The role of environmental practices and innovation in total factor productivity convergence -Evidence from small-and medium-sized manufacturing enterprises in Vietnam

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The role of environmental practices and innovation in total factor productivity convergence - Evidence from small- and medium-sized manufacturing enterprises in Vietnam[1]

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Abstract

This research investigates the nexus between environmental compliance, innovation, and Total Factor Productivity convergence. We use two measures of environmental practices: the firm environmental standard certification and environmental treatment. As for innovation, it has three increasing-levels: no innovation, product or process innovation, and both types of innovation. Using a sample of Vietnamese small- and medium-sized manufacturing enterprises from 2007 to 2015, the environmental practices are not correlated with total factor productivity. By contrast, there is a strong correlation between innovation and environmental treatment. Factors contributing to the firm productivity growth rate, and consequently the speed of convergence, are innovation, firm size, and legal form.

Keywords: Innovation, TFP growth rate, β-convergence, Environmental practices.

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Le rôle de pratiques environnementales et d'innovation dans la convergence de productivité totale des facteurs – L'exemple des petites et moyennes entreprises manufacturières au Vietnam

Résumé

Cette recherche examine le lien entre la conformité environnementale, l'innovation et la convergence de la productivité totale des facteurs. Nous utilisons deux mesures de pratiques environnementales : la norme de certification environnementale et le traitment environnemental. Quant à l'innovation, il s'agit d'une variable qualitative ayant trois modalités croissantes : aucune innovation, innovation de produit ou de procédé et deux types d'innovation. En utilisant une base de données des petites et moyennes entreprises manufacturières vietnamiennes entre 2007 et 2015, les pratiques environnementales ne sont pas corrélées avec la productivité totale des facteurs. En revanche, il existe une forte corrélation entre l'innovation et le traitement environnemental. Les facteurs qui contribuent au taux de croissance de la productivité des entreprises, et par conséquent à la vitesse de convergence, sont l'innovation, la taille de l'entreprise et la forme juridique.

Mots clés : Innovation, Taux de croissance de PTF, β-convergence, Pratiques environnementales.

1. Introduction

Productivity is considered 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 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 with those having higher productivity, which is called β-convergence (Barro and Sala-i Martin, 1992, 1997).

A large body of research on productivity convergence examines the β-convergence at the country, region, and/or industry level. Nevertheless, the Total Factor Productivity (TFP) convergence remains under-explored at the firm level. Nevertheless, investigating determinants of such a convergence is of great importance for at least two reasons. At the firm-level, it facilitates firms to define which critical drivers could enhance their performance and catch up with higher productivity firms. Besides, understanding factors affecting the firm TFP convergence is vital to improve productivity at the industry and/or province level, promote convergence between industries and/or provinces, and reduce inequality. 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), expenditure on R&D, innovation (Gemmell et al., 2018), human resources, and international trading activities (Ding et al., 2016).

Together with productivity, environmental quality is another essential factor of sustainable development. However, the trade-off between economic growth and environmental quality is ambiguous. 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, critical views argue that conventional views are static and do not account for the dynamic influence of environmental factors on innovation, which, in turn, can enhance productivity, competitiveness, and productivity growth (Porter, 1991; Porter and Van der Linde, 1995).

The literature on the impact of environmental practices on productivity is abundant and insightful but mainly focuses on developed countries. There is comparatively little attention on the context of developing countries. Besides, the literature is likely to overlook environmental factors' role in enhancing TFP convergence, especially when it comes to small- and medium-sized enterprises (SMEs). This research aims to fill this gap by relying on a sample of SMEs in Vietnam. Two questions are raised: (i) Is there evidence of a β-convergence in the firm TFP? (ii) How do the firm environmental practices and innovation affect its TFP growth rate, and so convergence?

Vietnam is an interesting case study for at least three reasons. First, it is a developing country with a high GDP growth rate. Second, SMEs play a vital role in the country's economic development, especially in contributing to GDP and creating employment opportunities. Between 2007 and 2009, SMEs accounted for nearly 97% of total enterprises, contributed more than 40% of GDP, and used approximately 51% of the labor force (Phan *et al.*, 2015). Third, environmental pollution (due to industrial activities, urbanization, and other anthropogenic activities) becomes a severe issue in Vietnam (Pham et al. 1995; Chu, 2018). Indeed, Vietnamese government has been aware of this problem by implementing about 300 legal documents on environmental protection (Chu, 2018). Relating to firms, we can mention the Law on Environmental Protection (LEP)[3] and Circular 2781/TT-KCM. To start or continue their activities, the LEP requires firms in some specific industries (e.g., textiles, leather) to provide environmental impact assessment reports. Likewise, Circular 2781/TT-KCM obligates firms in some sectors to have a certificate for meeting environmental standards (see Ho, 2016 for more detail about the context of environmental regulations in Vietnam).

[3]This Law was established in 1993 and revised two times: in 2006 and then in 2014. The last version (consisting of 170 articles divided into 20 chapters) "provides statutory provisions on environmental protection activities; measures and resources used for environmental protection; rights, powers, duties, and obligations of regulatory bodies, agencies, organizations, households, and individuals who are tasked with the environmental protection task." (Article 1).
For more details, please refer to the following link: http://extwprlegs1.fao.org/docs/pdf/vie168513.pdf

To answer our research questions, we first apply the Generalized Methods of Moment (GMM) developed by Wooldridge (2009) to compute the firm TFP. This method allows controlling for bias problems associated with the firm unobserved productivity and improves the limits of the Olley and Pakes (1996) or Levinsohn and Petrin (2003) method. Second, we perform regressions on the TFP growth rate to investigate β-convergence. To overcome potential endogenous issues related to the firm environmental practices and/or innovation, we introduce the 'control function methods' and the 'variable addition test' proposed by Wooldridge (2015).

Using panel data of Vietnamese SMEs over 2007-2015, we find evidence of a conditional β-convergence. Factors contributing to the firm TFP growth rate, and so convergence, are mainly the firm-specific characteristics as size, legal form, and to a lesser extent, industry- and location-characteristics. Unfortunately, the firm environmental practices do not directly affect its TFP growth rate. These factors instead affect the firm innovation capacity, and the latter, in turn, contributes to the firm productivity growth rate.

The remaining of this study 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

The productivity convergence is initially used as a measurement to answer the question of "Whether poor countries or regions tend to converge toward rich ones" (Barro *et al.*, 1991). From a macro perspective, unconditional (or absolute) β-convergence reveals that the growth rate of income per capita of a country tends to exceed that of a richer one. Besides, there is a conditional convergence when some factors appear to influence the convergence speed (Young et al., 2008). For example, trade openness, FDI, and regional integration contribute to cross-country income convergence (Ben-David, 1998; Zhang, 2001) or labor productivity convergence for OECD countries (Lee, 2009).

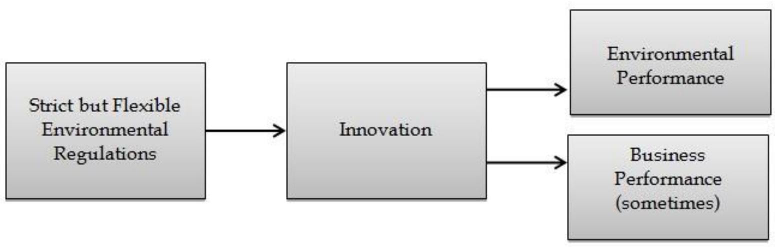
Following the seminal paper of Baumol (1986), and developed through Barro *et al.* (1991), Mankiw et *al.* (1992), and Barro and Sala-i-Martin (1995), a substantial literature on productivity convergence has been conducted but almost at the country, region, or industry level. Empirically, labor productivity convergence can be heterogeneous across different technological levels and sectors among countries (Bernard and Jones, 1996c). Besides, capital intensity can affect convergence speed, but the impacts vary across industries. Those impacts are small in the services sector and high in manufacturing (Gouyette and Perelman, 1997). The convergence speed is also different across regions as in India (Bernard and Durlauf, 1996) or the U.S. (Bernard and Jones, 1996b). Other factors affecting productivity convergence are 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).

Despite the rich literature on productivity convergence at the country and sector/provincial level, notice that research remains underdeveloped at the firm level. Some factors that may affect the firm productivity growth rate, and so the speed of convergence, are identified in several empirical studies. For instance, Nishimura (2005) found significant evidence of Japanese firms' productivity convergence. Also, the speed of convergence can be affected by corporate taxes since reducing tax may encourage firms to expand their production by increasing investment and expenditure on R&D (Gemmell et al., 2018, Fung, 2003). Besides, the speed of convergence is influenced by the firm internal characteristics such as ownership, firm age, export behavior, and geographic location (Ding et al., 2016). For Mexican firms, enhancing the firm technological capacity plays an essential role in catching up with the global frontier (Lacovone and Crepsi, 2010). Also, information technology and globalization may affect the productivity growth rate, which is healthier for the most productive firms (Chevalier et al., 2012). The spatial structure has a significant impact on the productivity convergence process. Firms in the high-technology group have higher convergence speed, which can be affected by technical capacity and spatial effects (Sanchez et al., 2009).

2.2. Environmental regulations, innovation, and productivity

Since the seminal work of Porter (1991) and Porter and Van der Linde (1995), a substantial body of literature has emerged examining the impact of environmental regulations on innovation and productivity.[4] According to the strong version of Porter hypothesis (henceforth 'strong PH'), more stringent environmental regulations may encourage firms to reduce their reliance on energy-intensive inputs and improve productivity as a way of controlling cost and maintaining their competitiveness. Besides, firms are motivated to become more environmentally conscious and creative in investing in new technology. Consequently, as firms expand on their innovation capacity, their performance is likely to be enhanced – a phenomenon known as 'weak PH' (Porter, 1991; Porter and Van der Linde, 1995; Jaffe and Palmer, 1997). The casual links between environmental regulations, the firm innovation capacity, and productivity are shown in Figure 1.

Figure 1. Casual links of PH. Source: Ambec et al. *(2013, p.4).*



Empirical evidence supporting the strong PH is reported for Japan (Hamamoto, 2006), Taiwan (Yang *et al.*, 2012), and France (Piot-Lepetit and Le Moing, 2007). However, negative or insignificant impacts of environmental stringency on the firm economic performance are found in Quebec (Lanoie *et al.*, 2008) and 17 European countries (Rubashkina *et al.*, 2015).[5] Likewise, examining the case of manufacturing firms in the Netherlands, Van Leeuwen and Mohnen (2017) found no significant evidence to support the strong PH. Also, spending more on pollution abatement may decrease the

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

[5]They are Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Hungary, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and United Kingdom.

firm efficiency in terms of both production and emissions (Shadbegian and Gray, 2006). This impact also varies across 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, empirical studies also provide controversial results. Positive impacts of stringent environmental regulations on the firm innovation capacity and/or expenditure on R&D are reported in some research. For instance, increasing R&D expenditure could be motivated by a firm to reduce spending on environmental compliance (Jaffe and Palmer, 1997 and Hamamoto, 2006) or to face stringent environmental regulations that lead to an improvement in innovation capacity (Ramanathan *et al.*, 2017; Yang *et al.*, 2012; Carrión-Flores and Innes, 2010). The firm innovation capacity, besides, can be influenced by government environmental regulations (Eiadat *et al.*, 2008) or other environmental pressures such as market pressure (Van Leeuwen and Mohnen, 2017) and managerial environmental concerns (Frondel *et al.*, 2008). However, the impact is heterogeneous over the technological level and market conditions. As for German manufacturing enterprises, environmental regulations may hinder the firm innovation capacity through 'pre-defined paths of technological solutions' (Rennings and Rammer, 2011). Such an impact is positive if firms operate in a lowly uncertain market and negative in highly uncertain markets (Blind *et al.*, 2017). Some studies also reveal a 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, the literature above shows no conclusive evidence supporting the strong or weak PH. Furthermore, most studies on this topic have been conducted for developed countries, while only a few studies examine the cases of developing ones.[6] Most importantly, they have almost investigated the strong or weak PH by relying on the reduced-form model but not the whole Porter causality chain, except Lanoie *et al.* (2011)

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[6] Some empirical studies on developing countries include China (Zhang et al., 2011; Xie et al., 2017), Mexico (Alpay et al., 2002), India (Murty et al., 2006; Murty and Kumar, 2003; Chakraborty, 2011), Rumania (Arouri et al., 2012), Spain (Ayerbe and Górriz, 2001), Brazil (Féres and Reynaud, 2012). Notably, in a Meta-analysis, Cohen and Tubb (2018) review 70 studies that mentioned the Porter hypothesis at the 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.

and Van Leeuwen and Mohnen (2017), who are the first two examining such causality. Our contribution to the existing literature is to fill this gap by reviewing both strong and weak PH, but for productivity convergence in the context of a developing country.

3. Data and methodology

3.1. Data

The data used in this research are from the bi-annual survey on Vietnamese SMEs over the period 2007-2015. Although the survey was started in 2005, the module on the environment has been only added to the questionnaire since 2007. After deleting firms with missing data, we obtain a sample of 4,530 observations on manufacturing SMEs. Table A.1 in the Appendix presents the main variables used in this research and their descriptive statistics. Table A2 displays some other statistics about the firm-specific characteristics.

Two measures of the firm environmental practices are available in the dataset. First, in response to the question 'does the firm do an environmental treatment?', firms are asked to confirm whether they have a treatment in air quality, fire, heat, noise, waste disposal, water pollution, or soil. Since observations on each category of the environmental treatment (*ET*) are few, we have chosen to group all responses into a sole category of having at least an *ET*. As reported in Table A2a, those firms cover about 27% of our sample. Second, firms are asked to confirm whether they have a 'Certification for registration of satisfaction of environmental standards' (*ESC*). About 13% of firms in the sample have such a certificate. In this research, *ESC* and *ET* are used as proxies for firm compliance with environmental regulations. Table A2a also reports a low incidence of firms having both *ESC* and *ET* (6%), while most of them have neither an *ESC* nor an *ET* (66%). 7% of our sample firms only have an *ESC*, and 21% of them only an *ET*.

Regarding the firm innovation, the questionnaire contains three questions: (i) Has the firm introduced new product groups (since the 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, 54% of the sample firms reported having no innovation, while 35% answered owning either a product or a process innovation. Only 11% of firms in the sample reported getting both types of innovation.

Tables A1 and A2 also show some other insights into the firm characteristics. They are almost micro-firm (60% of the sample) and have no or poor knowledge about environmental law (85%). Besides, most of them are household businesses (59%) and do not have export activities (93%). SMEs mainly operate in low-tech and medium-tech industries (43% and 49%, respectively). As for geographical location, a high incidence of firms is in the North (46%), followed by the South (32%), and then the Center (22%). Turning to some characteristics of the firm managers, they are almost men (69% of the sample), young (the average age is 45 with a standard deviation of 19), and have some qualifications (unskilled managers have only a low incidence of 16%).

3.2. Methodology

To investigate the impact of environmental practices and/or innovation on the firm TFP growth rate and consequently convergence speed, we separately process two estimation stages. First, we estimate TFP through the firm production function. Second, we find evidence of convergence by estimating the firm TFP growth rate.

3.2.1. The firm TFP estimation

To estimate the firm TFP, we refer to the Cobb-Douglas 'value-added' production function:[7]

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

where Y_{it} is output of firm i (i = 1,...,N) at period t (t = 1,...,T), and A_{it}, K_{it}, and L_{it} are its TFP, capital stock, and labor, respectively. Taking the logarithm of Equation (1) gives:

[7] Notice that the Cobb-Douglas production function is ubiquitously applied in theoretical and empirical works thanks to its numerous advantages. As for analyses of productivity, using a Cobb-Douglas form allows us to add different inputs and obtain the associated elasticity easily. Please refer to Felipe and Adams (2005) or Murthy (2002) for a more in-depth discussion about the advantages of using a Cobb-Douglas production function.

$$y_{it} = \ln A_{it} + \beta_k k_{it} + \beta_l l_{it} \tag{2}$$

where the lower case is the logarithm form. Notice that Equation (2) can be rewritten in econometric form as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \epsilon_{it} \tag{3}$$

where the firm's TFP is decomposed in an intercept (β_0) and an error term (ϵ_{it}).

Notice that the error term ϵ_{it} may contain an independent and identically distributed error (ε_{it}) and an unobserved productivity shock (ω_{it}). The latter is known by the firm manager but unknown by the econometrician. Failure to control such a productivity shock, using the panel fixed- or random-effects model may lead to biased results. This issue was first solved by Olley and Pakes (1996), who use investment as an appropriate instrument for inputs. However, sometimes, investment information is not available, particularly for SMEs. Levinsohn and Petrin (2003) (hereafter LP) use material cost as an intermediate input to deal with this problem. However, notice that the LP estimator suffers three limits. The first is associated with functional dependence. All variables are supposed to occur simultaneously by using the unconditional intermediate input demands. That could lead to a collinearity problem because the material would usually 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 this study, we apply the GMM estimator developed by Wooldridge (2009) to estimate the firm production function.[8] Accordingly, the firm unobserved productivity shock can be explained as a function of capital and raw materials:

$$\omega_{it} = g(k_{it}, m_{it}) \tag{4}$$

where m_{it} is the firm expenditure on raw materials (in log). Indeed, the firm profit maximization yields an optimal demand for material m_{it} as a function of capital k_{it} and unobserved productivity ω_{it}. In other words, the firm adjusts its demand for materials

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[8] Please refer to Wooldridge (2009, p. 112-113) for advantages of the GMM method over the two-step approaches used by Olley and Packes (1996) and LP (2003).

after stating its capital and its observed productivsity ω_{it}. Given the demand function for materials, unobserved productivity ω_{it} can be expressed as an inverted function of k_{it} and m_{it} as in Equation (4). Using such a control function can control the firm unobserved productivity and avoid potentially biased results.

Otherwise, one needs three assumptions to identify β_k and β_l. The first assumption relates to the error terms ε_{it}. They are assumed to be conditional mean independent of current and past inputs:

$$E(\varepsilon_{it}|k_{it}, l_{it}, m_{it}, k_{i,t-1}, l_{i,t-1}, m_{i,t-1}, \dots, k_{i1}, l_{i1}, m_{i1}) = 0, \quad t = 1, \dots, T \qquad (5)$$

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

$$E\left(\omega_{it}\middle|k_{it},, k_{i,t-1}, l_{i,t-1}, m_{i,t-1}, \dots, k_{i1}, l_{i1}, m_{i1}\right) = E\left(\omega_{it}\middle|\omega_{i,t-1}\right)$$

$$\equiv f\left[g\left(k_{i,t-1}, m_{i,t-1}\right)\right], t = 2, \dots, T \ (6)$$

together with an assumption that the capital stock k_{it} is uncorrelated with the random innovation: $a_{it} = \omega_{it} - E(\omega_{it}|\omega_{i,t-1})$

Replacing ω_{it} by $\left[g\left(k_{i,t-1}, m_{i,t-1}\right)\right] + a_{it}$, Equation (3) can be rewritten as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f\left[g\left(k_{i,t-1}, m_{i,t-1}\right)\right] + a_{it} + \varepsilon_{it} \qquad (7)$$

Notice that l_{it} is allowed to be correlated with a_{it} but the latter is assumed to be uncorrelated with k_{it}, past outcomes on (k_{it}, l_{it}, m_{it}), and all functions of theses (cf. Equation 6).

We can now specify two equations identifying β_k and β_l:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + g(k_{it}, m_{it}) + \varepsilon_{it}, \quad t = 1, \dots, T \qquad (8)$$

and $y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f\left[g\left(k_{i,t-1}, m_{i,t-1}\right)\right] + u_{it}, t = 2, \dots, T \qquad (9)$

where $u_{it} = \varepsilon_{it} + a_{it}$.

The orthogonality condition on the errors for Equation (8) is given by Equation (5), while that for Equation (9) is:

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

Finally, to estimate β_k and β_l parametrically, unknown functions $g(.,.)$ and $f(.)$ should be identified. Wooldridge assumes that $f(.)$ can be approximated by a polynomial in ω:

$$f(\omega) = \rho_0 + \rho_1\omega + \dots + \rho_G\omega^G$$

and $g(k_{it}, m_{it}) = \gamma_0 + c(k_{it}, m_{it})\gamma$ from where we obtain:

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + c_{it}\gamma + \varepsilon_{it}, \quad t = 1, \dots, T \tag{10}$$

and $y_{it} = \eta_0 + \beta_k k_{it} + \beta_l l_{it} + \rho_1(c_{i,t-1}\gamma) + \dots + \rho_G(c_{i,t-1}\gamma)^G + u_{it}, t = 2, \dots, T$ (11)

where α_0 and η_0 are the new intercepts, and $c_{it} \equiv c(k_{it}, m_{it})$.

The GMM can now be performed to estimate Equations (10)-(11). IVs for Equation (10) are:

$$z_{it1} \equiv (1, l_{it}, k_{it}, c_{it}^0)$$

where c_{it}^0 is c_{it} without k_{it} while those for Equation (11) are defined as:

$$z_{it2} \equiv (1, k_{it}, l_{i,t-1}, c_{i,t-1}, q_{i,t-1})$$

where $q_{i,t-1}$ is a set of nonlinear functions of $c_{i,t-1}$, probably consisting of low-order polynomials.[9]

Once β_k and β_l are estimated, the firm TFP (in log) is computed as:

$$\phi_{it} = y_{it} - \beta_k k_{it} - \beta_l l_{it} \tag{12}$$

[9] Please refer to Wooldridge (2009) for a detail discussion about IVs for Equations (10)-(11).

3.2.2. Estimation strategy for β-convergence

Environmental practices and *β*-convergence

To assess how the firm environmental practices affect its TFP growth rate, let us start with estimating the following regression:

$$\frac{\phi_{it+k}}{\phi_{it}} = \alpha + \beta_1\phi_{it} + \vartheta H_{it} + \gamma X_{it} + \mu_i + d_t + \varepsilon_{it} \qquad (13a)$$

In Equation (13a), the dependent variable refers to the firm TFP growth rate, and ϕ is the log of its TFP obtained in Equation (12). H is a vector of covariates capturing environmental practices (*ET* and *ESC*); X, a vector of time-variant control variables; μ, the firm fixed-effects (FE); d, the year-effects; and ε, the error terms.

Notice that Equation (13a) can be estimated by using the FE estimator that allows us to control both observed and unobserved time-invariant characteristics of the firm. However, in terms of policy recommendation, it is vital to investigate the impacts of some observed time-invariant specific characteristics (as size, location, etc.) on the firm TFP growth rate. To this end, the firm fixed-effects, μ, are replaced by its observed time-invariant specific characteristics. Equation (13a) is rewritten as:

$$\frac{\phi_{it+k}}{\phi_{it}} = \alpha + \beta_1\phi_{it} + \vartheta H_{it} + \gamma X_{it} + \theta Z_i + d_t + \varepsilon_{it} \qquad (13b)$$

where Z is a vector of sectoral/local or firm time-invariant variables as firm size, industry dummy, provincial dummy, etc. We can run an OLS to estimate Equation (13a).

It is noteworthy that estimating Equations (13a) and (13b) could be biased because of the potential endogeneity of *ESC* and *ET* as they can be affected by unobserved factors. Indeed, many factors can be the source of such endogeneity as, for example, (i) firms are motivated to become more environmentally friendly to satisfy clients, which become more sensitive to environmental issues, or (ii) they are forced to do that because of national/local authority obligations.

We refer to control function methods in a two-step estimation developed by Wooldridge (2015) to tackle the above potential endogeneity.[10] Since there are two possible endogenous variables, we need to find two excluded IV candidates. Although it is not easy to find relevant instruments, *ESC* and *ET* are instrumented here with the firm knowledge about the environmental law (*KEL*) and the average share of pollution abatement cost at the industry level (PACE intensity). The first is a categorical variable (*0* if no knowledge, *1* if poor knowledge, and *2* if good or average knowledge), while the second is proposed by Rubaskina et *al*. (2015).[11] According to the authors, there should be a strong correlation between environmental policies applied to various sectors. PACE intensity (*InPace*) would be strongly correlated with the firm *ESC* and *ET*, while this variable should not directly affect the firm TFP growth rate. The same argument can also be used for *KEL*. Firms in industries concerned with environmental policies should have a better *KEL* than the others. Consequently, they are more sensible either to obtain *ESC* or practice *ET*. Otherwise, *KEL* should not directly influence the firm TFP growth rate.

The estimation procedure is as follows:

(i) In the first step, we perform a bivariate probit model of *ET* and *ESC* on excluded IVs and all other covariates.

$$P(ET_{it}, ESC_{it} = 1 | InPace_{it}, KEL_{it}, \omega_{it}, X_{it}, Z_{it}, d_t) \quad (13.1)$$

We refer to the bivariate probit estimator because it allows us to control potential correlations between the two environmental variables.

[10] It is a two-step estimation in which, in the first step, we run an estimation of potential endogenous variables and then compute generalized residuals. In the second step, we introduce these generalized residuals in estimating the dependent variable, together with the potential endogenous variables and other control variables. Finally, we perform a test of the significance of generalized residuals. This test is called a joint-test with the null hypothesis that the potential endogenous variables are exogenous.

[11] Pace Intensity is defined as $InPace_i = \frac{Pace_i}{\sum_{j,j\neq i} VA_j}$ where $Pace_i$ is the total Pollution Abatement expenditure of industry *i* and *VA* is the value-added of industry *j*.

(ii) We compute the associated generalized residuals (e.g. $\hat{\varepsilon}_{it}^{et}$ and $\hat{\varepsilon}_{it}^{esc}$)[12] and then introduce them to the estimation of TFP growth rate (the second step). Equation (13a) can be rewritten as:

$$\frac{\phi_{it+k}}{\phi_{it}} = \alpha + \beta_1\phi_{it} + \vartheta H_{it} + \gamma X_{it} + \tau^{et}\hat{\varepsilon}_{it}^{et} + \tau^{esc}\hat{\varepsilon}_{it}^{esc} + \mu_i + d_t + \varepsilon_{it} \quad (13.2a)$$

and Equation (13b):

$$\frac{\phi_{it+k}}{\phi_{it}} = \alpha + \beta_1\phi_{it} + \vartheta H_{it} + \gamma X_{it} + \theta Z_{it} + \tau^{et}\hat{\varepsilon}_{it}^{et} + \tau^{esc}\hat{\varepsilon}_{it}^{esc} + \mu_i + d_t + \varepsilon_{it} \quad (13.2b)$$

Equation (13.2a) is estimated by a FE estimator, and Equation (13.2b) by an OLS estimator.

(iii) Finally, we perform a test of joint significance of the two generalized residuals ($\hat{\varepsilon}_{it}^{et}, \hat{\varepsilon}_{it}^{esc}$). As Wooldridge (2015) argued, the joint-test is a test of the null hypothesis that *ESC* and *ET* are exogenous.

Environmental practices, innovation, and *β*-convergence

It is possible that environmental practices do not directly affect the firm TFP growth rate but indirectly through *Innovation* (*Innov*). To assess the ecological practices' indirect impact, we perform a two-step estimation *à la Wooldridge* (2015). Our estimation strategy is as follows:

(i) In the first stage, *Innovation* is instrumented with environmental variables (*ESC* and *ET*) in an ordered probit model:

$$Innov_{\mathrm{it}} = \alpha^{innov} + \beta_1^{innov}\phi_{it} + \vartheta^{innov}H_{it} + \gamma_1^{innov}X_{it} + \theta_1 Z_i + d_t + u_{it} \quad (14)$$

(ii) In the second step, we run a FE estimator of TFP growth rate on *Innovation*, the computed generalized residuals $\hat{u}_{it}$[13], and other covariates:

[12] See Wooldridge (2015, p. 428) for the formula to compute the "generalized residuals".

[13] For the brevity purpose, formula to compute $\hat{u}_{it}$ is not reported here. It is available upon request.

$$\frac{\phi_{it+k}}{\phi_{it}} = \alpha+\beta_1\phi_{it} + \delta Innov_{it} + \gamma_2 X_{it} + \tau^{innov}\hat{u}_{it} + \mu_i + d_t + \varepsilon_{it} \qquad (15)$$

(iii) Last, we exert the test: $\tau^{innov} = 0$. The null hypothesis of the test implies the exogeneity of *Innovation*. Given our intuition that environmental variables affect *Innovation* and the latter, in turn, impact TFP growth rate, *Innovation* should be endogenous. That is equivalent to a reject of the test: $\tau^{innov} = 0$.

Speed of convergence and half-life time

Once Equations (13a-b), (13.2a-b), or (15) are estimated, the sign of the estimated coefficient β_1 allows us to confirm the existence of a β-convergence. If the sign is positive, there is a β-divergence. By contrast, a negative sign confirms a β-convergence, and the associated speed of convergence can be computed as:

$$\beta = \frac{-\ln\left(1+\frac{\beta_1}{k}\right)}{T}$$

where T is the length of the period. 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, the half-line time is the needed time for TFP to be halfway between the initial and the steady-state value.

Standard errors in a two-step estimation

As mentioned in several works, using two-step estimation always raises a problem of computing standard errors in the second step (see, for example, Murphy and Topel, 2002; Karaca-Mandic and Train, 2003; Wooldridge, 2015, among others). To tackle this issue, Murphy and Topel (2002) propose an asymptotic covariance for two-step estimation with maximum likelihood and OLS, when both stages use the same number of observations. Differently, Karaca-Mandic and Train (2003) argue that standard errors can be corrected with nested samples when the two stages use different observations. For both methods, an asymptotic covariance of the second step should be computed. More simply, Wooldridge states that those standard errors can be adjusted by bootstrapping methods.

The latter can be beneficial if "analytical methods are not readily available" (Wooldridge, 2015, p. 428). LP also suggest using this method to get correct standard errors in a two-step estimation of the firm production function.

Following Wooldridge, the second step estimation standard errors in this study are obtained by 1,000 bootstrap replications.

4. Empirical Findings

4.1. Environmental practices and TFP convergence

The present section investigates the impact of environmental practices (*ET* and *ESC*) on the firm TFP growth rate, and so does its TFP convergence. If *ET* and *ESC* are not endogenous, we perform an estimation with exogenous covariates and report the results in Table 1, columns 1-5.

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

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Dependent variable	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP
Estimator	FE	OLS	OLS	OLS	OLS	OLS	FE
lntfp	-1.172***	-0.469***	-0.471***	-0.490***	-0.607***	-0.608***	-1.174***
	(0.022)	(0.016)	(0.016)	(0.016)	(0.018)	(0.017)	(0.023)
Environmental practices							
ESC	-0.017			0.146***	-0.030	-0.029	-0.044
	(0.059)			(0.030)	(0.031)	(0.049)	(0.068)
ET	0.006			0.129***	0.070*	-0.026	-0.107
	(0.032)			(0.028)	(0.029)	(0.103)	(0.104)
Owner/Manager characteristics							
Age	0.000				-0.005***	-0.005***	-0.001
	(0.002)				(0.001)	(0.001)	(0.002)
Gender					0.030	0.026	
					(0.021)	(0.021)	
Education level (reference: Unskilled)							
Elementary worker					-0.008	-0.016	
					(0.034)	(0.036)	
Technical worker without certificate					0.022	0.014	
					(0.034)	(0.035)	
Technical worker with certificate					0.070*	0.060	
					(0.035)	(0.038)	
College/University/Post-graduate					0.001	-0.003	
					(0.040)	(0.041)	
Other firm characteristics							
Household business					-0.212***	-0.226***	
					(0.025)	(0.030)	

Investment (in log)	0.013				0.083	0.086	0.013
	(0.074)				(0.055)	(0.056)	(0.079)
Firm size (*reference: micro-firm*)							
Small firm					0.154***	0.160***	
					(0.024)	(0.024)	
Medium firm					0.270***	0.291***	
					(0.044)	(0.053)	
Industrial and Location characteristics							
Capital intensity	0.001				0.000	0.000	0.000
	(0.000)				(0.000)	(0.000)	(0.000)
Sector dummy (*reference: Low-tech industry*)							
Medium-tech industry					0.095***	0.102***	
					(0.021)	(0.022)	
High-tech industry					0.114**	0.126**	
					(0.040)	(0.042)	
Region (reference: North)							
Center					-0.053*	-0.054*	
					(0.022)	(0.023)	
South					0.072***	0.074***	
					(0.022)	(0.022)	
Cluster					-0.008	0.001	
					(0.042)	(0.042)	
$\hat{\varepsilon}_{it}^{esc}$						0.001	0.013
						(0.013)	(0.012)
$\hat{\varepsilon}_{it}^{et}$						0.049	0.060
						(0.048)	(0.049)
Constant	2.436***	1.080***	1.044***	1.069***	1.454***	1.494***	2.495***
	(0.099)	(0.036)	(0.036)	(0.036)	(0.071)	(0.083)	(0.113)
Year effects	Yes	No	Yes	Yes	Yes	Yes	Yes
Firm fixed-effects	Yes	No	No	No	No	No	Yes
Observations	4,530	4,530	4,530	4,530	4,530	4,530	4,530
R-squared	0.583	0.235	0.239	0.248	0.307	0.307	0.584
Number of id	1,930						1,930
β-convergence (%)	11,07	3,34	3,36	3,51	4,65	4,65	11,07
Half-life time (years)	6,26	20,75	20,65	19,73	14,91	14,91	6,26

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1. The standard errors are based on 1,000 bootstrap replications.

Let us start with Equation (13a) estimation and represent the results in Model 1 of Table 1. We reveal a significant and negative estimated coefficient associated with TFP, indicating a productivity convergence for the SMEs during 2007-2015. The convergence speed is 10.8%, and the associated half-life time is 6.4 years. Model 1 also reports that control variables almost appear statistically insignificant (even at the 10% level), including environmental variables (*ET* and *ESC*). Hence, the firm environmental practices should not impact its TFP growth rate and, consequently, the associated speed of convergence.

Notice that the firm unobserved characteristics may be strong and cancel other firm- and industry-specific characteristics. However, it is essential to examine how firm characteristics and location affect the TFP convergence for policy implications. To this end, we refer to Equation (13b).[14]

In Model 2 of Table 1, we examine the existence of an absolute convergence in which the only *lnTFP* is considered in the regression. The estimation shows a negative and significant estimated coefficient. Hence, there is an unconditional convergence in TFP, and the associated speed is 3.34%, implying a half-life time of 20.86 years. It is noteworthy that a large share of TFP might be driven by technical change. To account for this effect, we include time effects as a proxy in the regression (Model 3). However, no technical change likely appears for SMEs during the studied period because Model 3 displays a convergence speed of 3.36%, an incidence similar to that of an unconditional convergence.

In Model 4, the firm environmental variables are added into the regression, together with *lnTFP* and time effects. Both *ESC* and *ET* appear to be statistically significant, even at the 0.1% level. However, compared to Model 3, the change in the parameter associated with *lnTFP* is relatively small (-0.49 in Model 4 versus -0.47 in Model 3). Consequently, the speed of convergence reported in Model 4 is slightly higher than that shown in Model 3 (cf. 3.51% versus 3.36%).

In Model 5 (the full specification), other firm- and industrial/provincial-specific characteristics are considered. Important insights emerge. First, the speed of convergence is 4.5%, i.e., about 1% higher than that reported in Model 4. It follows that firm-specific characteristics should contribute to its TFP growth rate, and so its TFP convergence. Among them, we might mention the role of the firm size and its legal form. Indeed, the greater the firm size, the higher the convergence speed. As for the firm legal form, the household business should have a lower TFP speed of convergence than other firms. Besides, the firm manager's age matters: firms whose manager is young seem to have a higher convergence speed. Second, industrial/provincial variables also contribute to the

[14] Besides, OLS estimator is relevant compared to the random-effects model for our sample because the LM (Lagrange multiplier) is not significant. The estimation results for random effects and the LM test are available upon request.

firm TFP growth rate. Firms in medium- and high-tech industries would have a higher TFP growth rate than their counterparts in low-tech industries. Besides, compared to firms in the Nord region, those in the South should have a higher TFP growth rate while those in the Center should have a lower TFP growth rate, *ceteris paribus*. Third, *ESC* is no longer significant, while *ET* is only significant at the 5% level. Moreover, the estimated parameter of *ET* declines to 0.07 compared to 0.13 in Model 4. Fourth, the model explanation power (R^2) is also improved. It increases from 25% (Model 4) to 31% (Model 5).

As mentioned in the methodology section, the two environmental variables *ET* and *ESC* can be potentially endogenous. Dealing with this issue, we perform a two-step estimation of Equations (13.1-13.2a,b). The second step estimated results are reported in Columns 6 (OLS estimator) and 7 (FE estimator) of Table 1.[15] Estimated results show that neither $\hat{\varepsilon}_{it}^{esc}$ nor $\hat{\varepsilon}_{it}^{et}$ are statstically significant. Besides, the joint significance tests (of the null hypothesis that *ESC* and *ET* are exogenous) are not statistically significant.[16] Therefore, we cannot reject the null hypothesis that *ESC* and *ET* are exogenous, and the interpretations for Models1-5 in Table 1 remain relevant.

Notice that we can handle the potential endogeneity of two environmental variables by applying the estimation technique proposed by Windmeijer and Silva (1997). The estimation procedure is as follows:

- (i) Estimate the bivariate model of *ESC* and *ET* as shown in Equation (13.1) to get the fitted probabilities ($\widehat{\Phi}$), and then
- (ii) Run a two-stage least squares estimation where at the first stage $\widehat{\Phi}$ is used as the IVs for the potential endogenous variables.

The tests of endogeneity show a χ^2 of 0.145 and F of 0.072, which are not statistically significant even at the 10% level.[17] Thus, similar to what we obtain by using

[15] Please refer to Table A3 in Appendix for the first step estimation (cf. Equation 13.1). Notice, as expected, that the two instrumental variables, KEL and PACE intensity, are found to be correlated with ESC and ET.

[16] The associated statistic which follows a $\chi^2(2)$ distribution is 0.26 in Model 6 and 2.38 in Model 7 conducting to a p-value of 0.878 and 0.305, respectively.

[17] For the brevity purpose, we do not report the detail estimation results here. They are still available upon request.

the control function approach, we cannot reject the null hypothesis of the exogeneitiy of *ESC* and *ET*.

In summary, the estimated results reported in Table 1 indicate a conditional convergence in terms of TFP for Vietnamese manufacturing SMEs over the period 2007-2015. Factors contributing to the firm TFP growth rate are firm specific-characteristics as size, legal form, age of manager, and to a lesser extent, industry- and location-characteristics. The firm environmental practices appear to have no significant impact on its TFP growth rate.

The negligible impact of *ET* raises a question about the associated expenditure, namely PACE (Pollution Abatement and Control Expenditures). In our sample, the average value of PACE is about 2 million VND (equivalent to 100 U.S. dollars). This expenditure is not sufficiently high to significantly impact the firm TFP growth rate. On the other hand, the insignificant effect of *ESC* could be related to the firm motivation to obtain such a certification. Indeed, 64% of the sample-firms reported that they got *ESC* because local authorities required it. In comparison, only less than 10% cited a reduction in the long-run production cost or the environment protection as the main reason for spending on *ESC*. Since the motivation mainly comes from an obligation imposed by local authorities rather than from the firm strategic behavior, it is not surprising that *ESC* does not significantly impact the firm TFP growth rate.

The above findings on environmental variables are in line with empirical studies that do not support the strong PH. For example, Rubashkina *et al.* (2015) find a non-significant impact of environmental regulations on sectoral TFP growth of 17 European countries. Likewise, Van Leeuwen and Mohnen (2017) find no evidence to support that impact in the Netherlands.

4.2. The nexus between environmental practices, innovation, and TFP growth rate

Since the firm environmental practices only have negligent impacts on its TFP growth rate, the impact may be indirect through *Innovation*. To answer this question, we perform a two-stage estimation (cf. estimation of Equations 14 and 15) and report the results in Table 2. Recall that we run an ordered probit of *Innovation* in the first step of estimation on the two instrumented variables, *ESC* and *ET*, together with other covariates (cf. Equation 14). We compute, then, the generalized residuals of this estimation and introduce them into the second estimation of the control function (cf. Equation 15). Last, we test: $\tau^{innov} = 0$.

Table 2. The nexus between Environmental practices, Innovation, and TFP convergence

	First step				Second Step
Dependent variable	Innovation				dlnTFP
Estimator	Order probit				
	Estimation	Marginal effects			FE
	(1)	(2)	(3)	(4)	(5)
lntfp	0.202***	-0.072***	0.038***	0.034***	-1.196***
	(0.029)	(0.010)	(0.005)	(0.005)	(0.027)
Innovation (reference: No innovation)					
Product or Process Innovation					0.262*
					(0.122)
Both Innovation					0.372+
					(0.223)
τ^{innov}					-0.147+
					(0.087)
Environmental practices					
ESC	-0.060	0.021	-0.011	-0.010	
	(0.062)	(0.021)	(0.011)	(0.010)	
ET	0.126*	-0.045*	0.024*	0.021*	
	(0.058)	(0.020)	(0.011)	(0.010)	
Owner/Manager characteristics					
Age	-0.004*	0.002*	-0.001*	-0.001*	0.000
	(0.002)	(0.001)	(0.000)	(0.000)	(0.002)
Gender	0.042	-0.015	0.008	0.007	
	(0.040)	(0.014)	(0.008)	(0.007)	
Education level (reference: Unskilled)					
Elementary worker	0.234***	-0.083***	0.045***	0.038***	
	(0.063)	(0.023)	(0.013)	(0.011)	
Technical worker without certificate	0.236***	-0.084***	0.045***	0.038***	
	(0.059)	(0.021)	(0.012)	(0.009)	
Technical worker with certificate	0.221***	-0.078***	0.043***	0.035***	
	(0.067)	(0.023)	(0.013)	(0.011)	
College/University/Post-graduate	0.085	-0.030	0.017	0.013	
	(0.074)	(0.026)	(0.015)	(0.011)	
Firm characteristics					
Household business	-0.225***	0.080***	-0.042***	-0.038***	
	(0.050)	(0.018)	(0.009)	(0.009)	
Investment (in log)	-0.073	0.026	-0.014	-0.012	
	(0.104)	(0.034)	(0.018)	(0.016)	

Firm size (reference: micro-firm)					
Small firm	0.224***	-0.082***	0.044***	0.038***	
	(0.047)	(0.018)	(0.009)	(0.008)	
Medium firm	0.504***	-0.183***	0.084***	0.099***	
	(0.085)	(0.029)	(0.011)	(0.019)	
Industrial and Location characteristics					
Capital intensity	-0.002*	0.001*	-0.000*	-0.000*	0.001+
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Sector dummy (*reference: Low-tech industry*)					
Medium-tech industry	0.016	-0.006	0.003	0.003	
	(0.041)	(0.015)	(0.008)	(0.007)	
High-tech industry	0.033	-0.012	0.006	0.006	
	(0.083)	(0.027)	(0.014)	(0.013)	
Region (reference: North)					
Center	-0.019	0.007	-0.003	-0.003	
	(0.046)	(0.017)	(0.008)	(0.008)	
South	-0.136**	0.048**	-0.026**	-0.023**	
	(0.043)	(0.015)	(0.008)	(0.007)	
Cluster	0.099	-0.035	0.019	0.017	
	(0.079)	(0.027)	(0.014)	(0.013)	
Year effects	Yes				Yes
Observations	4,530				4,530
Number of id					1930
β-convergence (%)					11.4
Half-life time (years)					6.08

The standard errors in the second step of estimation are based on 1,000 bootstrap replications.
Significant levels: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Starting with the first step of estimation, column 1 of Table 2 represents the estimated results of Equation (14), and columns 2-4 show the associated marginal effects for the three categories of Innovation (‘No innovation’, ‘Process or Product innovation’, and ‘Both innovations’). *ET* appears to be positively correlated with Innovation. Having an *ET* decreases the probability of having ‘No innovation’ by 4.5% and increases the probability of getting ‘Process or Product innovation’ by 2.4% and ‘Both innovations’ by 2.1%. These findings are thus consistent with the positive impact of *ET* on Innovation displayed in Column 1 of Table 2. By contrast, *ESC* is statistically insignificant.

The positive correlation between *ET* and *Innovation* in this research is consistent with other studies supporting the weak PH. For example, the presence of environmental regulation increases the likelihood of undertaking both resource-saving and pollution-reducing eco-innovations (Van Leeuwen and Mohnen, 2017). Likewise, ecological constraints might stimulate firms to invest in new technology (Hamamoto, 2006) or increase their expenditure on R&D and pollution abatement (Yang *et al.*, 2012).

Besides, Table 2 shows that the firm's innovation capacity is somewhat related to its characteristics rather than geographical location or industry-characteristics. As for firm characteristics, household business seems to less engage in innovation. Having this legal form increases the probability of having '*No Innovation*' by 8% and reduces the likelihood of having innovation, either process or product or both, by 4%. Besides, the firm innovation probability is also related to its size: the higher it is the more innovation. For example, compared to a micro-firm, the chance of a medium-firm having innovation is about 10% higher, and a small firm, 8.4% higher. Regarding industry and location characteristics, only the firm geographical location matters. While there is no significant difference between the North and the Center, firms in the South appear to be less innovative than those located in the North.

As for the second step, the estimated results are reported in column 5 of Table 2. Notice that the computed robust t-statistics of the variable addition test for exogeneity is statistically significant at a 10% level. We can reject, at a 10% risk level, the null hypothesis that $\tau^{innov} = 0$. *Innovation* is, as expected, endogenous in our sample. Most importantly, this variable positively impacts the firm TFP growth rate. Compared to firms without innovation, the growth rate of those with 'Process or Product innovation' is about 0.3% higher, while the incidence is about 4% higher for those with 'Both innovation'. As a result, the convergence speed with innovation is about 11.4%. Notice that this rate is slightly higher than that without innovation of 11%.

As a robustness test, we perform the Windmeijer and Silva (1997) method to take the endogeneity of *Innovation* into account. The estimation procedure is as follows:

- (i) Estimate the ordered probit model of *Innovation* as shown in Equation (14) to get the fitted probabilities ($\widehat{\Phi}$), and then
- (ii) Run two-stage least squares estimation where at the first stage $\widehat{\Phi}$ is used as the excluded instrumental variables for *Innovation*.

We obtain similar findings as those of using the control function approach. More precisely, the estimation show that *Innovation* is likely to be endogenous (the statistic value $\chi^2$of 6.38, which is statistically significant at the 10% risk level and F of 3.27, which is statistically significant at the 5% risk level). Besides, *Innovation* is positively correlated with the firm TFP growth rate.[18]

4.3. Robustness verification

4.3.1. Does the measurement of the firm TFP matter?

Our analysis in Section 4.1 and 4.2 uses the firm TFP obtained by applying the Wooldridge GMM method to estimate the firm production function. We now investigate how the results change when performing another estimation method. For this purpose, the LP method is applied to estimate the firm production function and compute its TFP.

The estimation shows similar results regarding either the relationship between firm performance and environmental practices or the nexus between firm performance, innovation, and ecological practices.[19] As for the relationship between firm performance and environmental compliance, the latter is exogenous and has a marginal effect on its TFP growth rate. Besides, the associated speed of convergence appears to be the same as that obtained using the Wooldridge method. More precisely, the unconditional speed of convergence is 3.1%, while when environmental variables are added, that speed increases to 3.3%. The model with environmental variables and firm characteristics gives a speed of 4.4%, whereas the full specification provides a rate of convergence of 4.6%.

Turning to the nexus between TFP convergence, innovation, and environmental practices, only *ET* is significantly and positively correlated with *Innovation,* and in turn, *Innovation* has a positive impact on the firm TFP growth rate. We find a convergence speed of 11.2%, which is approximately equal to that obtained in Section 4.2.

[18] The estimated results are available upon request.

[19]The estimation results are available upon request.

4.3.2. Is the speed of convergence different across the TFP growth rate distribution?

Notice that the above regressions are estimated at the mean, whereas the convergence speed might differ at different productivity growth distribution rates. To this end, we perform quantile regressions.

If we are interested in the role of firm-specific effects, the regression at different quantile can be written as:

$$q_{\varrho}\left(\frac{\phi_{it+k}}{\phi_{it}}\right) = \alpha_{it}(\varrho) + \beta_1(\varrho)\phi_{it} + \vartheta(\varrho)H_{it} + \gamma(\varrho)X_{it} + +\theta(\varrho)Z_{it} + \varepsilon_{it} \quad (16)$$

where $q_{\varrho}\left(\frac{\phi_{it+k}}{\phi_{it}}\right)$ is the ϱ^{th} conditional quantile of the dependent variable (i.e. $\frac{\phi_{it+k}}{\phi_{it}}$), $\varrho \in (0{,}1)$. The estimated value of $\beta_1(\varrho)$ allows us to compute the speed of convergence at quantile ϱ^{th}.

The estimation results of Equation (16) are reported in Table A4 in the Appendix. For a comparison purpose, Column (1) of Table A4 provides the full specification estimation results at the mean (cf. Model 6 of Table 1) while Columns (2)-(6) respectively show the estimation results at the 10th, 25th, 50th, 75th, and 90th quantile of the TFP growth rate distribution. We only state a divergence associated with the impact of environmental variables along with the TFP growth rate distribution. *ESC* is significant at the 90th quantile (Column 6) and becomes no longer significant at other quantiles. By contrast, *ET* is statistically significant at the 10th quantile (Column 2) and turns out to be insignificant for the rest of the TFP growth rate distribution. Other covariates impact remains similar to those obtained at the mean estimation. Overall, Table A5 shows a negligent difference in speed of convergence. The latter only varies between 4.5% and 4.8%. Those incidences are nearly equal to the general convergence speed of 4.6% displayed in Column 1. It seems that Vietnamese manufacturing firms have the same speed of convergence, regardless of their position in the TFP growth rate distribution.

When the firm time-invariant unobserved characteristics are considered, we use the fixed-effects quantile regression[20] and represent the estimation results in Table A5 in the Appendix. Column (1) of the table shows the estimation results at the mean (cf. Model 1 of Table 1) while Columns (2)-(6) respectively show the estimation results at the 10th, 25th, 50th, 75th, and 90th quantile of the TFP growth rate distribution. Notice that convergence speed is similar from Columns (1)-(6), implying that such convergence does not depend on the firm position at the TFP growth rate distribution.

4.3.3. Are there other kinds of TFP convergence for Vietnamese SMEs

Notice that over the β-convergence, the literature also shows other types of convergence as σ-convergence or club-convergence. It is interesting to verify whether those convergences exist for Vietnamese SMEs.

According to Sala-i-Martin (1996), a σ-convergence exists when the cross-sectional variance decreases overtime and toward its steady state. Analyzing the existence of σ-convergence can provide some important insights since it allows us to verify whether the 'inequality' in terms of TFP between firms decreases overtime. To this end, we need to compute the cross-sectional variance of TFP (in log) at a given time as:

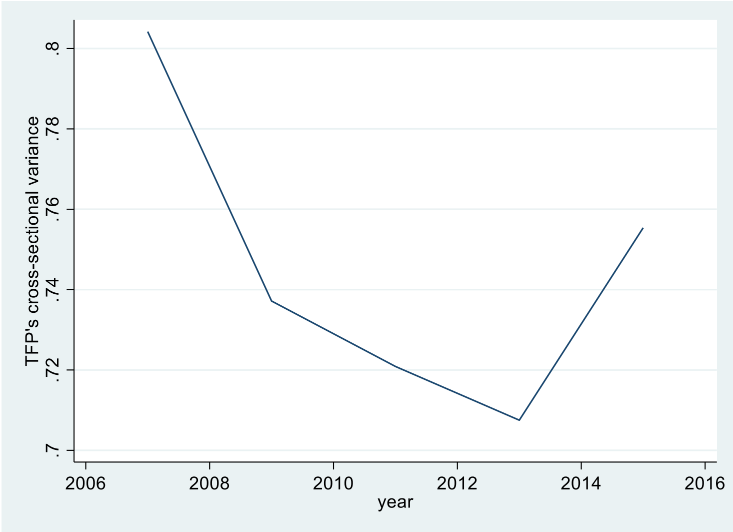
$$\sigma_t^2 = \frac{1}{N_t}\sum(\phi_{it} - \bar{\phi}_t)^2 \qquad (17)$$

where $\bar{\phi}_t = \frac{1}{N_t}\sum \phi_t$ and N is the number of observations.

If σ_t^2 in Equation (17) decreases over time, then there is a σ-convergence. In our sample, as it can be seen in Figure 1 below, it is not likely the case because the firm TFP cross-sectional variance does not decrease over time. Indeed, it decreased between 2007 and 2013 before re-augmenting in 2015. Notice that we should keep in mind such a result because to confirm the existence of a σ-convergence or divergence, we need to study the evolution of σ_t^2 in a long-time period, while the data used in this study only contain a short-term period between 2007 and 2015.

[20] We perform the quantile fixed-effects estimation proposed by Machado and Silva (2019).

Figure 1: Evolution of TFP's cross-sectional variance



Scholars also focus on a club-convergence because there is strong empirical evidence against global convergence at the macroeconomic level. A club-convergence occurs when there is a convergence for sub-samples but not for the entire sample (global convergence). In our study, there is a global TFP convergence. Besides, our above analysis on convergence across the TFP growth rate distribution is likely to support the presence of a club-convergence.[21] To have a more in-depth view, we provide two other club convergence analyses.

First, we study the TFP convergence by sub-sectors. More precisely, we group firms by three sub-samples: Low, Medium, and High-tech industries. We find evidence of club-convergence: firms in High-tech sectors have the highest TFP convergence speed, followed by those in Low-tech and those in Medium-tech industries.[22] However, the firm environmental practices are not likely to contribute to its TFP growth rate because neither *ESC* nor *ET* is statistically significant regardless of the considered industries.

[21] Miller and Upadhyay (2002) also use this method and find a club convergence. Indeed, while grouping countries by income quartiles, the authors find evidence of a TFP convergence for the highest and lowest income quartiles, but not for those in intermediate income quartiles.

[22] The TFP convergence speed for firms in High-tech, Low-tech, and Medium-tech industries is 12.3%, 11.3%, and 11%, respectively. The estimated results are available upon request.

Second, we construct different firm-groups by their environmental practices. There is also strong evidence of club-convergence. Indeed, the estimation shows that for the sub-sample of firms adopting at least one ecological practice, either *ESC* or *ET*, the convergence speed is about 12.7%. By contrast, for those without environmental practices, the convergence speed is only 11.5%. Particularly, firms having both *ESC* and *ET* experience a very high convergence speed of 19.2%.[23]

4.3.4. Is there another way that the firm environmental practices influence its productivity?

There might be another possibility to study the impacts of environmental standards on productivity convergence. Indeed, we can incorporate the firm investment to reach environmental standards into its production process. Namely, we follow the structural modeling of the firm production function developed by Malikov and Zhao (2019) and Malikov et al. (2020).[24] At the beginning of each period, the firm decides whether it hires new employees, invests in physical capital, or invests in environmental abatement/innovation to reach environmental standards requested by the authorities or the market. The firm, then, adapts its expenditure on freely varying inputs (materials). Consequently, the firm demand for freely varying inputs (m_{it}) depends not only on its observed productivity (ω_{it}) and state inputs (k_{it}, l_{it}), but also on its investment in environmental abatement/innovation (denoted by θ_{it}).[25]

The firm observed productivity (ω_{it}) given in Equation (4) is now became:

$$\omega_{it} = f(h(k_{it}, l_{it}, m_{it}), \theta_t) \equiv g(k_{it}, l_{it}, \theta_{it}, m_{it}) \tag{18}$$

Hence, the assumption on the error terms ε_{it} is rewritten as:

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[23] The estimated results are available upon request.

[24] In this framework, labor is considered as a quasi-fixed factor.

[25] In such a framework, the firm's dynamic optimization, expressed under the Bellman equation, is given as:

$$V_t(k_{it}, l_{it}, \theta_{it}, \omega_{it}) = \sup\{\Pi_t(k_{it}, l_{it}, \theta_{it}, \omega_{it}) - C_t(k_{it}, l_{it}, \theta_t) + \beta E[V_{t+1}(k_{i,t+1}, l_{i,t+1}, \theta_{i,t+1}, \omega_{i,t+1})|\iota_{it}]\}$$

where ι_{it} is the information available to the firm *i* for making decisions at the beginning of period *t*, $C_t(k_{it}, l_{it}, \theta_{it})$, the associated costs, and $\Pi_t(k_{it}, l_{it}, \theta_{it}, \omega_{it})$, the static profit function with materials being the variable choice (notice that $\Pi_t(.) \equiv y_{it}$ in our model). Maximizing $\Pi_t(.)$ yields the optimal demand for materials: $m_{it} = f_t(k_{it}, l_{it}, \theta_{it}, \omega_{it})$.

$$E(\varepsilon_{it}|k_{it}, l_{it}, \theta_{it}, m_{it}, \dots, k_{i1}, l_{i1}, \theta_{i1}, m_{i1}) = 0, \quad t = 1, \dots, T \tag{19}$$

and the assumption to restrict the dynamics in the productivity process:[26]

$$E\left(\omega_{it}\middle|k_{it}, l_{it}, \theta_{it}, k_{i,t-1}, l_{i,t-1}, \theta_{i,t-1}, m_{i,t-1}, \dots, k_{i1}, l_{i1}, \theta_{i1}, m_{i1}\right) = E\left(\omega_{it}\middle|\omega_{i,t-1}, \theta_{i,t-1}\right)$$

$$\equiv f\left[g\left(k_{i,t-1}, l_{it-1}, \theta_{i,t-1}, m_{i,t-1}\right)\right], t = 2, \dots, T \tag{20}$$

Plugging Equation (20) into the firm production function yields:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f\left[g\left(k_{i,t-1}, l_{it-1}, \theta_{i,t-1}, m_{i,t-1}\right)\right] + a_{it} + \varepsilon_{it} \tag{21}$$

Notice that estimating Equation (21) is not trivial and requires some special econometric techniques. Malikov and Zhao (2019) develop a semi-parametric estimation of the firm production function, while a nonparametric IV estimator has been applied in Malikov et al. (2020). Most importantly, data on $\theta_{i,t}$ must be available. Unfortunately, data on the firm investment in innovation/environment is available in our sample. That is why we have referred to dummy variables either for the firm environmental practices (*ESC* and *ET*) or for its innovations. Consequently, we could not estimate Equation (21), and this limit should be a future research perspective.

V. Conclusion

This research investigates the nexus between environmental practices, innovation, and TFP convergence for Vietnamese manufacturing SMEs over 2007-2015. We find that the firm environmental practices only have a marginal effect on its TFP growth rate and, consequently, a maginal effect on the associated convergence speed. However, ecological practices can indirectly affect the TFP growth rate through innovation. Environmental regulations may encourage firms to innovate, and innovation, in turn, contributes to their TFP growth rate.

This study has four contributions to the literature of PH and productivity convergence. From a methodological perspective, we develop a structural modeling

[26] In Malikov and Zhao (2019), the firm's observed productivity is expressed in a lag function of materials, state inputs (labor and capital), and foreign investment's spillovers. In Malikov et al. (2020), the latter are replaced by the export intensity of the firm's sales.

framework to assess both strong and weak PH. We also carefully consider the potential endogeneity of environmental variables and innovation. These allow us to investigate the nexus between environmental practices, innovation, and TFP convergence. Notice that empirical research on the PH topic almost uses a single equation, which only allows examining impacts of environmental regulations on the firm performance or its innovation, but not a nexus between them. Second, the literature on productivity convergence does not investigate the role of firm environmental practices. Considering these factors is of great importance since firms face more pressure from their stakeholders (authorities, clients, suppliers, etc.) about their environmental protection behaviors. Third, focusing on SMEs' case in Vietnam is of interest because it has not been explored in the literature to the best of our knowledge. Fourth, our findings could inform the policy debates surrounding the best way to support the firm TFP growth rate or promote firm innovation.

Policies should be firstly in favor of household businesses (59% of the sample) since they have a lower TFP growth rate and a smaller likelihood to innovate than other firms. Since household businesses are characterized by micro-size, lack of capital, and low human capital level,[27] policies could be financial aids (interest-free loan or loan with low-interest rate) or providing training for their employees. Reforms and policies to support firms located in the Center are also needed since they have a lower TFP growth rate than those in the North or the South. Most importantly, policies should help firms improve their environmental practices' effectiveness. Since *KEL* positively affects the firm environmental practices, information about environmental awareness should be primarily disseminated. Notice that only 21% of the sample firms reported having good knowledge of this environmental law, while most of them (57%) expressed no concerns about it. Training activities to enhance skills and ecological awareness might be another solution. Besides, since *ESC* has a non-significant impact either on the firm performance or on its innovation, authorities should revise the way to derive these certifications.

[27] Indeed, 84% of household business is micro-firms (less than 10 employees), and 47% of them are in the North. Their managers are almost technical workers without a certificate. Besides, their average total assets are about 514 million VND, i.e., three times lower than the general average.

Owing to data availability, this study presents two limits. The first relies on the choice of environmental variables. We have used two dummy variables, while the most common variable used in the literature on this topic is a quantitative one: the PACE (see, for example, Rubashkina et *al.*, 2015; Van Leeuwen and Mohnen, 2017). This variable is indeed available in the database. Still, since it almost takes the null or missing value (74% of the sample), it would not be relevant to use the variable to measure the firm environmental practice. Second, we have used one-year lagged variables. When it comes to SMEs, we might need more time-lagged so that environmental practices have a more substantial impact, either on the firm TFP growth rate or its innovation. We did not do it in this research to avoid reducing the number of observations.

This research suggests two directions for future research. On the one hand, a study for large firms' environmental behaviors, exceptionally since they are less financially constrained than SMEs, might shed light on the mediating role of credit constraint on the nexus between environmental practices, innovation, and TFP convergence. Besides, subject to the availability of the information either on firm investment in innovation or on its PACE, future research may apply the structural modeling of production function mentioned in Subsection 4.3.4. On the other hand, firms in polluting industries should be under consideration as the findings might enhance the understanding of both the strong and the weak PH.

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Data availability statement

The data that support the findings of this research are available from the corresponding author upon request.

Appendix

Table A1. Variables definition

Variable	Definition	Type	Mean	Std.Dev	Min	Max
TFP (in log)	The firm's TFP obtained from Equation (7)	Continuous	2.20	0.75	2.34	6.87
ET (Environmental treatment)	1 if the firm has a treatment for environmental pollution (air quality, fire, waste disposal, etc.)	Dummy	0.13	0.34	0	1
ESC	1 if the firm has Certificate for registration of satisfaction of environmental standards	Dummy	0.27	0.44	0	1
KEL (Knowledge about Environmental Law)	1 if No; 2 if Poor; 3 if Good or Average	Discrete	0.70	0.79	0	2
Intensity of Pollution Abatement Expenditure (InPace)	$InPace_i = \frac{Pace_i}{\sum_{j,j\neq i} VA_j}$ where $Pace_i$ is the total Pollution Abatement expenditure of industry *i* and *VA* is the value-added of industry *j*.	Continuous	0.04	0.06	0	0.33
Innovation	0 if no innovation; 1 if either a process or product innovation; 2 if both innovations	Discrete	0.57	0.68	0	2
Gender of Manager	1 if man	Dummy	0.69	0.46	0	1
Age	Age of Manager	Continuous	45	11	19	94
Education level of Manager	0 if Unskilled; 1 if Elementary; 2 if Technical without certificate; 3 if Technical with certificate; and 4 if College/University/Post-graduate	Discrete	2.11	1.33	0	4
Household	1 if Household business	Dummy	0.59	0.49	0	1
Investment	The firm's total level investment of firm	Continuous	1.07	0.63	1	23.83
Export	1 if the firm does export activities	Dummy	0.07	0.26	0	1
Firm size	0 if Micro-firm (less than 10 employees); 1 if Small firm (between 10 and 49 employees); and 2 if Medium firm (between 50 and 250 employees).	Discrete	0.48	0.63	0	2
Industrial capital intensity	Total industrial stock of capital/Total industrial employees	Continuous	83.54	38.02	34.60	362.53
Sector dummy	0 if Low-tech industry (e.g. Textiles, Apparel; Leather; Wood; Paper; Publishing and Painting); 1 if Medium-tech industry (e.g. Refined petroleum; Non-metallic mineral products; Basic Metals; Fabricated metal products); and 2 if High-tech industry (Chemical products; Electronic machinery, computer, radio; Other transport equipment)	Discrete	0.64	0.61	0	2
Cluster	1 if the firm belongs to a cluster	Dummy	0.07	0.25	0	1
Region	0 if the firm locates in the North; 1 if in the Center; and 2 if in the South	Discrete	0.86	0.87	0	2

Table A2. Some descriptive statistics

a. ESC and ET

ESC	ET		Total
	No	Yes	
No	3000	944	3 944
(%)	66.22	20.81	87.03
Yes	317	269	586
(%)	7.02	5.95	12.97
Total	3 317	1 213	4 530
(%)	73.24	26.76	100

b. Innovation

	Frequency	%
No Innovation	2 457	54.23
Product or Process Innovation	1 579	34.84
Both Innovation	494	10.93
Total	**4 530**	**100**

c. Manager Professional Education

	Frequency	%
Unskilled	708	15.67
Elementary	735	16.27
Technical without certificate	1 350	29.88
Technical with certificate	806	17.84
College/University/Post-graduate	919	20.34
Total	**4518**	**100**

d. Firm size

	Frequency	%
Micro-firm	2 736	60.34
Small firm	1 433	31.67
Medium firm	361	7.99
Total	**4 530**	**100**

e. Knowledge about Environmental Law

	Frequency	%
No	2 299	55.66
Poor	1 304	28.82
Average or Good	927	20.52
Total	**4 530**	**100**

f. Sector dummy

	Frequency	%
Low-tech industry	1 955	43.12
Medium-tech industry	2 233	49.34
High-tech industry	342	7.55
Total	**4 530**	**100**

e. Region dummy

	Frequency	%
North	2 084	46.02
Center	1 013	22.36
South	1 433	31.63
Total	**4 530**	**100**

A3. Endogeneity of Environmental variables

	Stage 1	
Dependent variable	ESC	ET
Estimator	Bivariate Probit	
lntfp	-0.320***	-0.134***
	(0.040)	(0.037)
Owner/Manager characteristics		
Age	-0.012***	-0.023***
	(0.002)	(0.002)
Gender	-0.167**	0.007
	(0.056)	(0.061)
Education level (reference: Unskilled)		
Elementary worker	-0.361***	-0.660***
	(0.096)	(0.118)
Technical worker without certificate	-0.355***	-0.461***
	(0.086)	(0.109)
Technical worker with certificate	-0.346***	-0.684***
	(0.092)	(0.116)
College/University/Post-graduate	-0.271**	-0.453***
	(0.102)	(0.130)
Firm characteristics		
Household business	-0.633***	-0.673***
	(0.067)	(0.070)
Investment (in log)	0.206+	0.015
	(0.122)	(0.147)
Firm size (reference: Micro-firm)		
Small firm	0.460***	-0.160*
	(0.071)	(0.072)
Medium firm	0.921***	0.122
	(0.104)	(0.122)
Industrial and Location characteristics		
Capital intensity	-0.001	-0.002+
	(0.001)	(0.001)
Sector dummy (*reference: Low-tech industry*)		
Medium-tech industry	0.311***	-0.294***
	(0.065)	(0.068)
High-tech industry	0.372***	-0.078
	(0.105)	(0.116)
Region (reference: North)		
Center	-0.093	-0.286***
	(0.072)	(0.074)
South	0.240***	0.442***
	(0.061)	(0.064)
Cluster	0.392***	0.440***
	(0.095)	(0.109)
Instrument variables		
Knowledge about Environmental law		
Poor	0.032	0.200**
	(0.067)	(0.067)
Average or Good	0.469***	0.278***
	(0.070)	(0.075)

Intensity in Pollution Abatement Cost	4.176***	2.728***
	(0.867)	(0.765)
Year effects	Yes	Yes
Observations	4,530	4,530
Chi2	33965***	

Table A4. Environmental practices and TFP convergence: Quantile regression

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP
Quantile	Mean	Q10	Q25	Q50	Q75	Q90
lntfp	-0.620***	-0.634***	-0.615***	-0.602***	-0.615***	-0.614***
	(0.018)	(0.022)	(0.015)	(0.013)	(0.011)	(0.020)
Environmental practices						
ESC	-0.023	-0.043	-0.019	-0.049+	0.046	0.120**
	(0.031)	(0.061)	(0.031)	(0.026)	(0.048)	(0.046)
ET	0.073**	0.150**	0.044	0.028	0.024	0.014
	(0.028)	(0.053)	(0.028)	(0.021)	(0.022)	(0.052)
Owner/Manager characteristics						
Age	-0.003***	-0.003*	-0.003**	-0.003***	-0.003***	-0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender	0.028	0.084*	0.041+	0.038*	-0.004	-0.071*
	(0.021)	(0.040)	(0.022)	(0.017)	(0.021)	(0.030)
Education level (reference: Unskilled)						
Elementary worker	-0.016	0.080	-0.019	-0.021	-0.081*	0.025
	(0.034)	(0.066)	(0.034)	(0.030)	(0.036)	(0.038)
Technical worker without certificate	0.016	0.097+	-0.005	0.008	-0.035	-0.017
	(0.032)	(0.055)	(0.033)	(0.030)	(0.036)	(0.045)
Technical worker with certificate	0.060+	0.135*	0.068+	0.059+	-0.031	-0.005
	(0.035)	(0.057)	(0.037)	(0.031)	(0.040)	(0.048)
College/University/Post-graduate	-0.008	0.074	0.002	0.019	-0.079*	-0.059
	(0.040)					(0.041)
Firm characteristics						
Household business	-0.195***	-0.195***	-0.206***	-0.183***	-0.198***	-0.264***
	(0.026)	(0.040)	(0.025)	(0.021)	(0.027)	(0.042)
Investment (in log)	0.085	0.029	0.044	0.096***	0.161**	0.085+
	(0.054)	(0.039)	(0.088)	(0.017)	(0.058)	(0.045)
Firm size (reference: Micro-firm)						
Small firm	0.152***	0.162***	0.110***	0.098***	0.144***	0.154***
	(0.024)	(0.037)	(0.024)	(0.020)	(0.027)	(0.038)
Medium firm	0.278***	0.290***	0.211***	0.190***	0.227***	0.256**
	(0.048)	(0.063)	(0.040)	(0.040)	(0.051)	(0.079)
Industrial and Location characteristics						
Capital intensity	0.001+	0.000	0.001	0.001*	0.001+	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Sector dummy (*reference: Low-tech industry*)						
Medium-tech industry	0.087***	0.138***	0.093***	0.034+	0.073***	0.064*
	(0.021)	(0.032)	(0.021)	(0.018)	(0.021)	(0.032)
High-tech industry	0.112**	0.100	0.070+	0.072+	0.108+	0.152*
	(0.040)	(0.075)	(0.039)	(0.038)	(0.065)	(0.070)

Region (reference: North)						
Center	-0.068**	-0.094**	-0.061*	-0.041*	-0.044*	-0.150***
	(0.022)	(0.033)	(0.025)	(0.020)	(0.020)	(0.033)
South	0.065**	0.014	0.073***	0.087***	0.100***	0.043
	(0.022)	(0.039)	(0.021)	(0.019)	(0.026)	(0.038)
Cluster	-0.012	-0.076+	-0.010	-0.050	0.016	-0.020
	(0.042)	(0.045)	(0.035)	(0.040)	(0.046)	(0.057)
Constant	1.505***	0.866***	1.166***	1.490***	1.861***	2.237***
	(0.071)	(0.101)	(0.068)	(0.058)	(0.067)	(0.101)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,530	4,530	4,530	4,530	4,530	4,530
β-convergence (%)	4,64	4,77	4,59	4,48	4,59	4,58
Half-life time (years)	14,94	14,54	15,09	15,48	15,09	15,12

Standard errors in parentheses. Significant levels: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Table A5. Environmental practices and TFP convergence: Quantile fixed-effects regression

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP	dlnTFP
Quantile	Mean	Q10	Q25	Q50	Q75	Q90
lntfp	-1.154***	-1.155***	-1.160***	-1.170***	-1.182***	-1.187***
	(0.023)	(0.062)	(0.050)	(0.041)	(0.064)	(0.081)
Environmental practices						
ESC	0.034	-0.034	-0.030	-0.020	-0.009	-0.004
	(0.056)	(0.105)	(0.084)	(0.070)	(0.109)	(0.137)
ET	0.053*	0.041	0.031	0.010	-0.012	-0.023
	(0.025)	(0.065)	(0.052)	(0.043)	(0.068)	(0.085)
Owner/Manager characteristics						
Age	0.002	-0.000	0.000	0.000	0.000	0.000
	(0.002)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Firm characteristics						
Investment (in log)	0.019	0.052	0.040	0.014	-0.015	-0.028
	(0.073)	(0.167)	(0.134)	(0.111)	(0.173)	(0.218)
Industrial and Location characteristics						
Capital intensity	0.001+	0.001	0.001	0.001	0.000	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,530	4,530	4,530	4,530	4,530	4,530
β-convergence (%)	10,75	10,77	10,84	10,99	11,18	11,25
Half-life time (years)	6,45	6,44	6,39	6,31	6,20	6,16

Standard errors in parentheses. Significant levels: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.