The role of environmental practices and innovation in TFP convergence - Evidence from manufacturing SMEs in Vietnam ☆

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Abstract

This paper investigates the nexus between environmental practices, innovation and Total Factor Productivity convergence in the case of Vietnamese manufacturing SMEs over the period 2007-2015. While 'environmental standard certificate' and 'environmental treatment' are used as two measures of environmental practices, innovation is divided in increasing-categories: 'no innovation', 'product or process innovation', and 'both innovations'. Environmental standard certificate is found to be neither correlated with Total Factor Productivity, nor with innovation. By contrast, there is a strong correlation between innovation and environmental treatment. On the other hand, innovation and industrial capital intensity are two main factors of firm's Total Factor Productivity convergence.

JEL codes: D24, O3, Q55

Keywords: Environmental practices, Innovation, β-convergence, stochastic TFP, Vietnamese manufacturing firms.

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1. Introduction

Productivity is viewed as the most crucial driver of economic growth. According to Krugman (1994, p.13), "Productivity is not everything, but in the long run it is almost everything. A country's ability to improve its standard of living overtime 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 with those which have higher productivity, which is called β-convergence (Barro and Sala-i Martin, 1992, 1997). The literature on productivity convergence has been considerably developed. Nevertheless, most of studies consider a β-convergence at country, region and/or industry level,[1] while the Total Factor Productivity (TFP) convergence at firm level remains under-explored. Investigating determinants of firms' TFP convergence is of great importance because it allows firms to define key drivers that help them not only to enhance their performance but also catch up to higher productivity firms. Several determinants affecting TFP convergence are frequently examined, such as corporate taxes, policies and institutions (McMillan and Rodrik, 2012), international technology transfer (Cameron et al., 2005), business cycles (Escribano and Stucchi, 2014). The catch-up process is also affected by micro indicators like expenditure on R&D, innovation (Gemmell et al., 2016), human resources, international trading activities (Ding et al., 2016).

Recently, the environment has been emerged as one of the most important factors in sustainable development. However, the trade-off between economic growth and environmental quality is ambiguous, and whether more stringent environmental regulations could improve environmental performance and maintain economic growth simultaneously is still a controversial issue. Conventional views argue that more stringent environmental regulations may increase costs, reduce production and lose profitable opportunities, which in turn reduces productivity and competitiveness (Simpson and Bradford III, 1996). In contrast, revisionists argue that conventional views are too static and do not account for the dynamic influence of environmental factors on innovation which can enhance productivity, competitiveness, and productivity growth (Porter, 1991; Porter and Van der Linde, 1995).

Studies on the impact of environmental practices on productivity abound. However, most of them focus on developed countries, while only a few investigations on this issue for developing countries are conducted. In addition, the literature seems to overlook the role of environmental factors in enhancing TFP convergence, especially in the case of small and medium-sized enterprises (SMEs). This research aims to fill this gap by investigating the catch-up in TFP of manufacturing SMEs in Vietnam addressing the nexus between environmental practices, innovation, and TFP convergence. Two questions are raised: (i) Is there evidence of a β-convergence in firm's TFP? (ii) How firm's environmental practices and its combination with innovation affect the convergence? Vietnam is an interesting case study for at least two reasons. On the one hand, it is a developing country with a high GDP growth rate. On the other

[1] See for example Barro et al. (1991); Bernard and Jones (1996a); Pascual and Westermann (2002).

hand, SMEs play a very important role in economic development of the country especially in terms of contributing to GDP and creating employment. Between 2007 and 2009, 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 labor force (Phan et al., 2015).

Unlike most studies which estimate firm's TFP as the residue of the production function, or using Olley and Pakes (1996) or Levinsohn and Petrin (2003) (here after LP), we use the Generalized Methods of Moment (GMM) estimator developed by Wooldridge (2009) to estimate firms' stochastic TFP. We find evidence of a β-convergence for SMEs over the period 2007 - 2015. In addition, the firm environmental practices do not directly impact its TFP convergence. These factors only matter once they are accompanied by firm innovation.

This research is organized as follows. Section 2 provides a review of relevant literature. Section 3 describes the data and variables, followed by the econometric specifications. Section 4 presents the main findings of the paper. Conclusions and policy implications are reported in Section 5.

2. Literature review

2.1. β-convergence and its determinants

Productivity convergence is initially used as a measurement to answer the question as to "Whether poor countries or regions tend to converge toward rich ones" (Barro et al., 1991). The productivity is measured by the output value per effective labor and depends on technology, natural resources, as well as governmental policies. Theoretically, β-convergence reveals that the growth rate of income per capita of a poor country tends to exceed that of a rich one. This convergence also tends to be higher in open economies because of capital and technology transfer from richer to poorer countries.

Starting from the milestone research by Barro et al. (1991), substantial literature on productivity convergence is conducted at the level of countries, regions, or industries. Empirically, the labor productivity convergence can be heterogeneous across different technological levels and sectors among countries (Bernard and Jones, 1996c). In addition, capital intensity could affect the speed of convergence, but the impacts vary across sectors. Those impacts are small in services sector and high in manufacturing one (Gouyette and Perelman, 1997). The speed of convergence is also different across regions as in India (Bernard and Durlauf, 1996) or in the U.S. (Bernard and Jones, 1996b). Other factors that may affect the productivity convergence include expenditure on R&D, innovation, human resources, and international technology transfers (Cameron et al., 2005), policies and institutions (McMillan and Rodrik, 2012), or business cycles (Escribano and Stucchi, 2014).[2]

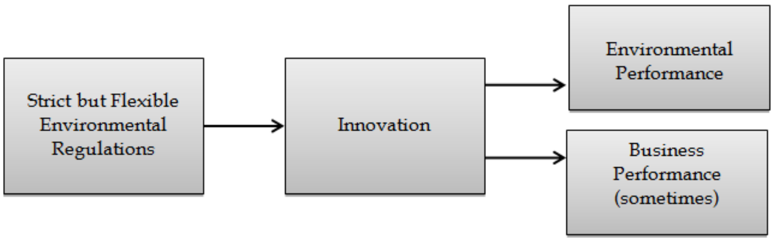
[2] Escribano and Stucchi (2014) examine the case of Spanish manufacturing factor and find an existence of convergence in productivity in business recessive period because followers with scale advantages could reduce cost and be more productive. In contrast, no convergence is found in business expansive periods because firms with high productivity frequently have higher innovation performance compared to those with lower productivity. Cameron et al. (2005) use a panel of 14 manufacturing

Meanwhile, research that investigates determinant factors of productivity convergence at firm level is still limited. For instance, such convergence can be affected by corporate taxes because reducing tax may encourage firms to expand their production by increasing investment and expenditure on R&D (Gemmell et al., 2016). It is also influenced by internal characteristics such as firm's political affiliation, ownership, firm age, export behavior, geographic location (Ding et al., 2016). It should be noted that the role of environmental factors in the firms' TFP convergence is still underdeveloped. Investigating this relationship could be thus one of the main contributions of this paper.

2.2. Environmental regulations, innovation, and productivity

Starting from the seminal work of Porter (1991) and Porter and Van der Linde (1995), the literature about the relationship between environment regulations, innovation, and productivity has been considerably developed.[3] Environmental stringency could encourage firms to revise their consumption of energy and other inputs more efficiently. As a result, production cost is reduced, which in turn enhances productivity and competitiveness. This is the so-called strong Porter's hypothesis (henceforth 'strong PH'). In addition, such stringency may incite firms to increase investment in new technology, improve pro-environmental awareness, and be more creative. Consequently, they could improve innovation capacity, which in turn increases firms' performance. This is the well-known 'weak PH' (Porter, 1991; Porter and Van der Linde, 1995; Jaffe and Palmer, 1997). The casual links of PH can be shown in Figure 1.

Figure 1: Casual links of PH



Source: Ambec et al. (2013, p.4).

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). However, negative or insignificant impacts of environmental stringency on firms' economic performance are also expressed in other regions or countries such as Quebec (Lanoie et al., 2008) or European countries (Rubashkina et al., 2015). Likewise, examining the case of manufacturing firms in the Netherlands, Van Leeuwen

sectors in United Kingdom and the U.S and find the evidence that lower productivity industries have higher productivity growth rate; R&D impacts on productivity growth indirectly through innovation, and human capital does give significant additional impact on productivity growth.

[3]See Brännlund and Lundgren (2009) and Ambec et al. (2013) for a survey.

and Mohnen (2017) do not find significant evidence to support the 'strong PH'. In addition, spending more on pollution abatement may decrease firms' efficiency in terms of both production and emissions (Shadbegian and Gray, 2006). This impact also varies over regions within a country; for example, the oil refineries in Los Angeles, where environmental regulations are more stringent, have higher TFP than those in other states in the U.S. (Berman and Bui, 2001).

As for the 'weak PH' version, empirical studies are also far to be converged. Positive impacts of stringer environmental regulations on firm's innovations and/or expenditure on R&D are pointed out in some papers. For instance, increasing R&D expenditure could be motivated by firm to reduce expenditure on environmental compliance (Jaffe and Palmer, 1997 and Hamamoto, 2006) or to face stringent environmental regulations, leading to an improvement in innovation capacity (Ramanathan et al., 2017; Yang et al., 2012; Carrión-Flores and Innes, 2010). Firm's innovations, in addition, can be influenced by government environmental regulations (Eiadat et al., 2008) or other environmental pressure such as market pressure (Van Leeuwen and Mohnen, 2017) and managerial environmental concerns (Frondel et al., 2008). However, the impact is heterogeneous over technological level and market conditions. As for German manufacturing enterprises, the environmental regulations may hinder firm's innovation capacity through "pre-defined paths of technological solutions" (Rennings and Rammer, 2011). Such an impact is positive if firms operate in low uncertain market, and negative in highly uncertain markets (Blind et al., 2017). Some studies also show negative impact or inconclusive evidence for this relationship (Walker et al., 2008; Triebswetter and Hitchens, 2005; Sanchez and McKinley, 1998; Jaffe and Palmer, 1997)

To sum up, it is important to reiterate that the aforementioned literature shows no conclusive evidence supporting the strong or weak PH version. Furthermore, most studies on this topic have been conducted for the cases of developed countries, while only a few studies examine the cases of developing ones.[4] Most importantly, they have almost investigated the strong PH version by relying on reduced-form model but not the whole Porter causality chain described in Figure 1. For instance, Lanoie et al. (2011) and Van Leeuwen and Mohnen (2017) are the first who examine such causality in OECD countries. However, we have found none existing research investigating the nexus between environmental practices, innovation, and productivity convergence for the case of SMEs in developing countries. It should be thus another important contribution of the present research.

[4]Some investigations into the case of developing countries include China [the case of 30 provinces (Zhang et al., 2011; Xie et al., 2017)], Mexico (food sector) (Alpay et al., 2002), India [sugar industry (Murty et al., 2006; Murty and Kumar, 2003), textile and leather industry (Chakraborty, 2011)], Rumania (Arouri et al., 2012), Spain (Ayerbe and Górriz, 2001), Brazil [manufacturing firms (Féres and Reynaud, 2012)]. Particularly, in a Meta-analysis, Cohen and Tubb (2016) review that there are 70 studies mentioned the Porter hypothesis at firm or industry level. Most of them are conducted in the contexts of OECD, European countries, and the U.S., while only 9 are examined for the case of other countries.

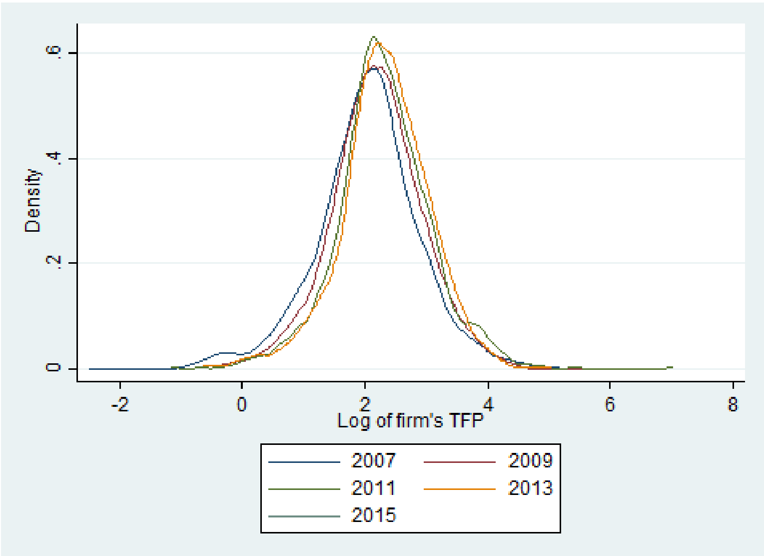
3. Data and methodology

3.1. Data

Data used in this research are conducted from the bi-annual survey on Vietnamese SMEs, starting from 2005 still 2015.[5] Notice however that the section about environment is only introduced in the questionnaire since the 2007 wave. Hence, this paper uses the data covering the period 2007-2015. After deleting firms with missing data or those in other sectors (agriculture or service), we obtain a sample of 4,584 observations. Table Appendix.1 presents the definition of main variables used in this research while their descriptive statistics are reported in Table Appendix.2.

Figure 2 shows the distribution of firms' TFP (in log). The SMEs are likely to improve their TFP since their distribution curve continuously shifts to the right-hand side from 2007 to 2015.

Figure 2: Distribution of firm's TFP (in log)



Two measures of firms' environmental practices are available in the data. On the one hand, in response to the question "does the firm do an environmental treatment?", firm is asked to confirm whether it has a treatment in air quality, fire, heat, noise, waste disposal, water pollution, or soil. Since observations in each category of the environmental treatment (ET) are few, we group all of them under a sole category of having at least an ET. As reported in Table Appendix.2, those firms cover about 25% of our sample. On the other hand, firm is asked to confirm whether it has a "Certificate for registration of satisfaction of environmental standards" (ESC). About 13% of firms in the sample have such certificate.

Turning to firms' innovation, three questions are introduced in the questionnaire: (i) Has the firm

[5]The survey is realized by the Institute of Labor Studies and Social Affairs of Vietnam in collaboration with the Department of Economics of the University of Copenhagen and financially funded by DANIDA, a term used for Denmark's development corporation under the Ministry of Foreign Affairs of Denmark.

introduced new product groups (since last survey)? (ii) Has the firm implemented any improvements of existing products or changed specification? and (iii) Has the firm introduced new production process/new technology? Overall, 55% of the firms in the sample have no innovation while 35% of them have either a product or process innovation. Only 10% of the firms in the sample have both types of innovation.

We also introduce other control variables which are likely to have an impact on firm's TFP convergence as the share of professional workers in their total workforce, total investment, and the capital intensity of the industry where the related firms are located.

3.2. Methodology

3.2.1. TFP estimation strategy: a stochastic approach

To estimate firms' TFP, we start with the Cobb-Douglass production function:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} \tag{1}$$

where Y_{it} is output of firm i ($i = 1, ..., N$) at period t ($t = 1, ..., T$), and A_{it}, K_{it}, L_{it} are TFP, capital stock and labor, respectively. The firm's TFP can be expressed as $A_{it} = A_0 exp(\omega_{it} + \varepsilon_{it})$ where ε_{it} is the error term and ω_{it} the stochastic productivity shock.

Taking logarithm of Equation (1) gives:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it} \tag{2}$$

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

If the OLS, the panel fixed effects (FE) or random effects (RE) models are used to estimate Equation (2), then the unobservable productivity shock ω_{it} is not taken into consideration making the estimation biased. This issue is firstly solved by Olley and Pakes (1996), in which investment is used as an appropriate instrument for inputs. However, investment information, sometimes, is not available, particularly in the case of SMEs. To deal with this problem, LP use material cost as an intermediate input instead of investment. However, notice that the LP estimator suffers three major limits. The first is associated with the functional dependence. More precisely, all variables are supposed occur at the same time by using the unconditional intermediate input demands. That could lead to a collinearity problem because material would normally be chosen after labor (Ackerberg et al., 2015). Second, the LP estimator overlooks the probability of the correlation of error terms in the moments. Third, it could not be efficient because of serial correlation or heterogeneity (Wooldridge, 2009).

In the present paper, we follow Wooldridge (2009) to estimate firms' TFP. Indeed, to correct these limitations of the LP method, the author proposes the GMM estimator because it could improve efficiency by using the cross-equation correlation and the optimal weighting matrix. Hence, the productivity function could be derived as:

$$\omega_{it} = \omega(k_{it}, m_{it}) \tag{3}$$

where m_{it} is intermediate inputs.

At the beginning, assume that

$$E\left(\varepsilon_{it} \mid l_{it}, k_{it}, m_{it}\right) = 0 \quad t = 1, \ldots, T \tag{4}$$

then we have the following regression function:

$$\begin{aligned} E\left(y_{it} \mid l_{it}, k_{it}, m_{it}\right) &= \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \omega(k_{it}, m_{it}) \\ &= \beta_l l_{it} + f(k_{it}, m_{it}) \end{aligned}$$

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

To identify β_l, we need three assumptions. The first concerns ε_{it} such that Equation (4) could be derived as:

$$E\left(\varepsilon_{it} \mid l_{it}, k_{it}, m_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{i1}, k_{i1}, m_{i1}\right) = 0 \quad t = 1, \ldots, T$$

The second assumption is to restrict the dynamic in the productivity process:

$$E\left(\omega_{it} \mid \omega_{it-1}, \ldots, \omega_{i1}\right) = E\left(\omega_{it} \mid \omega_{it-1}\right) \quad t = 2, \ldots, T$$

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

$$\tau_{it} = \omega_{it} - E\left(\omega_{it} \mid \omega_{it-1}\right)$$

In the second stage, the conditional expectation applied to find β_k depends upon (k_{it-1}, m_{it-1}). Therefore, τ_{it} must be uncorrelated with (k_{it-1}, m_{it-1}) and then a sufficient condition could be formulated as:

$$E\left(\omega_{it} \mid l_{it}, k_{it}, m_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{i1}, k_{i1}, m_{i1}\right) = E\left(\omega_{it} \mid \omega_{it-1}\right) = f\left[\omega\left(k_{it-1}, m_{it-1}\right)\right]$$

Notice that components of l_{it} are allowed to be associated with τ_{it}. Then the production function can be driven as:

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

Hence, to find β_k and β_l, two functions are derived below:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega\left(k_{it}, m_{it}\right) + \varepsilon_{it} \quad t = 1, \ldots, T$$

and

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

where $u_{it} \equiv \tau_{it} + \varepsilon_{it}$. The orthogonal conditions are stated as:

$$E\left(u_{it} \mid k_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{i1}, k_{i1}, m_{i1}\right) = 0 \quad t = 2, \ldots, T$$

Estimating β_k and β_l requires investigating the unknown function $f(.)$ and $\omega(.)$ and Wooldridge (2009) proposes that:

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

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

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

from where the production function can be rewritten as:

$$y_{it} = \zeta_0 + \beta_k k_{it} + \beta_l l_{it} + c_{it}\gamma + \varepsilon_{it} \quad t = 1, \ldots, T \tag{5}$$

and

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \rho_1(c_{i1}\gamma) + \cdots \rho_n(c_{it-1}\gamma)^n + u_{it} \quad t = 2, \ldots, T \tag{6}$$

where $\zeta_0 = \beta_0 + \gamma_0$ and $\alpha_0 = \zeta_0 + \rho_0$.

According to Wooldridge (2009), the GMM is performed to estimate Regressions (5)-(6).[6] Once β_k, β_l and β_l are estimated, the firm's TFP (in log) is computed as:

$$\omega_{it} = y_{it} - \beta_k k_{it} - \beta_l l_{it} - \beta_m m_{it} \tag{7}$$

3.2.2. Estimation strategy for β-convergence

Environmental practices and β-convergence

To estimate how the firm's environmental practices affect its TFP convergence, we base on the following regression:

$$\left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1\omega_{i,t} + \theta H_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \tag{8}$$

where ω is log of the firm's TFP obtained in Equation (7) and the dependent variable refers to the firm's TFP growth rate. H is a vector of covariates capturing environmental practices (ET and $PACE$). X is a vector of control variables including the firm and industrial characteristics. In accordance with numerous empirical studies on this topic, the FE methods can be applied to estimate Equation (8).[7] However, it should be noted that such estimation could be biased since $PACE$, ET might be potentially endogenous as they can be affected by unobserved factors. To overcome this issue, we introduce both the 'variable addition test' and the 'instrumental variables estimation with panel data' proposed by Wooldridge (2005, 2014). The procedure is as follows:

(i) At the first step, a probit model for ET and a FE estimator for $PACE$ are performed. These variables are instrumented with a discrete variable measuring firms' knowledge about the environmental law (KEL): *1* if Good or average knowledge, *2* if poor knowledge, and *3* if no knowledge. This excluded IV should be validated for two reasons. On the one hand, there should be a strong correlation between KEL and environmental practices (e.g. the potential endogenous variables). On the other hand, it is hardly difficult that KEL may impact the firm's TFP growth, the dependent variable.

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

[7] See for example Rodrik (2013); Escribano and Stucchi (2014).

(ii) For each regression of the first step, we compute the associated generalized residuals and the latter are then introduced to the usual FE estimator of Equation (8).

(iii) Finally, we perform a robust test for the null hypothesis that all coefficients associated with the generalized residuals are zero. Accepting the null hypothesis implies the exogeneity of *PACE* and *ET*. According with Koné et al. (2017), this test is called *robust* because it is based on robust standard errors.

Innovation and β-convergence

It is possible that environmental practices have non-significant impacts on TFP convergence. However, we expect that they may indirectly contribute to this convergence through *Innovation*. Putting it differently, it might be that environmental practices first affect *Innovation* and the latter in turn influences firms' TFP convergence. If it is true, the following equations can be applied:

$$Innovation_{i,t} = \alpha_i + \beta_1 \omega_{i,t} + \kappa H_{i,t} + \gamma_1 X_{i,t} + u_{i,t} \quad (9)$$

$$\left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1 \omega_{i,t} + \delta Innovation_{i,t} + \gamma_2 X_{i,t} + \epsilon_{i,t} \quad (10)$$

To estimate Equations (9, 10), the 'variable addition test' and the 'instrumental variables estimation with panel data' are performed. At the first stage, *Innovation* is instrumented with *ESC* and *ET* in an ordered probit model. Notice that the potential endogeneity of *ESC* and *ET* is also taken into account. We then compute the related generalized residuals and introduce it to Equation (10). Last, we test whether the coefficient associated with these residuals equals to zero. The null hypothesis means the exogeneity of *Innovation*.

It should be noted that environmental practices are here expected to have significant impacts on *Innovation* but not on TFP convergence. Consequently, they may be used as excluded IV at the first stage. If the strong version of PH obtained from estimating Equation (7) is supported, estimation of Equation (10) becomes irrelevant. In this case, we are only interested in how environmental practices impact *Innovation*.

Speed of convergence and half-life time

Once Equations (8) and (10) are estimated, the sign of the estimated coefficient $\hat{\beta}_1$ allows us to confirm the existence of a β-convergence. If the sign is positive value, there is a β-divergence. By contrast, if that sign is negative, a β-convergence is found and the associated speed of convergence can be computed as:

$$\beta = -\frac{\ln(1 + \frac{\hat{\beta}_1}{k})}{T} \quad (11)$$

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

$$hl = \frac{\ln 2}{\beta} \quad (12)$$

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. Empirical Findings

4.1. Environmental practices and TFP convergence

This subsection aims to study the impacts of environmental practices on TFP convergence. As mentioned in Section 3, *ESC* and *ET* could be endogenous due to unmeasured omitted factors driving to an under- or over-bias in the estimation of their impacts on the TFP convergence. Table 1 reports the two-stage estimations that take into consideration the potential endogenous issue.

Table 1: Impacts of *ESC* and *ET* on firm's TFP convergence

	Stage 1				Stage 2		
Dependent variable	*ET*		*ESC*		*dlnTFP*		
Estimator	Probit		Probit		FE		
	Estimation	Marginal effect	Estimation	Marginal effect			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TFP (in log)	0.344***	0.105***	0.434***	0.036***	-1.145***	-1.147***	-1.145***
	(0.029)	(0.009)	(0.073)	(0.006)	(0.023)	(0.023)	(0.022)
Environmental practices							
ESC					-0.015	0.035	
					(0.089)	(0.056)	
ET					-0.076+	-0.078+	
					(0.043)	(0.043)	
Firm and industrial characteristics							
Firm's investment (in log)	-0.267*	-0.082*	0.634**	0.052**	0.016	0.009	
	(0.109)	(0.033)	(0.209)	(0.017)	(0.074)	(0.074)	
Share of professional workers	-0.010	-0.003	-0.168	-0.014	-0.008	-0.008	
	(0.030)	(0.009)	(0.132)	(0.011)	(0.021)	(0.021)	
Industrial capital intensity	0.526***	0.161***	0.337**	0.028**	0.103**	0.101**	
	(0.054)	(0.017)	(0.127)	(0.010)	(0.035)	(0.035)	
Generalized residuals of *ESC*					0.007		
					(0.010)		
Generalized residuals of *ET*					0.093**	0.095**	
					(0.030)	(0.029)	
Firm fixed effects	-	-	-	-	Yes	Yes	Yes
Constant	-4.302***		1.388***		2.120***	2.130***	2.593***
	(0.601)		(0.120)		(0.157)	(0.157)	(0.050)
Excluded IV							
Knowledge about the environmental law							

continued next page

Table 1: Impacts of *ESC* and *ET* on firm's TFP convergence (continued)

	Stage 1				Stage 2		
Dependent variable	*ET*		*ESC*		*dlnTFP*		
Estimator	Probit		Probit		FE		
	Estimation	Marginal effect	Estimation	Marginal effect			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(Reference: Good or average knowledge)							
Poor knowledge	-0.082	-0.027	-0.749***	-0.076***			
	(0.057)	(0.019)	(0.119)	(0.013)			
No knowledge	-0.284***	-0.089***	-1.224***	-0.111***			
	(0.054)	(0.018)	(0.124)	(0.013)			
Observations	4,584	4,584	4,584	4,584	4,584	4,584	4,600
Number of firms	1,941	1,941	1,941	1,941	1,941	1,941	1,941
R-squared					0.574	0.574	0.572
Test for endogeneity	-	-	-	-	5.43**	10.41***	-
Beta-convergence (%)	-	-	-	-	-	10.59	10.62
Half-life time (years)	-	-	-	-	-	6.54	6.52

Robust standard errors in parentheses.

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

Considering the first stage, the estimations are reported in columns 1-4 in which the two first columns concern estimation and the associated marginal effect for *ET* and the two following columns are for *ESC*. *KEL* is used as excluded instruments for the two potential endogenous variables. As expected, this variable is shown to be strongly correlated with either *ESC* or *ET*. Comparing to a firm having *Good or average knowledge*, that with *No knowledge* is less likely to exert an *ET*. The associated probability is 8.9% lower. The picture is even clearer for *ESC*: firms with *Good or average knowledge* about environmental law is much more likely to obtain an ESC. The probability is respectively 7.6% and 11.1% higher than firms with *Poor knowledge* and those with *No knowledge*.

Turning to the second stage, the estimations are displayed in columns 5-7 of Table 1. Column 5 shows the estimation with taking into consideration both *ESC* and *ET* as endogenous. The test for endogeneity is likely to confirm their endogeneity. However, the estimated coefficient associated with the generalized residuals of *ESC* is non-significant. In addition, we perform the endogeneity test on the sole variable *ESC*, the test fails to reject its exogeneity. By contrast, the estimated coefficient associated with the generalized residuals of *ET* is statistically significant. To sum up, it appears that *ESC* is not endogenous while *ET* is in these estimations. As a result, column 6 of Table 1 represents estimations with endogeneity of *ET* and exogeneity of *ESC*. The test for endogeneity displayed in this column confirms once again the endogeneity of *ET*.

Notice that column 6 of Table 1 shows a significant and negative estimated coefficient associated with TFP. Hence, there is a $\beta-$convergence for the SMEs during the period 2007-2015. The related speed is 10.6% conducting to a half-life time of 6.5 years. As for the role of environmental practices, it appears that *ESC* has a positive but insignificant impact on the TFP growth rate. By contrast, *ET* has a negative impact but it is only significant at 10% level. As for other firm and industrial characteristics, only *Industrial capital intensity* has a significant impact, while that of *Firm's investment* and *Share of professional workers* is statistically non-significant.

To have a deeper insight on impacts of environmental variables on TFP convergence, we also refer to the unconditional convergence. The related estimations are shown in column 7 of Table 1. Yet, the estimated coefficient of TFP is similar to that reported of column 6 (-1.145 vs -1.147). Hence, it implies that environmental practices only have a negligible effect on the TFP convergence. These findings about the role of environmental variables are consistent with those in Rubashkina et al. (2015), who find a non-significant impact of *PACE* on sectoral TFP growth of 17 European countries. Likewise, Van Leeuwen and Mohnen (2017) find no-evidence to support that impact in the Netherlands. However, our findings contrast those of Hamamoto (2006) and Yang et al. (2012), who argue for the positive impact of environmental stringency on TFP growth at sector level in Japan and Taiwan, respectively.

In summary, there is a $\beta-$convergence for Vietnamese manufacturing SMEs over the period 2007-2015. However, the firm environmental practices appear to have non-significant impacts on its TFP convergence. This result may be explained by the following arguments. On the one hand, the negligible impact of ET raises a question about the amount of expenditures associated with ET, namely $PACE$. It is possible that $PACE$ is not sufficiently high to have a non-negligible impact on its TFP convergence because, as proved by Bruno et al. (2009). Indeed, the authors argue that the level of investment should exceed a threshold such that it has a significant impact on the economy. In our sample, more than 75% of firm-observations exhibited a null value of $PACE$ while for those having positive value of $PACE$, their average real expenditures are about 2 million VND (equivalent to 100 U.S. dollars). On the other hand, the non-significant impact of ESC should be related to the firm motivation to obtain it. Indeed, 64% of firms declare that they have such certificate because it is requested by officials/law while less than 10% of them do it to reduce cost in the long run or to protect the environment. Since the motivation comes from an obligation imposed by local authorities rather than from the firm strategic behavior, it is not surprising that ESC does not have a significant impact of TFP convergence.

Notice that the non-significant impacts of ET and ESC seems to support our aforementioned intuition. It is possibly that environmental practices do not directly improve the TFP convergence but indirectly through *Innovation* and the latter in turn may contribute to the convergence.

4.2. The nexus between Environmental practices, Innovation and TFP convergence

In this subsection, we investigate whether environmental practices indirectly affect the TFP convergence through *Innovation*. Since ESC and ET are not correlated with the TFP growth rate, we can perform the estimations of Equations (9) and (10) and the two environmental variables can be used as excluded IV. Notice that while estimation of Equation (9), the endogeneity test supports the exogeneity of ET and ESC. In addition, ESC has a non significant impact on *Innovation*.[8] Consequently, Table 2 reports the estimations of Equations (9) and (10) with using ET as the sole excluded IV.

Table 2: Environmental practices, Innovation and TFP convergence

	Stage 1				Stage 2	
Dependent Variable	*Innovation*				*dlnTFP*	
Estimator	Ordered Probit				FE	FE
	Estimation	Marginal effect				
	(1)	(2)	(3)	(4)	(5)	(6)
TFP (in log)	0.303***	-0.110***	0.059***	0.051***	-1.156***	-1.151***
	(0.028)	0.009)	(0.005)	(0.005)	(0.023)	(0.022)
Firm's innovations						
(Reference: No innovation)						
Product or process innovation	-	-	-	-	0.026	-
					(0.024)	

continued next page

[8]The related estimated results and the endogeneity test are available upon request.

Table 2: Environmental practices, Innovation and TFP convergence (continued)

	Stage 1				Stage 2	
Dependent Variable	*Innovation*				*dlnTFP*	
Estimator	Ordered Probit				FE	FE
	Estimation	Marginal effect				
	(1)	(2)	(3)	(4)	(5)	(6)
Both Innovations	-	-	-	-	0.152+	-
					(0.086)	
Environmental practices						
ET	-0.388***	0.140***	-0.075***	-0.065***	-	-
	(0.045)	(0.016)	(0.008)	(0.008)		
Firm and industrial characteristics						
Firm's investment (in log)	0.186	-0.068+	0.036+	0.031+	0.002	0.004
	(0.119)	(0.035)	(0.019)	(0.016)	(0.074)	(0.075)
Share of professional workers	-0.134***	0.049**	-0.026**	-0.023**	-0.010	-0.009
	(0.040)	(0.016)	(0.008)	(0.007)	(0.021)	(0.021)
Industrial capital intensity	-0.115*	0.042*	-0.022*	-0.019*	0.111**	0.104**
	(0.053)	(0.018)	(0.010)	(0.009)	(0.034)	(0.034)
Generalized residuals of *Innovation*	-	-	-	-	-0.079*	-
					(0.032)	
Constant	-	-	-	-	2.176***	2.16***
					(0.153)	(0.150)
Firm fixed effects	-	-	-	-	Yes	Yes
Observations	4,598	-	-	-	4,598	4,598
Number of firms	1,941	-	-	-	1,941	1,941
R-squared					0.575	0.5733
Fisher test for endogenous	-	-	-	-	5.93*	-
Beta-convergence (%)	-		-	-	10.8	10.7
Half-life time (years)	-		-	-	6.4	6.47

Robust standard errors in parentheses.

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

At the first stage, we consider some factors that may affect the firm's probability to innovate. Column 1 in Table 2 reports the estimated results while columns 2-4 represent the related marginal effects on the three categories of *Innovation* (that is *'No innovation'*, *'Process or Product innovation'*, and *'Both innovations'*) respectively. *ET* appears to be strongly correlated with *Innovation* in the manner that this variable increases the probability of having *No innovation* by 14% and reduces the probability of having *'Process or Product innovation'* and *'Both innovation'* by 7.5% and 6.5%, respectively. Since *ET* is likely to discourage firms to innovate, it is possible that introducing both *Innovation* and *ET* are much costly for firms, especially in the circumstance that most of them are lacking capital and face credit constraints. They must choose between either *ET* or *Innovation*. As a result, firms practicing *ET* are less likely to innovate. These findings are thus consistent with the negative impact of ET on $Innovation$ displayed in column 1.

Notice that the existence of a negative correlation between ET and $Innovation$ makes our paper differs to conventional results on the weak PH version. For example, the presence of environmental regulation increases the occurrence probability of both resource-saving and pollution reducing eco-innovations (Van Leeuwen and Mohnen, 2017). Likewise, stringer environmental regulations might stimulate firms to invest in new technology (Hamamoto, 2006) or increase its expenditure on R&D and pollution abatement (Yang et al., 2012).

Looking at how *Innovation* affects TFP convergence, the estimated results are represented in column (5) of Table 2. The Fisher test for endogeneity of $Innovation$ is statistically significant at 5% level implying the endogeneity of this variable. In addition, there is a correlation between $Innovation$ and $d\ln TFP$. Compared to firms having *No-innovation*, the TFP growth rate of those with both *Product* and *Process innovation* is 16% higher. Most importantly, Table 2 displays a β-convergence of 10.8% leading to a half-life time of 6.4 years. This rate is higher than that of the unconditional convergence reported in column 7 of Table 1. If should be noted that in the absence of *Innovation*, the speed of convergence slightly declines to 10.7% (column 6 of Table 2). Overall, while comparing the β-convergence in Table 2 to that of Table 1, there should be a conditional convergence in the manner that firms having *Innovation* and/or locating in capital intensity industries exhibit higher speed of convergence than those do not.

5. Conclusion and remarks

This research investigates the nexus between environmental practices, innovation and TFP convergence for Vietnamese manufacturing SMEs over the period 2007-2015. We find that the firm's environmental practices only have a marginal effect on its TFP convergence. However, there is a non-negligent indirect impact in the manner that imposing environmental treatment on firms have may discourage them to innovate while innovation positively contributes to TFP convergence. The level of industrial capital intensity is other important factor that contributes to such convergence.

Some policy recommendations can be driven from these results. First, since KEL positively affect the firm's environmental practices, information about environmental awareness should be largely diffused. This is of great importance because only 3% of firms in the sample respond that they have good knowledge of this law while most of them (52%) are shown to no concern over it. Second, supporting policies for improving firms innovation capacity should be considered. This could be implemented through providing favorable credits for SMEs investing in new environmental friendly technology, R&D, and environmental practices. In addition, since the majority of firms in our sample are small and micro-scaled and lacking capital, other complementary alternatives such as improving production process, reducing wasted energy, and saving energy should be also encouraged. Training activities to enhance skills and environmental awareness might be another solution. Third, investment in physical capital should be strengthened because this improves the industrial capital intensity and the latter in turn contribute to the TFP convergence. Finally, under the increasing globalization with more intense competition, firms should follow international environmental norms to enhance their competitiveness. Hence, implementing supporting policies for SMEs in obtaining international environmental certificates is of essential.

The present research has two important contributions to the literature. As indicated in Van Leeuwen and Mohnen (2017), almost all empirical studies investigate the PH through a single-equation models for searching the role of environmental regulation in productivity. By contrast, the use of structural equations in this paper allows to find corroboration of both strong and weak PH version. Second, empirical findings are mostly at country or sectoral levels. Differently, our paper attempts the role of environmental regulation to SMEs' TFP convergence in a developing country, a case-study that is still scare either in TFP convergence or PH topics.

This research leaves open two research lines. On the one hand, it is interested to study the environmental behaviors of large firms, particularly since they are less financed constraints than SMEs in our sample. In addition, a focus on those in polluted industries should bring clearer evidence on both strong and weak version of PH. On the other hand, it might that environmental practices do not contribute to SMEs performance but their survival probability and it is of importance to investigate this relationship.

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Appendix

Appendix.1. Definition of variables

Variable		Definition	Type
TFP		The firm's TFP obtained from Equation (7)	Continuous
Environmental and innovation practices			
ET		Environmental treatment. ET = 1 if the firm has a treatment for environmental pollution (air quality, fire, waste disposal, etc.)	Dummy
ESC		1 if the firm has Certificate for registration of satisfaction of environmental standards	Dummy
Knowledge about Environmental Law			Discrete
	1	if Good or Average	
	2	if Poor	
	3	if No	
Innovation			Discrete
	1	if no innovation	
	2	if either a process or product innovation	
	3	if both innovations	
Firm characteristics			
Share of Professional Workers		The share of professional workers over the firm's total employees	Continuous
Investment		The firm's total level investment of firm	Continuous
Industrial characteristics			
Industrial capital intensity		Total industrial stock of capital/Total industrial employees	Continuous

Appendix.2. Descriptive statistics

	Mean	Std. Dev.	Min	Max
TFP (in log)	2.15	0.792	-2.492	7.026
ET	0.268	0.443	0	1
ESC	0.13	0.336	0	1
Firm's investment (in log)	0.028	0.19	0	3.171
Share of Professional Workers	0.807	0.692	0	0.99
Industrial capital intensity	4.348	.377	3.543	5.893
N	4598			