhile, only very few studies on TFP (total factor productivity) convergence in developing countries are available, for example Rodrik (2013) on manufacturing in low-income countries, Kumar and Managi (2012) on states in India, Wang and Szirmai (2013) and Bas and Causa (2013) on China, and the case of the manufacturing sector in Viet Nam by Nguyen-Huu (2016).

Furthermore, as mentioned in Barro et al. (1991) and Fung (2005), productivity convergence could be affected by some indicators called conditional variables. These variables may be technological differences (Pascual and Westermann 2002), for instance, or business cycles through recession and expansion periods (Escribano and Stucchi 2014). The macroeconomic environment—such as trade reform or financial markets (Bas and Causa 2013), policies, and institutions (Rodrik 2013)—could be considered important factors in productivity growth. Moreover, internal characteristics of firms, such as their size, market power, and legal ownership, could have a significant impact (Nguyen-Huu 2016).

Recently, environmental quality has begun to take one of the most crucial roles in development policies aiming for sustainability. Accordingly, the study of productivity growth in relation to environmental compliance has been increasing. However, most of these studies mainly concern this link from macroeconomic perspectives, such as at the level of countries, regions, or industries. For instance, Nakano and Managi (2008) found that reform in environment regulations can positively affect productivity growth in Japanese electric industries. The level of influence of environmental regulation on TFP could be varied across sectors; in Organisation for Economic Co-operation and Development (OECD) countries (Oh and Heshmati 2010), and in US manufacturing (Färe et al. 2001). In another approach, looking at 41 developed countries, Kumar (2006) produced evidence that the influential power of environmental regulation is dependent upon productivity growth capability. Nevertheless, expenditure on pollution abatement does not always lead to a decline in productivity (Weber and Domazlicky 2001).

To our knowledge, none of the existing studies examines the impact of environmental compliance on firms' TFP convergence, particularly SMEs, despite its potential contribution to firms' performance, as mentioned in Porter and Van der Linde (1995a), Simpson and Bradford III (1996), Ambec and Barla (2002), Wagner (2003), Brännlund and Lundgren (2009), and Rubashkina et al. (2015). This inspires us to examine the link between environmental compliance and productivity convergence for the case of manufacturing SMEs in Viet Nam, which, as mentioned, play a crucial role in economic development. Conducting research on this issue is worthwhile from both scientific and policy practical perspectives. Two research questions are raised here. (i) Is there TFP β- and σ-convergence of SMEs in Viet Nam? And (ii) to what extent, and how does environmental compliance impact on firms' productivity convergence?

To conduct the research, we rely on the SMEs surveys over the period 2005–15. Firms' TFP is first estimated; however, unlike many previous studies that calculated TFP using the deterministic method, we estimate stochastic TFP by applying the method of Wooldridge (2009). Second, the phenomenon of β- and σ-convergence in TFP, following the framework of Barro et al. (1991), and Barro and Sala-i Martin (1992, 1997), will be analysed. In particular, the role of environmental compliance in such convergences will be considered. Thus, we found evidence of a β-convergence but a σ-divergence of Vietnamese SMEs over the period 2005 to 2015. Importantly, no significant direct impact of environmental practices on TFP convergence was detected. This variable only matters once its interaction with innovation is taken into account, although the magnitude of such impact is small. The industrial identity of firms appears to be another factor contributing to β-convergence, while the firms' own characteristics, such as size or level of investment, are found to have insignificant effects.

This research is organized as follows. Section 2 presents a literature review. Section 3 describes the data and variables, followed by the econometric strategy. Section 4 provides the main findings of the paper; while conclusions and remarks are reported in Section 5.

2 Literature review

2.1 TFP convergence and its determinants

Starting from the milestone research of Baumol (1986), Wolff (1991), Barro et al. (1991), and Barro and Sala-i Martin (1992, 1997), there is substantial literature on productivity convergence, which has mainly examined this convergence at the level of countries, regions, or industries. For example, investigating 13 advantaged economies in the period from 1963 to 1982, Dollar and Wolff (1988) demonstrated that productivity convergence could be affected by capital intensity in every manufacturing sector. However, studying 14 OECD countries, Bernard and Jones (1996b) found no significant evidence of productivity convergence. Taking into account the influences of technological differences, productivity convergence is likely to vary across countries (Bernard and Jones 1996c; Gouyette and Perelman 1997; Pascual and Westermann 2002). For the case of the USA, productivity convergence has not always appeared in all industries, and its speed in the manufacturing sector seems slower than that in service sector (Bernard and Jones 1996b).

Productivity convergence could also be affected by variables such as expenditure on R&D, knowhow, international technology transfers (Cameron et al. 2005), or policies and institutions (Rodrik 2013). Similarly, the role of tax system progressiveness is also concerned in analysis of productivity convergence at country and regional levels (O'Neill and Van Kerm 2008). Examining Spanish manufacturing firms, Escribano and Stucchi (2014) pointed out that this convergence could be affected by business cycles; their study also illustrated the role of human capital and process innovation. Meanwhile, Kumar and Managi (2012) showed that productivity changes could vary and spread across regions in India. Concerning the influence of innovation and the spillover ability of innovation, Nishimura et al. (2005) demonstrated a considerable heterogeneity of convergence speed across industries. From another perspective, Oh and Heshmati (2010) maintained that efficient change plays a major role in the speed of productivity growth in the earlier stage, while technological change has considerable impact in the later period. Concerning the impact of environmental regulation in upstream industries on firm performance in downstream manufacturing in China, Bas and Causa (2013) proved that trade reform and upgrading products could increase productivity convergence speed.

From another viewpoint, as mentioned in Barro et al. (1991), if there is dispersion of deviation in the productivity of firms, 'σ-convergence' may be a concern and should be detected. For instance, studying the cases of the United States, Japan, and five European countries by calculating the unweighted cross-sectional standard deviation for the log of income, Sala-i Martin (1996) found evidence of σ-convergence regionally in terms of income distribution over time. This is consistent with Frantzen (2004), who found that the TFP deviation of the manufacturing sector in OECD countries is likely to be reduced. In contrast, Young et al. (2008) pointed out the impossibility of detecting σ-convergence even if considerable β-convergence is found. This finding, like many others, leads to the conclusion that β-convergence is just a necessary condition, but not a sufficient condition for σ-convergence.

For the case of Viet Nam, TFP convergence is still relatively under-explored; at firm level, only very few studies in this field are available. For instance, applying a stochastic production frontier and using a panel dataset of manufacturing firms covering the period 2000 to 2011, Minh et al. (2014) pointed out the negative impact of foreign direct investment (FDI) on firms' efficiency convergence. Further, technological diffusion can stimulate conditional convergence faster than it stimulates unconditional convergence (Minh et al. 2015). Likewise, Nguyen-Huu (2016) applied the method of Levinsohn and Petrin (2003) to estimate the stochastic TFP of Vietnamese manufacturing firms over the period 2000 to 2012 and showed evidence of conditional β-convergence.

2.2 Environmental regulations and productivity

It can be seen that the relationship between the environment and TFP convergence is a rich research avenue for further investigation. To our knowledge, there is no research investigating the impact of environmental compliance, especially at firm level, and particularly for SMEs. Meanwhile, the literature on the link between the environment and productivity is abundant and has been extended considerably. In this literature the core arguments of Porter and Van der Linde (1995b), the so-called Porter's hypothesis (henceforth PH),[3] is considered the primary hypothetical framework.

This hypothesis argued that environmental stringency could make firms more efficient and thus improve their productivity; this is the so-called 'strong version' of PH. A possible explanation might be that, under stringent regulation, firms would have to conduct environmental compliance by rechecking their resource use, improving the production process, and using more appropriate alternative inputs. As a result, production costs may be reduced, and then profitability would be improved. Furthermore, enterprises could invest more in technological improvement, training, and R&D that could help them to stimulate innovative thinking and enhance their capability to innovate. Consequently, productivity and competitiveness would be enhanced. This is the so-called 'weak version' of PH (Jaffe et al. 1997). However, such impacts, either the 'strong' or 'weak' version of PH, in reality are still ambiguous.

On the one hand, empirical evidence supporting the strong version is found in some countries, such as Japan (Hamamoto 2006), Taiwan (Yang et al. 2012), or France (Piot-Lepetit and Le Moing 2007). On the other, negative or insignificant impacts of environmental stringency on firms' performance are also experienced in other regions or countries such as Quebec (Lanoie et al. 2008), or in European countries more broadly (Rubashkina et al. 2015). Controversial impacts are even evident within the same country, for instance in the USA, where the 'strong version' is supported in Berman and Bui (2001), while insignificant evidence and negative impacts are found in Jaffe et

[3] See Ambec and Barla (2002), Wagner (2003), and Brännlund and Lundgren (2009) for a survey.

al. (1995), Shadbegian and Gray (2005), and Becker (2011). In addition, spending more on pollution abatement probably increases firms' costs and the latter, in turn, might make firms inefficient in terms of both production and emissions (Färe et al. 2007; Shadbegian and Gray 2006).

One could perceive that impact of environmental compliance on enhancing productivity growth may vary across countries and depend upon the technological level of each country or each enterprise. For the case of Viet Nam, a transition economy, most firms are SMEs; they are frequently lacking not only capital but also knowhow, and have low technology, and lack managerial skills, and so on. Hence, the most important priority for them is how to survive and make a profit, rather than a concern over environmental issues. Hence the role of environmental compliance in productivity convergence would be insignificant. In order to take a closer look, this link will be examined empirically.

Furthermore, as mentioned in the 'weak version' of PH, productivity could be affected positively by innovation induced by environmental compliance. Here, the possible explanation might be that environmental compliance may help firms invest more in new technology and use resources more efficiently. Those sub-objectives could have positive effects not only in enhancing innovation capability but also in terms of workers' perception and behaviour regarding environmental protection. Consequently, they are able to increase frequency of innovative thinking and improve innovation performance (Jaffe et al. 1997; Porter and Van der Linde 1995b).

However, in reality, these implications might be not appropriate, particularly for a transition economy like that of Viet Nam. A possible explanation might be that such an economy frequently has limited resources of capital and knowhow to invest in environmental compliance and innovation efficiently. Moreover, there may be an optimal investment threshold with respect to innovation investment efficiency, such that volume of investment needs to be sufficient, or over the threshold to be efficient (Bruno et al. 2008; Le Van et al. 2010). Therefore, the influence of environmentally induced innovation on enhancing productivity growth for this case is still ambiguous. In order to explore this issue, it is necessary to investigate the impact of a combined strategy of environmental compliance and innovation on TFP convergence.

3 Data and methodology

3.1 Data and variables of interest

The data used in this research are from the biannual survey series conducted in collaboration between the Institute of Labor Studies and Social Affairs (ILSSA) in the Ministry of Labour, Invalids and Social Affairs (MOLISA) of Viet Nam and the Department of Economics at the University of Copenhagen with funding from DANIDA (the Danish International Development Agency). The survey focuses on collecting data for Vietnamese SMEs. It is a rich dataset of over 2,500 firms interviewed in several waves (2005, 2007, 2009, 2011, 2013, and 2015). These different waves were gathered to constitute a panel dataset. 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 joint-stock). Data is collected in 10 provinces and covers information on firm characteristics, production, inputs, economic performance, bureaucracy and informality, and trade. Information regarding environmental questions covers environmental treatment, the existence of environmental standards certificates, knowledge level about environmental law, firms' location decisions. We focus on firms in the manufacturing sector.

After deleting firms with missing data or those in other sectors (agriculture or service), we obtain a panel dataset containing 17,454 observations. Table 1 represents the main variables used in this research and their descriptive statistics.

Table 1: Descriptive statistics of the interest variables

Variable	Definition	Min.	Max.	Mean
TFP (in log)	TFP of firms	-5.1	7.19	1.89
Environmental and innovation practices				
PACE (in log)	Pollution abatement and control expenditure: investment in equipment to reduce pollution	0	1.35	0.002
ET	Environmental treatment. ET = 1 if firm has a treatment for environmental pollution (air quality, fire, waste disposal, etc.)	0	1	0.26
Innovation	1 if firm has a new product, new process, or improvement in product	0	1	0.43
Firm characteristics				
Firm size				
1	if micro firm (fewer than 9 employees)	0	1	0.69
2	if small firm (between 10 and 49 employees)	0	1	0.25
3	if medium firm (between 45 and 300 employees)	0	1	0.06
Investment (in log)	Total level investment of firm	0	10.82	1.16
Industrial characteristics				
Cluster	1 if firm belongs to an industrial, export processing, or high-tech zone	0	1	0.2
Capital intensity	Total industrial stock of capital/total employees	2.9	7.4	4.6

Source: Authors' own compilation using the SMEs survey 2005–15.

As can be seen, 26 per cent of firms exhibit at least some kind of environmental treatment (air quality, fire, heat, lighting, noise, etc.). Most of them have no environmental treatment. On the other hand, 43 per cent of firms in our sample declare they have an innovation, either in a new product, or new process, or product improvement. Table 1 also shows a very high incidence of micro firms (firms with fewer than 9 employees). The latter cover 69 per cent of firms in the sample while the medium firms amount to only 6 per cent. Hence, it is likely that such particular characteristics of firms in our sample leads to a weak capacity, as shown by the low level of investment and PACE (Pollution Abatement and Control Expenditure).

3.2 Methodology

3.2.1 TFP estimation strategy

We start with 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 TFP in capital stock, and labour, respectively. Taking a logarithm of Equation (1) gives:

$$\ln Y_{it} = \ln A_{it} + \beta_k lnK_{it} + \beta_k \ln L_{it} + \varepsilon_{it} \tag{2}$$

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

$$\ln Y_{it} = \ln A_0 + \omega_{it} + \beta_k \ln K_{it} + \beta_l \ln L_{it} + \varepsilon_{it} \tag{3}$$

or

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

where $\beta_0 = \ln A_0$, $\ln Y = y$, $\ln K = k$, *and* $\ln L = l$.

If we use traditional methods, in particular the OLS (ordinary least squares), 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 ε_{it}. This issue can be solved using the method of Olley and Pakes (1996; OP, for short), 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, we follow Levinsohn and Petrin (2003) (LP for short) by using material cost as an intermediate input demand function to invert out ω_{it}; then the production function in value can be derived as:

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

where y_{it}, k_{it}, l_{it} are log of revenue, capital stock, and total regular employees respectively; m_{it} is supposed as a set of intermediate inputs measured by materials cost; $m_{it} = m_{it}\ (\omega_{it}, k_{it})$ is the demand function for intermediate goods; and ω_{it} is considered as the stochastic productivity.

LP perform a two-stage estimation, in which the first stage is to estimate the coefficient of labour β_l. However, one could see there is a problem with LP, which is functional dependence; to be more specific, all variables are supposed occur at the same time by using the unconditional intermediate input demands; that could lead to collinearity. However, in reality, material (m_{it}) would normally be chosen after labour (l_{it}) (Ackerberg et al. 2015).

Furthermore, the two-stage estimation of LP also has disadvantages. The first is that it overlooked the probability of the correlation of error terms in the moments. Second, it could also not be efficient because of serial correlation or heterogeneity (Wooldridge 2009). To solve this problem, we apply GMM (generalized method of moments), because it could improve efficiency by using the cross-equation correlation and the optimal weighting matrix (Wooldridge 1996, 2009).

Following Wooldridge (2009), the productivity function could be derived as:

$$\omega_{it} = (k_{it}, m_{it}) \quad (6)$$

where m_{it} is intermediate inputs. In the beginning, assume that ω_{it} is invariant over time. Then under the assumption:

$$E(\varepsilon_{it}\ | l_{it}, k_{it}, m_{it}) = 0, t = 1, 2, \ldots\ldots, T \quad (7)$$

we have the following regression function:

$$E(y_{it}\ | l_{it}, k_{it}, m_{it}) = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \omega\ (k_{it}, m_{it})$$

$$= \beta_l l_{it} + f(k_{it}, m_{it})$$

$$f(k_{it}, m_{it}) \equiv \beta_0 + \beta_k k_{it} + \omega\ (k_{it}, m_{it})$$

For identifying β_l following the methods of OP and LP, we need to add two assumptions. The first concerns ε_{it} and (7) could be derived as:

$$E(\varepsilon_{it} \,|l_{it}\,, k_{it}, m_{it}, l_{i,t-1}\,, k_{i,t-1}, m_{i,t-1}, \dots, l_{i1}\,, k_{i1}, m_{i1}\,) = 0, t = 1, 2, \dots, T$$

Next, using the assumption proposed by LP in order to restrict the dynamic in the productivity process:

$$E(\omega_{it} \,|\omega_{i,t-1}\,, \dots, \omega_{i1}) = E(\omega_{it} \,|\omega_{i,t-1}), t = 2, 3, \dots, T$$

together with an assumption that k_{it} is uncorrelated with the productivity innovation (τ) derived as follows:

$$\tau_i = \omega_{it} - E(\omega_{it} \,|\omega_{i,t-1})$$

In the second stage of LP, according to Wooldridge (2009), the conditional expectation applied to find β_k depends upon $(k_{i,t-1}, m_{i,t-1})$. Therefore, τ_i must be uncorrelated with $\left(k_{i,t-1}, m_{i,t-1}\right)$ and then a sufficient condition could be formulated as:

$$E(\omega_{it}|k_{it}, l_{i,t-1}, k_{i,t-1}, m_{i,t-1}, \dots, l_{i1}, k_{i1}, m_{i1}) = E(\omega_{it}|\omega_{i,t-1}) = f[\omega(k_{i,t-1}, m_{i,t-1})]$$

It should be noted that components of l_{it} are allowed to be associated with τ, which means that k_{it}, the values of $l_{i,t-1}\,, k_{i,t-1}, m_{i,t-1}$ and before, and those functions, are not related with τ_{it}. Then Equation (4) can be reformed as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f\left[\omega\left(k_{i,t-1}, m_{i,t-1}\right)\right] + \tau_{it} + \varepsilon_{it}$$

Finally, for finding β_k and β_l, two functions are derived below:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega(k_{it}, m_{it}) + \varepsilon_{it}, t = 1,2, \dots, T$$

and

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f\left[\omega\left(k_{i,t-1}, m_{i,t-1}\right)\right] + u_{it}, t = 2, \dots, T$$

where $u_{it} \equiv \tau_{it} + \varepsilon_{it}$. Then, following Wooldridge (2009), the orthogonal conditions are stated as follows:

$$E(u_{it} \mid k_{it}, l_{i,t-1}\,, k_{i,t-1}, m_{i,t-1}, \dots, l_{i1}\,, k_{i1}, m_{i1}\,) = 0, t = 2, \dots, T$$

Estimating β_k and β_l requires investigating the unknown function f(.) and ω(.). To deal with this issue, Wooldridge (2009) proposes that:

$$\omega(k_{it}, m_{it}) = \gamma_0 + c(k_{it}, m_{it})\gamma$$

And f(.) can be approximately explained by a polynomial in ω

$$f(\omega) = \rho_0 + \rho_1\omega + \dots + \rho_n\omega^n$$

from where the production function can be rewritten as:

$$y_{it} = \vartheta_0 + \beta_k k_{it} + \beta_l l_{it} + c_{it}\gamma + \varepsilon_{it}, t = 1,2, \dots, T \quad (8)$$

and

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \rho_1(c_{i1}\gamma) + \cdots + \rho_n\left(c_{i,t-1}\gamma\right)^n + u_{it}, t = 2, \dots, T \quad (9)$$

where $\vartheta_0 = \beta_0 + \gamma_0$ and $\alpha_0 = \vartheta_0 + \rho_0$.

According to Wooldridge (2009), the GMM is performed to estimated regressions (8) and (9).[4]

3.2.2 Estimate strategy for TFP convergence/divergence

β-convergence

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

$$\frac{1}{k}\ln\left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1 \ln(\omega_{i,t}) + \theta H_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \quad (10)$$

where ω is log of the firm's TFP and H captures environmental practices (ET and PACE) and/or innovation's variables. X is a vector of control variables which are divided into two groups. The first group is firm characteristics, including firm size and investment. The firm size contains three elements: micro firm, small firm, and medium firm.

The second group is industrial characteristics, including cluster and capital intensity.

Regressions are based mainly on Equation (10) which will be categorized into four models. Model 1, considered as the baseline model, aims to detect unconditional convergence without control variables. In Model 2, environmental practices are added in the baseline model. Then, in Models 3 and 4, firms' characteristics and industrial characteristics are controlled for respectively. Here, econometrically, in accordance with numerous empirical studies on this topic (Escribano and Stucchi 2014; Frantzen 2004; Rodrik 2013), the fixed-effect method is applied for all specifications.

For detecting the phenomenon of convergence, if the coefficient $\hat{\beta}_1$ estimated in Equation (10) 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 (β-convergence) can be computed as follows:

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

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

$$hl = -\frac{\ln 2}{\beta}$$

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

[4] In Stata, command *prodest* allows the Wooldridge estimation for production function. This command is provided by Mollisi and Rovigatti (2017).

σ-convergence

Based on the definition from Sala-i Martin (1996) about the relationship between β-convergence and σ-convergence, we construct the formula to estimate σ-convergence by starting with the formula of the log(TFP)'s sample variance:

$$\sigma_t^2 = \frac{1}{n} \sum_{i=1}^{N} (\omega_{it} - \overline{\omega}_t)^2$$

where $\overline{\omega}_t$ is the mean of ω_{it}. One could see that when N is high enough, Equation (10) can be applied to drive the evolution of σ_t (i.e. the cross-sectional variance of TFP) over time:

$$\sigma_t^2 \cong (1 + \beta_1)^2 \sigma_{t-1}^2 + \sigma_u^2 \quad (11)$$

where β_1 is the parameter associated with $\omega_{i,t}$ in Equation (10) above.

Here, if no evidence for β-convergence is found, the cross-sectional variance increases over time, implying a non-existence of σ-convergence. In other words, the existence of β-convergence is a necessary condition for σ-convergence. If this is the case, the value of σ_t^2 can be computed as:

$$\sigma_t^2 = (\sigma^*)^2 + (1 + \beta_1)^2 [\sigma_{t-1}^2 - (\sigma^*)^2] \quad (12)$$

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

$$(\sigma^*)^2 = \frac{\sigma_u^2}{1+(1+\beta_1)^2} \quad (13)$$

It is noteworthy that the existence of β-convergence is not a sufficient condition for σ-convergence. As be seen in Equation (11), although the value of β_t^2 is negative, σ_t^2 can increase or decrease towards its steady state $(\sigma^*)^2$ once the latter is lower or higher than the initial value of σ^2.

4 Empirical findings

4.1 Environmental regulation and TFP convergence

The aim of the present subsection is to examine impacts of firms' environmental practices on their TFP convergence. Estimates based on Equation (10) are reported in Table 2. H_{it} includes environmental practices containing PACE and ET. As in the literature (Rubashkina et al. 2015; Sanchez-Vargas et al. 2013; Yang et al. 2012, among others), PACE is used as a proxy for stringent environmental regulations. Besides, ET is considered as the proxy for firm compliance.

Table 2: Determinants of TFP convergence (full sample)

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
lnTFP	-0.598***	-0.597***	-0.602***	-0.601***
	(0.008)	(0.008)	(0.008)	(0.008)
PACE (in log)		-0.009	0.023	0.023
		(0.152)	(0.145)	(0.147)
ET		-0.094***	-0.093***	-0.091***
		(0.019)	(0.019)	(0.019)
Firm characteristics				
Firm size (reference: micro firm)				
Small firm			0.030+	0.031+
			(0.018)	(0.018)
Medium firm			0.095*	0.098**
			(0.038)	(0.038)
Investment (in log)			0.013***	0.013***
			(0.003)	(0.003)
Industrial characteristics				
Cluster				-0.050*
				(0.025)
Capital intensity				0.035+
				(0.020)
Sector dummy	*No*	*No*	*No*	*Yes*
Firm fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Constant	1.716***	1.715***	1.687***	1.584***
	(0.023)	(0.023)	(0.023)	(0.086)
Observations	8,818	8,818	8,818	8,818
R-squared	0.526	0.529	0.532	0.532
Number of id	3,300	3,300	3,300	3,300
F	1142***	829.4***	586.8***	415.9***

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Source: Authors' own compilation using the SMEs surveys 2005–15.

Model 1 shows a significant and negative coefficient of lnTFP. It implies that there is an unconditional β-convergence for Vietnamese SMEs during the period 2005 to 2015. The respective speed is 9.2 per cent, corresponding to a half-life time of 7.5 years. In Model 2, firms' environmental practices are introduced to the estimation. PACE is shown to have a negative but insignificant impact on the growth of firm TFP. In contrast, the impact of ET is found to be negative and statistically significant at 0.1 per cent. This shows that by applying an ET, the firm's TFP growth rate is about 9 percentage points lower.[5] However, it seems that, overall,

[5] -9 = [exp(-0.094) - 1]*100

environmental practices only have a negligible effect on firms' TFP convergence since Model 2 reports a similar coefficient of lnTFP as that in Model 1.

These findings are thus consistent with those in Rubashkina et al. (2015). Investigating the role of environmental regulations, the authors find no evidence of significant impact of PACE, on factor productivity or sectoral TFP growth in 17 European countries.[6] Further, Leeuwen and Mohnen (2013) find no significant evidence to support the 'strong version' because environmental regulations have not impacted directly on TFP. Otherwise, it is in contrast with Hamamoto (2006) and Yang et al. (2012), since these authors show the positive impact of environmental regulations' stringency on TFP growth at sector level in Japan and Taiwan, respectively.

In Model 3, the firm characteristics are controlled for. PACE turns out to have positive impact but its impact remains insignificant while the coefficient associated with ET appears to be the same. Firm size positively affects its TFP growth rate. Compared to micro firms, TFP growth rate of small businesses and medium firms is respectively 3 and 9 percentage points higher.[7] On the other hand, firms' investment level positively contributes to TFP growth rate, but the impact is marginal. An increase of 10 per cent in investment in the previous year leads to an increase of 0.13 percentage point in TFP growth rate in the current year. Importantly, it is likely that firms' characteristics have negligible contribution to TFP convergence because the parameter associated with variable lnTFP slowly decreases from -0.598 in Model 2 to -0.602 in Model 3. Consequently, the associated speed of convergence remains 9.2 per cent followed by a half-life time of 7.5 years.

In Model 4, firms' industrial characteristics are taken into account. One important point is that the parameter associated with *cluster* is negative and significant at 5 per cent level. It follows that cluster proximity has a negligible influence on firms' TFP growth rate. This specification also reports a positive impact of industrial capital intensity on TFP growth rate of firms located in the industry under consideration. A 1 per cent increase in the former results in an improvement of 0.035 percentage point in the latter. Overall, it should be noted, however, that the value of the parameter related to lnTFP does not change compared to that of Model 3; this evidence implies no impact of industrial characteristics on the convergence.

We now consider the existence of σ-convergence/divergence. Relying on Equation (11) and estimated coefficients of lnTFP reported in Table 2, the evolution of σ_t^2 over time can be represented in Figure 1. Figure 1(a) displays the unconditional convergence; while in Figures 1(b) and 1(c), environmental practices and then firm characteristics are controlled for. Figure 1(d) shows the full specification where environmental practices, firm characteristics, and industrial characteristics are all taken into account.

Concerning unconditional convergence, Figure 1(a) shows an upward tendency. Over the period 2005 to 2015, the dispersion of TFP slightly increases from 0.34 to 0.36 log point, diverging from its steady-state value of 0.25 log point. Hence there is no evidence of σ-convergence but σ-divergence. When controlling for environmental practices by firms, Figure 1(b) highlights the same incidence indicating (i) the insignificant impact of the environmental dimension and (ii) the existence of σ-divergence. Likewise, Figure 1(c) and 1(d) display a similar pattern of the evolution of firms' TFP dispersion, but with lesser incidence. It appears that firms' characteristics and industrial characteristics have a marginal effect on TFP dispersion.

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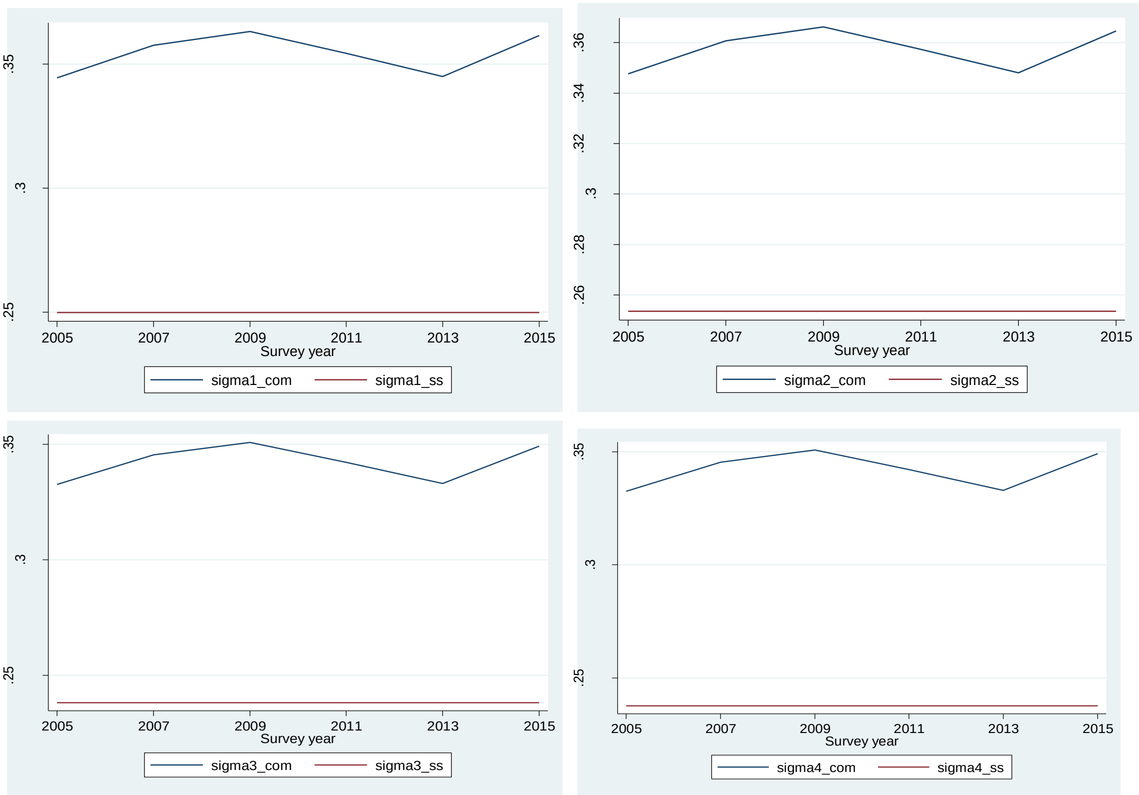
[6] Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Hungary, Lithuania, Poland, Hungary, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK.

[7] $-3 = [\exp(0.03) - 1] * 100; 9 = [\exp(0.095) - 1] * 100$

Figure 1: σ-convergence/divergence: role of environmental practices



(a) Model 1: Unconditional convergence (b) Model 2: Role of environmental practices (c) Model 3: Role of environmental practices and firm characteristics (d) Model 4: Role of environmental practices, firm characteristics, and industrial characteristics

Note: Blue curve: Evolution of σ_t^2. Red line: its steady-state value.

Source: Authors' own compilation using the SMES surveys 2005–15.

In summary, there is a *β*-convergence and a *σ*-divergence for Vietnamese manufacturing SMEs over the period 2005 to 2015. In addition, all controlled covariates appear to have a marginal or no contribution to firms' TFP convergence, implying that evidence for absolute convergence is much clearer than for conditional convergence. Following Fung (2005), this finding suggests that companies converge to an average steady-state growth rate rather than their own steady-state growth rate. This result may be explained by the following arguments.

First, the negligible impact of environmental practices raises a question related to the amount of PACE. There should be a threshold of investment that is likely to exist and that plays a crucial role in determining whether these environmental investments have significant effects on TFP convergence speed. The theory of optimal growth can help us investigate this ambiguous property. According to Bruno et al. (2008) and 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 is possible that firms' expenditures in treating environmental pollution are not sufficiently high to have a non-negligible impact on TFP growth. In fact, more than 75 per cent of firm-observations in this study exhibited a null value of PACE. As for firms with positive value of PACE, their average real expenditures are VND 8.5 million, that is, only 0.3 per cent of their average real revenue.

Second, the insignificant impact of environmental practices (PACE, ET) could be associated with the duration such that the latter could affect firms' TFP. According to Yang et al. (2012) and

Rubashkina et al. (2015), the main reason is that firms need sufficient time to feel the pressure, discover and adopt new technology, and record impacts on productivity. These authors suggest that a two-year lag for variables including PACE could be sufficient. However, this suggestion does not matter in our case because our sample contains SMEs and it is likely that the necessary time-lag is longer.

Last but not least, it is possible that environmental stringency does not directly improve firms' TFP except indirectly, through the incentive to innovate. This result highlights the need to look at evidence for the role of innovation and its interaction with environmental variables in the following subsection.

4.2 Impact of interaction between environment and innovation on TFP convergence

The main purpose of this subsection is to examine whether environmental stringency indirectly affects convergence through the innovation. Estimates are based on Equation (10) and reported in Table 3 with H_{it} now including innovation and interaction between innovation and environmental practice variables.

In Model 1, only innovation is considered. The associated coefficient appears to be negative and statistically significant at 10 per cent level. Consequently, the estimated coefficient associated with lnTFP is higher than in Model 1 of Table 2. Hence, it seems that innovation has a negative impact on firms' TFP convergence, although the magnitude of this impact appears to be small. As a result, Model 1 displays a convergence speed of 8.3 per cent, lower than that of an unconditional convergence.

In Model 2, interaction variables between innovation and environmental practices are added into the regression. The interaction between innovation and ET is shown to be negative but statistically insignificant. In contrast, the impact of interaction between innovation and PACE is found to be statistically positive. However, it could be argued that these interactions have no impact on firms' TFP convergence since Model 2 highlights the same estimated coefficient of lnTFP as that stated in Model 1. When firms' characteristics are taken into account (Model 3), nothing is significantly changed, and firms still experience a speed of convergence in TFP of around 8.3 per cent.

Interestingly, the above findings completely change in the full specification (Model 4). In particular, innovation turns out to have a positive but insignificant impact while its interaction with ET now becomes significant and the extent of the associated impact is higher. In addition, firms that experience both high PACE and innovation also have a higher productivity growth rate. The impacts of firm size and investment are shown to be more important, both quantitatively and quantitatively. As for the role of firms' industrial characteristics, it is likely that the more an industry is capital-intensive, the more it contributes to the growth of TFP of localized firms. However, it is not beneficial to a firm to be in a cluster. Most importantly, Model 4 reports a lower coefficient of lnTFP than that represented in the three first specifications. As a consequence, firms exhibit a higher speed of TFP convergence (8.9 per cent vs. 8.3 per cent). These findings imply that innovation, environmental practices, and firm characteristics only matter when industrial locations are taken into account and there is a conditional β-convergence. Hence, it implies that omitting firms' industrial characteristics may lead to bias in estimated results and this makes associated policy implications inconsistent.

Table 3: Impact of combinations between environment and innovation on TFP convergence

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
lnTFP	-0.562***	-0.562***	-0.563***	-0.588***
	(0.008)	(0.008)	(0.008)	(0.008)
Innovation and environmental practices				
Innovation	-0.016+	-0.015	-0.021*	0.013
	(0.010)	(0.010)	(0.010)	(0.010)
*Innov*PACE*		0.196+	0.207*	0.238*
		(0.100)	(0.102)	(0.106)
*Innov*ET*		-0.011	-0.008	-0.054**
		(0.020)	(0.020)	(0.021)
Firm characteristics				
Firm size (reference: micro firm)				
Small firm			0.015	0.022
			(0.018)	(0.018)
Medium firm			0.085*	0.091*
			(0.038)	(0.038)
Investment (in log)			0.006*	0.012***
			(0.003)	(0.003)
Industrial characteristics				
Cluster				-0.108***
				(0.013)
Capital intensity				0.079***
				(0.017)
Sector dummy	*No*	*No*	*No*	*Yes*
Firm fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
	1.733***	1.732***	1.722***	1.451***
Constant	(0.025)	(0.025)	(0.025)	(0.077)
Observations	8,818	8,818	8,818	8,818
R-squared	0.499	0.499	0.500	0.517
Number of id	3,300	3,300	3,300	3,300
F	2281***	1141***	656.7***	465.6***

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

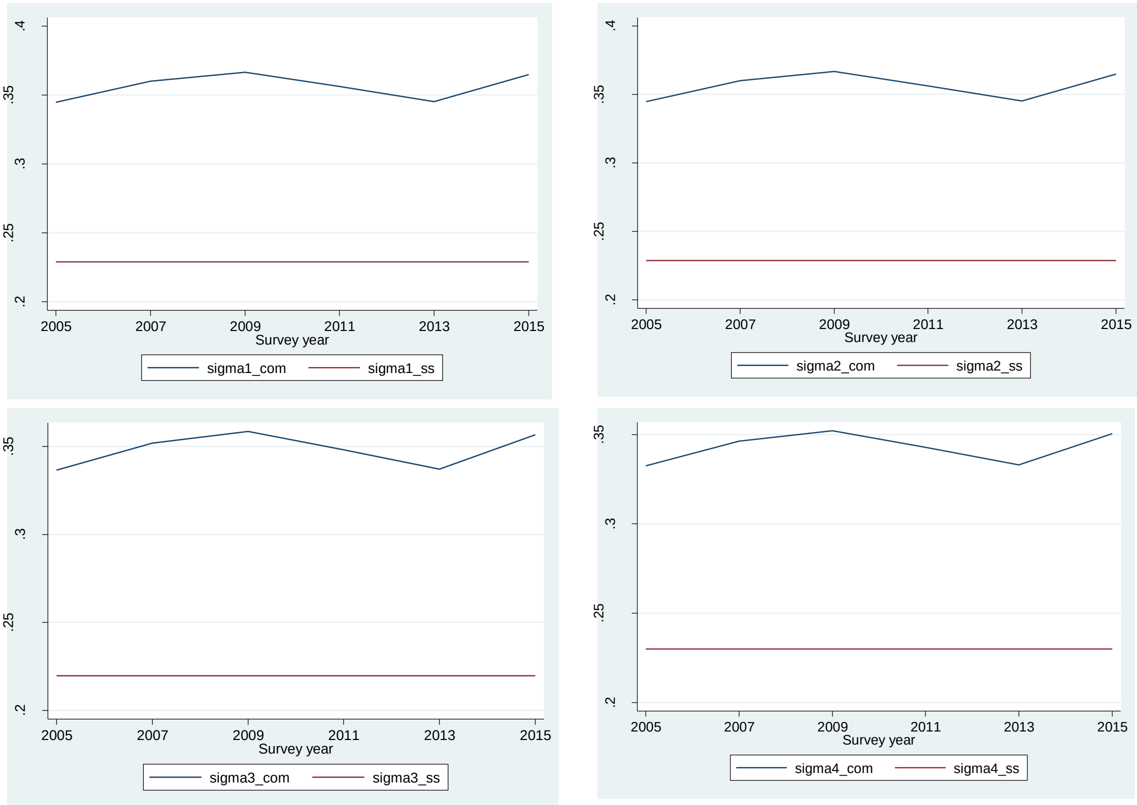
Source: Authors' own compilation using the SMEs surveys 2005–15.

Our findings appear to be consistent with Fung (2005), since the author, by examining the case of UK firms, observes a positive impact of R&D expenditure on firms' TFP convergence. Otherwise, the estimates reported in the full specification seem to imply that environmental regulation contributes to firms' TFP growth through innovation. Increasing pollution costs stimulate firms to improve their product or even create a new product or a new process that has a positive impact on firm's performance. However, it is possible that introducing both innovation and ET increases firms' costs and then negatively affects performance. The positive impacts of innovation and its interaction with PACE make our findings consistent with various empirical studies supporting the 'weak PH', such as Eiadat et al. (2008), Hamamoto (2006), Yang et al. (2012), and Leeuwen and Mohnen (2013). Indeed, Eiadat et al. (2008) state that environmental innovation is associated with firms' performance and this link may be affected by environmental regulations. Similarly, Hamamoto (2006) asserts that more stringent environmental regulations might stimulate firms to invest in new technology aiming first to enhance productivity, but in turn, this investment will also benefit environmental quality. Likewise, Yang et al. (2012) find that the stricter environmental regulations may pressure firms to increase expenditure on R&D and on pollution abatement. Besides, Leeuwen and Mohnen (2013) point out that environmental regulations by government or market pressure all have a positive effect not only on environmental innovation but also on the production process.

By contrast, our finding differs from those of Worrell et al. (2001), and Rennings and Rammer (2011). In fact, the influence of innovation on productivity is probably affected by different types of environmental innovation (Rennings and Rammer 2011). Further, in certain circumstances, an emerging environmental issue could be influenced by technical innovation which may cause adverse effects on the environment (Lewis 2007; Worrell et al. 2001).

Turning now to σ-convergence, Figure 2 displays the evolution of dispersion in firms' TFP (in logarithm) which is computed from Equation (11) and Table 3.

Figure 2: σ-convergence/divergence: role of environmental practices and innovation



(a) Model 1: Role of innovation (b) Model 2: Role of innovation and environmental practices (c) Model 3: Role of innovation, environmental practices, and firm characteristics (d) Model 4: Role of innovation, environmental practices, and firm and industrial characteristics

Note: Blue curve: evolution of σ_t^2, Red line its steady-state value

Source: Authors' own compilation using the SMEs surveys 2005–15.

It appears that Figure 2 displays similar pattern of firms' TFP dispersion as that observed in Figure 1 whatever the related model. More precisely, an upward tendency is stated, implying a *σ*-divergence in TFP for Vietnamese SMEs over the period 2005 to 2015.

4.3 Alternative estimations for firm's TFP

Our above estimates on convergence are based on the Wooldridge estimator for firms' TFP. We apply here the fixed effects (FE) and LP methods to investigate the robustness of our findings; the estimation results are reported in Tables A1 through A4 (see Appendix).

Without controlling for innovation and its interaction with PACE and ET, we state that in comparison to Table 2, Tables A1 and A3 show some slightly divergent impacts of environmental practices, firm characteristics and industrial characteristics on firms' TFP growth. However, the coefficients associated with lnTFP are shown to be similar, whatever the related specification or estimation method for TFP. It follows that Vietnamese SMEs strongly exhibit an unconditional β-convergence over the period 2005 to 2015.

When innovation and its interactions with PACE and ET are taken into account, Tables 3, A2 and A4 show similar results. Hence, it strongly implies that environmental practices do not directly impact firms' TFP convergence but only indirectly via innovation. In other words, environmental regulations stimulate firms to innovate and this, in turn, positively affects firms' performance.

Turning to σ-convergence/divergence, Figures 1, 2 and A1 to A4 display a similar tendency in firms' TFP dispersion. More precisely, the latter slightly increases from 2005 to 2015 and diverges from its steady state. Hence, this shows evidence of a σ-divergence in firms' TFP dispersion.

Overall, our analysis in this subsection shows a strong robustness of firms' TFP convergence, whatever the method used to estimate it. This makes the policy implications in what follows more consistent.

4.4 Policy implications

Since environmental practices (PACE and ET) only affect firms' TFP convergence via innovation, policy recommendations must take this into consideration. First, actions might focus on information diffusion about environmental law. Such diffusion of information remains particularly important since only 2 per cent of firms in 2015 declare that they have good levels of knowledge about this law, while most of them (54 per cent) do not show concern over it.

Second, supporting policies that stimulate firms to improve their environmental practices voluntarily are likely to be necessary because most of them only do so when required to by the authorities. Since, the majority (67 per cent) of firms belong to households and operate on a small scale, investment in new technology to reduce emissions is a really difficult task, or may even be impossible. In fact, environmental protection is not important to entrepreneurs because their main concern is survival and profitability. Hence, environmental practices should be encouraged through improving production processes to reduce wasted energy, and to save energy. Therefore, the policy implications are to help firms to update their information and improve their capacity in terms of logistics management. Also, training activities to enhance skills, environmental awareness (not only for entrepreneurs, but also for the community as a whole) might be another solution.

Third, innovation in the form of new products should be stimulated through funding and support from local governments. This can be handled by providing low interest or free loans for enterprises that invest in new environmentally friendly technology. Likewise, supportive policies that help firms to increase their expenditure on technologies (R&D, patents, and human resources) are also essential as SMEs are characterized by their lack of capital and financial capacity. In such circumstances, public investment would be the first step in implementing policies to support SMEs.

Furthermore, the market has changed rapidly in terms of perceptions; customers are more concerned about both product quality and the environment, because both may have a negative impact on health. Obviously, enterprises need to recognize the coming challenges in terms of competition in both global and domestic markets. To survive and be productive, firms have to follow global environmental norms. Hence, appropriate policies should be initiated to encourage firms to register and obtain international certificates in terms of product and environmental quality.

5 Conclusion and remarks

The present research deals with the existence of TFP divergence/convergence of manufacturing SMEs in Viet Nam over the period from 2005 to 2015 Importantly, the method of Wooldridge (2009) is applied to estimate the stochastic TFP, allowing us to control for impacts of unobserved productivity shocks.

This research shows some important results. First, Vietnamese SMEs exhibit a β-convergence but a σ-divergence in their TFP over the period studied. Second, environmental practices (including regulations and compliance) only affect firms' TFP convergence through innovation. Third, such convergence is influenced by industrial characteristics of firms rather than their size or investment.

The present research inevitably has some limitations, and further research will be required. On the one hand, fixed-effect quantile regression can be used to deal with the possible existence of a threshold associated with PACE and the non-linear convergence associated with firm size. On the other hand, two steps of estimation could be applied in order to better investigate the impacts of environmental practices through innovation on firms' TFP convergence.

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Appendix

LP method for TFP estimation

Table A1: Determinants of TFP convergence

Variables	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
lnTFP	-0.601***	-0.601***	-0.602***	-0.601***
	(0.007)	(0.007)	(0.007)	(0.007)
PACE (in log)		0.029	0.051	0.048
		(0.134)	(0.132)	(0.136)
ET		-0.069***	-0.068***	-0.067***
		(0.017)	(0.017)	(0.017)
Firm characteristics				
Firm size (reference: micro firm)				
Small firm			0.036*	0.036*
			(0.016)	(0.016)
Medium firm			0.065+	0.067*
			(0.034)	(0.034)
Investment (in log)			0.007**	0.007**
			(0.003)	(0.003)
			(0.003)	(0.003)
Industrial characteristics				
Cluster				-0.026
				(0.022)
Capital intensity				0.031+
				(0.019)
Sector dummy	*No*	*No*	*No*	*Yes*
Firm fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Constant	1.082***	1.082***	1.056***	0.946***
	(0.014)	(0.014)	(0.016)	(0.080)
Observations	8,818	8,818	8,818	8,818
R-squared	0.563	0.564	0.566	0.566
Number of id	3,300	3,300	3,300	3,300
F	1421***	1026***	722.8***	514.4***

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Source: Authors' own compilation using the SMEs surveys 2005–15.

Table A2: Impact of combinations between environment and innovation on TFP convergence

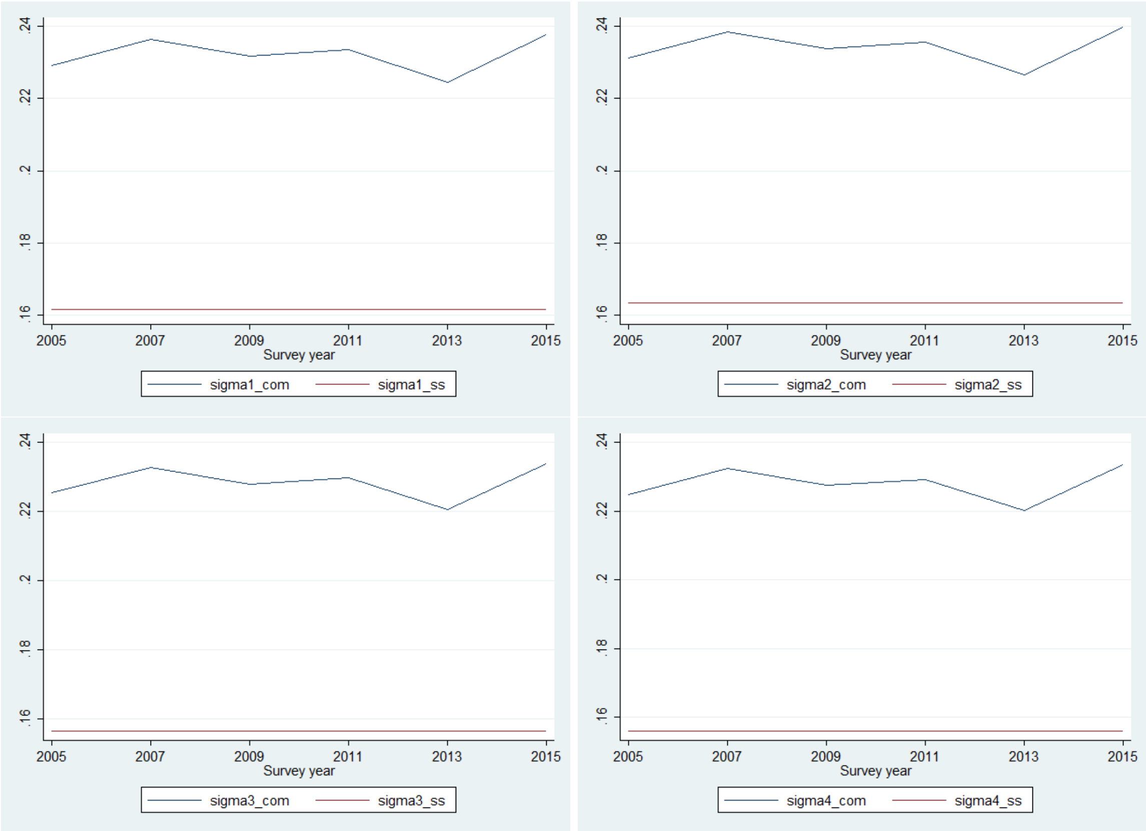
Variables	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
lnTFP	-0.585***	-0.585***	-0.585***	-0.598***
	(0.007)	(0.007)	(0.007)	(0.007)
Innovation and environmental practices				
Innovation	0.005	0.007	0.004	0.030**
	(0.009)	(0.009)	(0.009)	(0.009)
*Innov*PACE*		0.219**	0.232**	0.247**
		(0.081)	(0.080)	(0.080)
*Innov*ET*		-0.020	-0.018	-0.062***
		(0.018)	(0.018)	(0.019)
Firm characteristics				
Firm size (reference: micro firm)				
Small firm			0.029+	0.034*
			(0.017)	(0.017)
Medium firm			0.067+	0.071*
			(0.035)	(0.035)
Investment (in log)			0.003	0.007*
			(0.003)	(0.003)
Industrial characteristics				
Cluster				-0.061***
				(0.012)
Capital intensity				0.087***
				(0.016)
Sector dummy	*No*	*No*	*No*	*Yes*
Firm fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Constant	1.121***	1.120***	1.107***	0.745***
	(0.014)	(0.014)	(0.015)	(0.071)
Observations	8,818	8,818	8,818	8,818
R-squared	0.549	0.549	0.550	0.560
Number of id	3,300	3,300	3,300	3,3
F	3176***	1589***	914.6***	625.2***

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Source: Authors' own compilation using the SMEs surveys 2005–15.

Figure A1: σ-convergence/divergence: role of environmental practices



(a) Model 1: Unconditional convergence (b) Model 2: Role of environmental practices (c) Model 3: Role of environmental practices and firm characteristics (d) Model 4: Role of environmental practices, firm characteristics, and industrial characteristics

Note: Blue curve: evolution of σ_t^2, Red line: its steady-state value.

Source: Authors' own compilation using the SMEs surveys 2005–15.

Figure A2: σ−convergence/divergence: role of environmental practices and innovation

(a) Model 1: Role of innovation (b) Model 2: Role of innovation and environmental practices (c) Model 3: Role of innovation, environmental practices, and firm characteristics (d) Model 4: Role of innovation, environmental practices, and firm and industrial characteristics

Note: Blue curve: Evolution of σ_t^2, Red line: its steady-state value.

Source: Authors' own compilation using the SMEs surveys 2005–15.

FE method for TFP estimation

Table A3: Determinants of TFP convergence

Variables	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
lnTFP	-0.607***	-0.607***	-0.606***	-0.606***
	(0.007)	(0.007)	(0.007)	(0.007)
PACE (in log)		0.086	0.103	0.100
		(0.115)	(0.113)	(0.118)
ET		-0.049**	-0.048**	-0.048**
		(0.016)	(0.016)	(0.016)
Firm characteristics				
Firm size (reference: micro firm)				
Small firm			0.028+	0.028+
			(0.016)	(0.016)
Medium firm			0.028	0.031
			(0.032)	(0.032)
Investment (in log)			0.005*	0.005*
			(0.003)	(0.003)
Industrial characteristics				
Cluster				-0.019
				(0.021)
Capital intensity				0.032+
				(0.018)
Sector dummy	*No*	*No*	*No*	*Yes*
Firm fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Constant	-0.069***	-0.069***	-0.090***	-0.201**
	(0.008)	(0.008)	(0.010)	(0.076)
Observations	8,818	8,818	8,818	8,818
R-squared	0.589	0.590	0.590	0.590
Number of id	3,300	3,300	3,300	3,300
F	1575***	1135***	798.0***	569.3***

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Source: Authors' own compilation using the SMEs surveys 2005–15.

Table A4: Impact of combinations between environment and innovation on TFP convergence

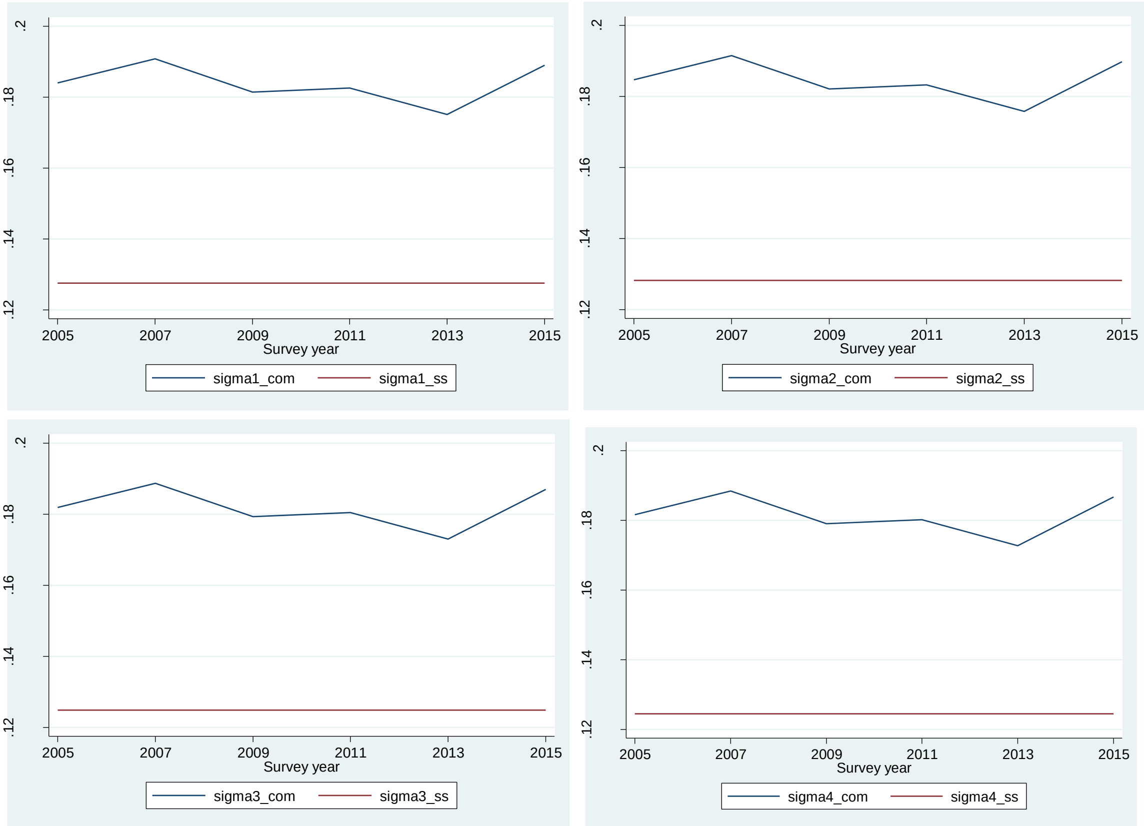
Variables	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
lntfp	-0.583***	-0.584***	-0.583***	-0.600***
	(0.007)	(0.007)	(0.007)	(0.007)
Innovation and environmental practices				
Innovation	-0.004	-0.006	-0.007	0.022*
	(0.009)	(0.009)	(0.009)	(0.009)
*Innov*PACE*		0.233***	0.240***	0.260***
		(0.071)	(0.070)	(0.069)
*Innov*ET*		0.014	0.014	-0.033+
		(0.017)	(0.017)	(0.017)
Firm characteristics				
Firm size (reference: micro firm)				
Small firm			0.023	0.026
			(0.016)	(0.016)
Medium firm			0.037	0.035
			(0.034)	(0.033)
Investment (in log)			0.000	0.005+
			(0.003)	(0.003)
Industrial characteristics				
Cluster				-0.069***
				(0.012)
Capital intensity				0.094***
				(0.015)
Sector dummy	*No*	*No*	*No*	*Yes*
Firm fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.023***	0.022***	0.014*	-0.398***
	(0.004)	(0.004)	(0.007)	(0.067)
Observations	8,818	8,818	8,818	8,818
R-squared	0.569	0.570	0.570	0.583
Number of id	3,300	3,300	3,300	3,3
F	3330***	1682***	965.7***	675.2***

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Source: Authors' own compilation using the SMEs surveys 2005–15.

Figure A3: σ-convergence/divergence: role of environmental practices

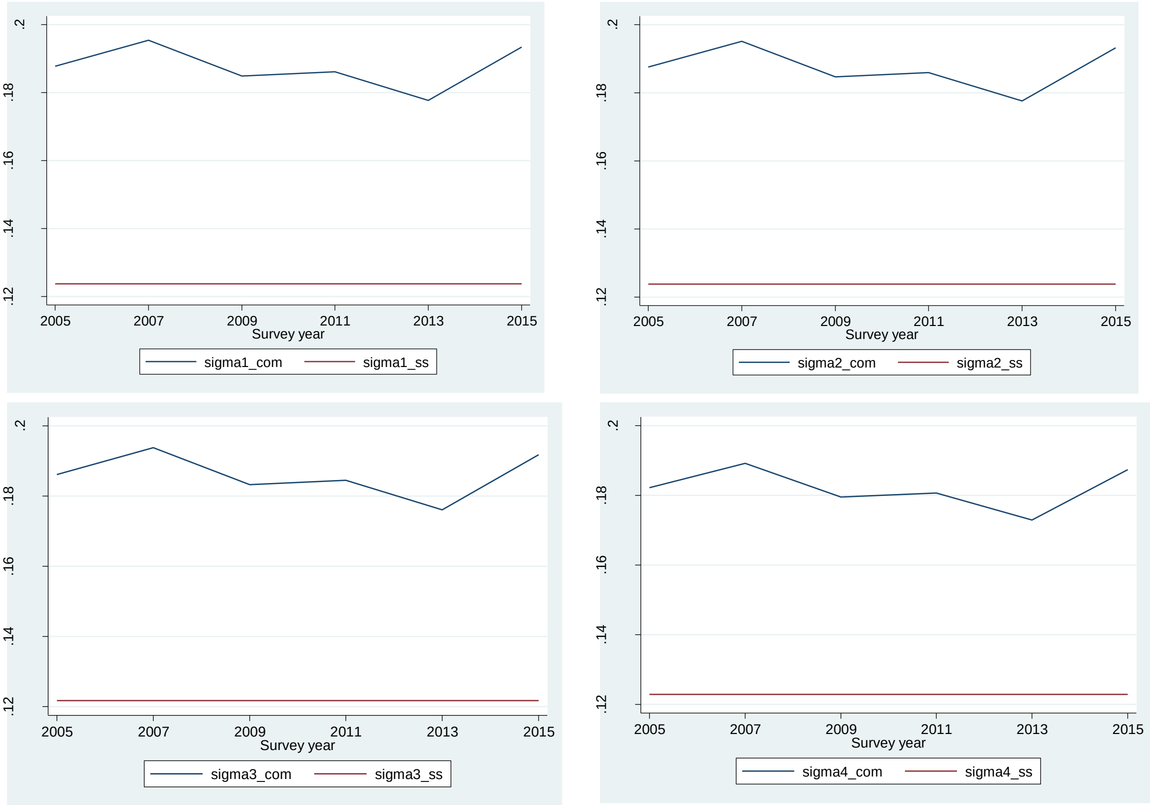


(a) Model 1: Unconditional convergence (b) Model 2: Role of environmental practices (c) Model 3: Role of environmental practices and firm characteristics (d) Model 4: Role of environmental practices, firm characteristics, and industrial characteristics

Note: Blue curve: Evolution of σ_t^2, Red line: its steady-state value.

Source: Authors' own compilation using the SMEs surveys 2005–15.

Figure A4: σ-convergence/divergence: role of environmental practices and innovation



(a) Model 1: Role of innovation (b) Model 2: Role of innovation and environmental practices (c) Model 3: Role of innovation, environmental practices, and firm characteristics (d) Model 4: Role of innovation, environmental practices, and firm and industrial characteristics

Note: Blue curve: Evolution of σ_t^2, Red line: its steady-state value

Source: Authors' own compilation using the SMEs surveys 2005–15.