Synergy in environmental strategies and productivity of small and medium-sized enterprises in Vietnam

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2016

Abstract: *This paper aims to revisit the Porter hypothesis using a panel data set of manufacturing SMEs in Vietnam covering 2007 - 2015. It contributes to the literature by employing the complementarity and substitutability test to analyze synergy between environmental protection, innovation, and export; the 'Weak version' of Porter hypothesis is also first extended associated with export participating. We apply the stochastic method developed by Olley and Pakes (1996), Levinsohn and Petrin (2003) and Ackerberg et al. (2006) to estimate stochastic TFP. The theory of supermodularity (Milgrom and Roberts, 1990; Milgrom and Roberts, 1995) is also used to investigate the impacts of pairwise combinations between firm's strategies on TFP. We found the significant positive impact of environmental compliance on TFP. Meanwhile, we found no any significant impact on TFP of combinations between this compliance and innovation as well as between the compliance and export participating. However, complementarity and substitutability of these strategies are not clear. The findings are likely to support partially the 'Strong version' of the Porter.*

Keywords: Porter hypothesis, Supermodularity, Complementarity, TFP stochastic, Environmental regulation, Innovation, Export

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1 Introduction

The tradeoff between the economic performance of firms in developing countries and the adoption of environmental-friendly strategies has become a key issue given in the modern industrialization processes of large countries such as China, India, Brazil (Arrow et al., 1996). The conventional literature has indicated that stringent environmental standards might be detrimental for firms' competitiveness (Simpson and Bradford III, 1996). That because under financial constraints, spending more on resources to comply with environmental regulations can make production cost increase and investment in other profitable opportunities may be decreased (Rubashkina et al., 2015). On the contrary, the Porter hypothesis (Porter, 1991; Porter and Van der Linde, 1995a) stressed that well-designed environmental standards could improve firms' performance, that known as "Porter hypothesis" (hereafter, PH). That because the appropriate environmental policies can help to recheck efficiency of resources using in the production process, improve facilities and promote innovation to lower cost of compliance as well as enhancing productivity.[1] In turn, it can help firms improve efficiency in using resources and increasing product value. Then, compliance-cost can be offset, and productivity would be enhanced. Therefore, the win-win state of a both-side better in term of environmental quality and productivity simultaneously (Rubashkina et al., 2015).

Almost empirical studies on this issue have been conducted in US and Europe countries (Rubashkina et al., 2015). Moreover, most existing works were interested in the reduced-form relationship between environmental performance and economic performance of firms by controlling several relevant factors (Anton et al., 2004; Cole et al., 2005; Cole et al., 2008; Carrión-Flores and Innes, 2010; López-Gamero et al., 2009). Few studies proposed a structural analysis, except Leeuwen and Mohnen (2013) which performed a supermodularity test (Milgrom and Roberts, 1990; Milgrom and Roberts, 1995) to investigate the synergy between different types of innovation in the total factor productivity (hereafter, TFP) of Dutch firms. This research found an existence of complementarities between these types of innovation and a clear synergy. However, a drawback of Leeuwen and Mohnen (2013) is that TFP is deterministic and computed as the residual of the production function. Moreover, few existing works on the Porter hypothesis are related to developing countries; in particular for the case of Small and Medium - sized Enterprises (henceforth, SMEs).

[1] Innovation can be various forms "a product's or service's design, the segments it serves, how its is produced, how it is marketed and how it is supported."(Porter, 1991; Porter and Van der Linde, 1995a)

The crucial question raised is that whether PH is plausible for the case of SMEs, especially in developing countries, like Vietnam. It is the fact that existing studies related to TFP and SMEs in Vietnam include, for example, the issue related to production frontier (Minh and Long, 2009) and productivity of Vietnamese firms (Hansen et al., 2009; Howard et al., 2014; Newman and Narciso, 2009; Newman et al., 2014b,a). Nevertheless, only a few of them are related to environmental questions that are mentioned in the PH. Therefore, we will revisit the Porter hypothesis by using panel firm-level data for manufacturing SMEs surveyed in ten provinces in Vietnam, covering the period of 2007-2015. We apply a structural modeling where TFP is regarded as a stochastic process. However, we just focus on investigating the 'Strong version' and its extended version associated with export participating.

The present paper aims to examine the impacts of the environmental related strategies of firms (which are formed from environmental, innovation, export participating) practices on TFP. Another objective is to investigate whether these strategies are complementary or substitute in determining firms' productivity.

2 Theory and hypotheses

The literature relating to the Porter hypothesis (henceforth PH) is abundant (see Wagner, 2003; Brännlund and Lundgren, 2009; Ambec and Barla, 2002 for a survey). The main contents of the hypothesis posit that stringent environmental regulations can improve productivity and competitiveness through pushing firms to reduce inefficiency in resource using and stimulate innovation (Leeuwen and Mohnen, 2013; Porter and Van der Linde, 1995b), which may be divided into three versions. First, 'Narrow version' proposes that "Flexible environmental regulations, such as market-based instruments, increase firms' intensities to innovate compared to prescriptive regulations such as performance - based or technology - based standards". Second, 'Weak version' advocates that "The positive effect of well-crafted environmental regulations on environmental innovation (even when such innovation comes at an opportunity cost that exceeds its benefits for a firm)". Third, 'Strong version' prescribes that "Innovation induced by well-crafted environmental regulations could more than offset additional regulating costs and, consequently, increase firms' competitiveness and productivity" (Rubashkina et al., 2015).

Further, the well-designed environmental policies can play a pivotal role in forming equality in the business environment because it prevents firms taking advantages of uncomplying regulations. Besides, it probably raises more pressure on companies and helps them re-check efficiency and explore more potential capacity. It may also create more pressures on competition, which stimulate firms to raise corporate awareness to share information or knowledge to reduce costs. Consequently, innovation could be prompted, leading to an enhancing in competitiveness and productivity. Then, all players could get win-win position (Porter and Van der Linde, 1995a). Besides, pollution and intermediate material using can be reduced simultaneously without decreasing in productivity (Bernstein et al., 1990 and Boyd and McClelland, 1999). However, several empirical studies surveyed in Ambec et al. (2013), Brännlund and Lundgren (2009) and Ambec and Barla (2002) assert conventional neoclassical notions that scare of resources can be diverted into meeting environmental disciplines; as a result in causing an increase in cost and, leading to decreasing in profitability and competitiveness. That has been criticized for being too static because it takes inefficiencies in the situation without dynamic spillovers of environmental regulation (Porter and Van der Linde, 1995b). Therefore, it can be seen that *'The Porter hypothesis is still ambiguous.'*

2.1 Environment and Firm productivity - Strong version

The literature shows an existence of the link between environmental regulations and productivity. Intuitively, PH proposes that companies can increase productivity if investing on environmental compliance appropriately. There are two main existing controversial streams about this hypothesis.

First, this compliance can make production cost increase and take a part of firms' limited resources which can be used to invest in other profitable opportunities; consequently, productivity may be influenced detrimentally, particularly in the short-term. Second, stringent well-designed environmental policy framework can generate more positive pressure on firms and demand them have to be more efficient in using resources, organizing operation, and production process. It also stimulates businesses improve technology or invest new technology that, in turn, help them reduce compliance cost. Consequently, innovation activities might be more efficient, enhancing TFP and competitiveness, especially in the medium and long-term (Rubashkina et al., 2015).

Empirically, Hamamoto (2006) and Yang et al. (2012) use PACE (Pollution abatement cost expenditure) as a proxy of stringent environmental regulation and point out a active link between the stringency of environmental regulations and R&D which may increase TFP. Likewise, Piot-Lepetit and Le Moing (2007) supports the state "win-win" of PH by finding a positive relation between environmental regulations and business efficiency (Berman and Bui, 2001; Russo and Fouts, 1997).

Whereas, Jaffe and Stavins (1995), Shadbegian and Gray (2005), (Lanoie et al., 2008), (Greenstone et al., 2012), Koźluk and Zipperer (2013) posit the negative impact of stringent environmental regulations on productivity. Barbera and McConnell (1990) point out a small negative effect of these regulations on TFP growth. Similarly, appearing pollution abatement costs in pollution insensitive industries in Germany makes TFP reduce 2.5% (Conrad and Wastl, 1995); that because environmental policies may cause investment cost increase (Simpson and Bradford III, 1996).

Additionally, Becker (2011) finds no significant evidence to state that the impact is significant in a country having higher environmental compliance costs. Spending more on pollution abatement, plants tend to be inefficient in both production and emission (Shadbegian and Gray, 2006; Färe et al., 2007). Also, Leeuwen and Mohnen (2013) and Becker (2011) assert no any significant evidence to support 'Strong version' of PH. It is consistent with Rubashkina et al. (2015) 'Strong version.' They conclude that effects of environmental policies are not strong enough to push firms to reallocate their production, instead of other factors such as wages, capital costs, competitiveness and market share expanding are becoming more and more important factors that firms have to adjust to being more productive.

By above discussion, it can be seen that most of them are lacking capital, know-how, low technology level. Meanwhile, the environmental investment may be costly while firms can not assure whether this cost is trade-off positively or not, especially in the short-term. It is the fact that the most critical thing companies concern is how to survive and maximize profit, instead of environmental issues. In fact, the relationship between environmental regulation and firm's productivity is still ambiguous.

Therefore, we suspect no existence the link between environmental compliance and productivity, that is not in line with 'Strong version' of PH. We suppose the first hypothesis as below:

Hypothesis 1. *Other things being equal, environmental compliance has no effect on firm's productivity.*

2.2 Environment and innovation

Besides can be tested by evaluating the link between environment and company's performance, PH can be assessed by evaluating by integrating this effect associated with innovation and other causes (Lanoie et al., 2010). Additionally, Hamamoto (2006) and Yang et al. (2012) find the positive impact of stringent environmental provisions on innovation. This evidence explained that innovation could be stimulated through improving technological capacities or knowledge capital (Horbach, 2008). The positive link between stringent regulation and environmental innovation - 'Weak version' of PH has also been asserted significantly (Leeuwen and Mohnen, 2013). This finding may be explained that the cost-saving innovation is more than the cost of environmental compliance because the well-designed regulation framework and the flexible environmental mechanism are likely to motivate more firms' innovative activities, rather than prescriptive regulations (Jaffe and Palmer, 1997). Also, Kammerer (2009) argues both customers and regulations all play a crucial role in environmental-friendly product innovations. While Eiadat et al. (2008) indicate that the link between the adaptation of innovation strategy and firms' performance might be influenced by environmental regulations. In fact, the most important driver of reducing toxic emission in the United States (US) is environmental innovation and competitiveness (Carrión-Flores and Innes, 2010). Further, it may help firms reduce unexpected outputs and stimulate adoption of new energy-saving technology; as a result, TFP can be improved (Zhang et al., 2011) and firm's market value also be highly appreciated (Dowell et al., 2000).

However, this impact may be lagged; that means investing in emission reduction within one or two years may enrich firm's operating performance in the following years (Hart and Ahuja, 1996). Furthermore, Rennings and Rammer (2011) find that in term of profit, there is no significant evidence to confirm the performance of environmental innovation is lower than other innovations. Studying seven European countries by using energy tax to proxy stringency, Franco and Marin (2014) show that stringency plays a major role in indirect influence to innovation and productivity. Further, the role of innovation in competitiveness can be moderated by types of environmental innovation (Rennings and Rammer, 2011).

For the case of Vietnam, studies on this issue are still sparse. Lin et al. (2013) study impact of market demand on green product innovation and the link between green product innovation and firm performance for the case of 4 motorcycle foreign companies in Vietnam. As a result, they point out that market demand is positively associated with green product innovation and positive impacts of this innovation on firm performance. It implies that evidence that conducting green innovation in production can help businesses take advantage and enhance product's market value.

However, in general, Dieu (2006) find that Vietnamese SMEs are regular lacking of capital and human resource to invest as well as set up and update a new production process. The capacity of technology integrating to enhance the productivity is low, and their ability to increase investment to improve technological facilities proactive environment often are limited. Further, Tuan et al. (2012) poses a view that environmental regulation of Vietnam is mainly based on 'end of pipe' solution to meet waste disposal appropriate standards. Then environmental regulations are often supervised by inspections of authorities, which help them to check whether firms are complying legally environmental standards or not. For this reason, enterprises frequently do compliance to deal with these inspections and whenever the inspections implemented. Because of lacking of capital and skills, they are rarely set up treatment processes to comply the regulations voluntarily.

Moreover, even large companies, investment in environment and technology is not always efficient. Effectively, appearing new environmental problems could be affected by technical innovations (Worrell et al., 2001) which, for that reason, should be used carefully with much more attentions to the environment because it may give adverse effects (Lewis, 2007). Further, increasing in innovation can help firms increase the capacity of export (Co et al., 2015). Then, we suspect that environmental compliance is not likely to result in any significant impacts on the link between innovation and firms' productivity, especially to SMEs.

By this, we mean the difference between the impact of innovation and that of innovation combined with environmental compliance is not crucial significantly. Following the lights of the extended 'Strong version', we raise the next hypothesis is formed as follows:

Hypothesis 2. *Other things being equal, environmental compliance plays a significant role on the impact of innovation on TFP.*

2.3 Environment and export

Stringent environmental regulations can help firms approach the international market as companies are expected to comply these regulations for adopting international standards. Consequently, innovation could also be stimulated through this process (Porter and Van der

Linde, 1995b, Bigliardi et al., 2012). For instance Costantini et al. (2013); Costantini and Mazzanti (2012) study the case of European countries and assert that firms' export participating may be affected by environmental policies. They reveal that environmental policies are not like to be detrimental for export competitiveness; indeed, the association between innovation and energy tax policies can enhance export capacity.

Additionally, international trade can motivate firms complying global environmental standards by obtaining international certificates (for example, ISO 14001) because they want to take advantages, particularly when trading with countries whose enterprises also adopted rules to protect environment (Prakash and Potoski, 2006). Hence, the policy framework should encourage firms to perceive that environmental regulations should be considered as an opportunity to elevate their competitiveness rather than a bottleneck increasing compliance-cost (Porter and Van der Linde, 1995b). It may also provide positive pressure; such that firms have to increase investment to enhance productivity as well as competitiveness, especially in the international market. For instance, countries with more stringent standards are likely to become surplus exporters of environmental proactive new technologies (Costantini and Crespi, 2008).

For the case of Vietnam, innovation has a positive effect on exporting probability because it can help firms enrich their competitiveness in term of price and quality (Co et al., 2015). In contrast, using cross-sectional data of manufacturing of SMEs in 2011, Anh et al. (2011) indicate that participating international trade could help firms increase innovation ability. While Vu (2012) set forth that export participating is not correlated to company's profit growth.

Then, we have a suspicion of the consistency of the 'Strong version' of PH for the case of SMEs in Vietnam, considering the role of environmental regulation on the impact of export on TFP in particular. We are, therefore, aspirated to expand this version corresponded to export through the following hypothesis:

Hypothesis 3. *Other things being equal, the impact of Export combined with Environment on productivity is higher than that of Export separately.*

Furthermore, export involving is also found be affected by innovation and environmental regulation (Costani and Crepsi, 2008; Costani and Mazarti, 2012). Besides, Co et al. (2015) show that Vietnamese firms have the higher probability of export if they have more improvement in innovation. Then, we raise the final hypothesis as below:

Hypothesis 4. *Other things being equal, the impact of combination between export and innovation on the productivity of exported-firms is higher than that of non-exported ones.*

2.4 Other control variables

Sector

The impact of sectors on the link between environmental regulation and productivity is different. For instance, studying chemical manufacturing in US, Domazlicky and Weber (2004) find that environmental protection may impact negatively on productivity growth. Whereas, this link is likely to be more efficient for the US power plants (Fleishman et al., 2009). More detail, López-Gamero et al. (2009) clarify effects of environmental protection on firms' performance are different and changed depending on specific sectors. For instance, pollution regulations have no any impact on productivity in the US food manufacturing. Brännlund and Lundgren (2010) test the validity of the Porter's hypothesis for Swedish manufacturing sector and also find no supported evidence; while this link is found positively in Mexico (Alpay et al., 2002).

Geography

Location of main production plants could play a significant role in the relation between environment and productivity. Thus, geographical factors are likely to be considered as the important indicators of the environmental proactive and regulations (González-Benito and González-Benito, 2006). Otherwise, the critical roles of the provisions in creating locational competition can have effects on firms' decisions in choosing where main production facilities should be located. Theoretically, firms seem to prefer to set up plants in abroad if the provisions at home become stricter (Conrad, 2005). Besides, the effects of environmental regulations also depend on regional characteristics such as population density, unemployment rates, age structures, and incomes per capita (Berman and Bui, 2001, Cole et al., 2005).

Cluster

The scale of region and sector may also affect to performance of environment and innovation (Costantini et al., 2013). In China, impacts of environmental regulations on productivity are different via economic zones. For example, the highest changed growth rate of TFP is in the Southern Coastal zone, say 7.06%; whereas, this rate is negative in the Southwest economic zone, approximately 1.03% (Zhang et al., 2011). More general, innovation is defined having linkage with environmental regulation, management and perception (Wagner, 2008; Frondel et al., 2008) and spillover of technological change or innovation may depend on upon particular sectors in specific regions. That is not only due to geographical economics but also of cognitive proximity (Costantini et al., 2013).

3 Data

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

Data surveyed in 10 provinces cover information on firm characteristics, production, inputs, economic performance, bureaucracy and informality, and trade. Information regarding environmental questions includes environmental-friendly practices, existences of environmental standards certificates and environmental regulations (law, compliance inspections), firm's localization decision. We focused on enterprises in manufacturing sectors and divided into two groups: the first is 'Urban-city' (proxied by $Location = 1$) including enterprises located in the first-ranked cities in Vietnam (Hanoi, HCMC, Haiphong) and the second is 'Province' containing enterprises located in other provinces ($Location = 0$).[2]. We categorize firms having main production facilities located in industrial Industrial Park/zone (IZ), High-Tech Park/Zone (HTZ), and Export Processing park/zone (EPZ) into one group ($Cluster = 1$), and otherwise.

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

3.1 Descriptive statistics

Basing on figures in Appendix B, in the full-sample of 12550 firm-observations, the rate of firms having the environmental standard certificate(ESC) is 14.43%, fluctuate in the interval of 9% and 20% over years. The rate of enterprises participating export is relatively small, below 7% in all year and 6.22% in average. While the rate having innovation activities is higher although it has been decreased slightly over years; in which the rate of firms having products improved is highest, 35.57% in average; followed by companies introducing new products and new production process, around 13.31% and 14.03%, respectively (Table 9).[3]

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

Mentioning to the environmental perception measured by levels of knowledge about environmental law, the majority of them have poor or no or do not care about this law that alters from 23% to nearly 31% and 43 to 54% over years respectively. Whereas, the numbers of firms having good and average levels are too small, say 2.23 - 7.37 % and 14.69 - 26.73% (Table 11). Besides, 29.50% of firms answered that air quality standard is the most difficult factor in environmental compliance, only 5.04% and 7.15% for standards of waste disposal and water pollution (Table 12). Similarly, more than 40% of firms responding air quality standard is the most difficult in term of compliance cost, and only 4.38% and 5.21% for waste disposal and water pollution (Table 13). As the figures in Table 14, the main reason is adding capacity, around 60% firms answered. Meanwhile, this rate for improving

[3]See detail in Appendix B

productivity is low, only 8.36% and for innovation activities as introducing new products, improving product are relatively small, just more and less 3%.

Finally, Table 15 shows that added value[4] is not significant changed, around the average value, 346.88 million VND[5] per year. Above all, total physical assets were sharply increased in 2015, reach 5340 million VND, compared to 2111 million VND in average. Total labor and investment are not significant changed, fluctuating from 13.61 to 17.45 employees and 1124 to 1612 million, respectively.

3.2 Descriptive statistics in the survey of 2015

In 2015, as presented in Table 16, an average of added value in the sector of rubber (Rubber) is highest, more than 1000 million VND, followed by Paper and Apparel, around 877 and 740 million, respectively. Food and beverage acquire the lowest, 176 million. The highest investment has belonged to Paper with 922 million, followed by Electronic machinery, 561 million. The fabricated metal sector has the lowest investment, just nearly to 88 million in average. Similar to full sample, the average number of employee in 2015 is still kept stable at 14.08 persons; in which Apparel has largest number and the next is Paper with 33.81 persons. While, Food and beverage sector has the lowest, only 7.24 employees.

As mentioned in Table 17, in 2015, Food and beverage industry has 86 having ESC, account the highest percentage, 24.02% of ESC obtaining. Rubber and Fabri-Metal are the next ones, at 12.29 % (44 of 159 firms) and 10.89% (39 of 450 companies) respectively. Food and beverage are also got the largest part in term of introducing new products, 27.65% (175 of 838 enterprises in this sector); 19.55% (69 firms) and 31.01% (40 enterprises) have improved existing products and applied new production process. The fabric-metal sector also has real innovation performance, 128 of 322 firms introducing new products (20.22% for all sample). This rate is little lower for improving products and applying new process, appropriately 16% for both. Regarding export activities, 36 of 141 firms in Apparel has shipped, accounted the highest share in the total sample, 19.46%. The sectors of Wood and Food-beverage are followed with (30 in 291 firms) and (26 in 838 businesses), correspondingly 16.22 and 14.05% in whole sample 2015.

[4]Real value are calculated basing on the base price of the year 1994

[5]Vietnam Dong

4 Methodology

4.1 TFP estimation specification

The specification of calculating TFP can be started 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 $t(t = 1, ..., T)$, A_{it}, K_{it}, L_{it} are total factor productivity (TFP), capital stock and labour, respectively. If taking log, we have:

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

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

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

or it can be rewritten as:

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

If we use traditional methods, in particular, the OLS, the panel fixed effects or random effects estimators, then the estimators may be biased because the presence of the unobserved and stochastic part in ε_{it} may prevent the estimation of appropriate TFP as the residual of the production function as in Leeuwen and Mohnen (2013). The main reason for that is firm's decisions on inputs and technological level (which specially relates to the unobserved part) closely linked. Consequently, input elasticities in the production function and the stochastic TFP cannot be separately identified.

To solve this problem, Olley and Pakes (1996) developed an alternative that employs investment as an appropriate instrument for inputs in the regression model. Nonetheless, OP method may be failed in some cases because investment can not always available all periods of time; on that account, Levinsohn and Petrin (2003) proposed employing an intermediate input demand function to invert out ω_{it}, then the production function is reformed as:

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

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

Nevertheless, the problem of collinearity may appear in the first stage of LP. Thus, an alternative developed by Ackerberg et al. (2006) that can eliminate the problem by using a proxy variable of intermediate inputs reacting to the observed TFP, which recently has been extended and applied by Martino and Nguyen-Van (2014). The alternative is only appropriate under the assumptions including (i) Materials are flexible and chosen at time t after knowing ω_{it}; (ii) Capital is strictly convex and chosen in period $t-1$; and (iii) Labors are assumed dynamic and chosen at $t-b$ $(0 < b < 1)$. In fact, labor would be determined at time $(t-b)$, before choosing material (x) decided at t and before decision of capital (k_{it}) done at $(t-1)$. Then, demand for material inputs depends on the Ω_{it} considered as the space of information of enterprises' production characteristics:

$$m_{it} = f_t(\omega_{it}, k_{it}, l_{it}) \tag{6}$$

or

$$\omega_{it} = f_t^{-1}(m_{it}, k_{it}, l_{it}) \tag{7}$$

where ω_{it} assumed in link with the first order Markov process between $t-1$, $t-b$, and t. Because the material demand function is assumed be strictly increasing monotonic, the function of added value can be derived as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f_t^{-1}(m_{it}, k_{it}, l_{it}) + \varepsilon_{it} \tag{8}$$

Then, the impact of the composite term, $\hat{\psi}_{it}$, can be found from:

$$\psi_t(m_{it}, k_{it}, l_{it}) = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + f_t^{-1}(m_{it}, k_{it}, l_{it}) \tag{9}$$

This equation shows that, now, ω_{it} is controlled because impacts of unanticipated factors on output are eliminated (Ackerberg et al., 2006), so we can get free of ε_{it} and productivity can be generalized as:

$$\omega_{it} = E[\omega_{it}|\Omega_{i,t-1}] + \xi_{it} \tag{10}$$

Because in $\Omega_{i,t-1}$, productivity at $t-1$, ω_{t-1}, is the most important factor in determining ω_{it}; then the first moment equation can be derived as:

$$\omega_{it} = E[\omega_{it}|\omega_{i,t-1}] + \xi_{it} \tag{11}$$

where ξ_{it} stands for the mean independent of $\Omega_{i,t-1}$.

In addition, basing on assumptions by OP and LP about the independence between k_{it} ($k_{it} \in \Omega_{i,t-1}$) and the shock of productivity at t (ξ_{it}), Ackerberg et al. (2006) suggested the second moment equation as follows:

$$E[\xi_{it}|k_{it}] = 0 \tag{12}$$

In addition, because investment l_{it-1} decided at time $t-b-1$, it is belonged to $\Omega_{i,t-1}$ and completely independent with ξ_{it}. That means:

$$E[\xi_{it}|k_{it}, l_{i,t-1}] = 0 \tag{13}$$

or

$$E\left[\xi_{it}\left(\beta_k.\beta_l\right)\begin{pmatrix} k_{it} \\ l_{i,t-1} \end{pmatrix}\right] = 0 \tag{14}$$

Then, a sample analogue to this moment can be derived by employing values of $\mu_{it}(\beta_k, \beta_l)$ indicated as the residual of the equation (13), as below:

$$\frac{1}{T}\frac{1}{N}\sum_t\sum_i \xi_{it}(\beta_k, \beta_l)[k_{it}, l_{i,t-1}] \tag{15}$$

That will be minimized to find β_k and β_l. Empirically, we can find ω_{it} by two stage: (i) using generalized additive model (gam) and (ii) GMM regression which can help us identify β_k and β_l by minimizing the criterion function described as:

$$\left[\sum_{t=1}^{T}\sum_{i=1}^{N}\xi_{it}\left[k_{it}, l_{i,t-1}\right]\right]'.C.\left[\sum_{t=1}^{T}\sum_{i=1}^{N}\xi_{it}\left[k_{it}, l_{i,t-1}\right]\right] \tag{16}$$

Finally, we replace β_k and β_l into the production function to estimate the stochastic TFP unbiasedly, say ω_{it}, as follows:

$$\omega_{it}(\beta_k, \beta_l) = \hat{\psi} - \beta_0 - \beta_k k_{it} - \beta_l l_{it} \tag{17}$$

4.2 Supermodularity test

For testing supermodularity and submodularity test, we base on the plausible methods and arguments in Milgrom and Roberts (1990, 1995), Mohnen and Röller (2005), Leeuwen and Mohnen (2013) and Mothe et al. (2015). The objective function aims to prove whether existing 'complementary or substitutability' in these strategies on TFP. Supposing that TFP is affected by choosing of strategies S_g, where $g = \{1, 2, ..., k\}$ which are form from n practices. Then, TFP of firm i at time t can be derived as $TFP(S_{git}, \phi_{gi})$, where ϕ_{gi}

denotes characteristics of firm i under strategy g. The optimal problem of a firm is to chose one in the set strategies such that TFP could be maximized: $\max TFP(s_g, \phi_{gi})$. To solve the problem, we can test whether $TFP(S_{git}, \phi_{gi})$ is supermodular in s_{gi} or not; then existence of complementary could be concluded.

As supposed before that $\omega_{it} \equiv lnA_{it}$ or $\omega_{it} \equiv lnTFP_{it}$, then for testing *supermodularity*, basing on suggestions from Mohnen and Röller (2005), we specifies the productivity function as below:

$$lnTFP_{it} = \sigma_0 + \sigma_1 I_{it} + \sum_{g=0}^{2n-1} \gamma_g S_{git} + Z'_{it}\phi + \varepsilon_{it} \tag{18}$$

where S_{git} is the vector binary variables representing for the strategies of firm; I_{it} is investment expenditure and Z_{it} is a vector of control variables.

If we have 3 practices, g is considered as strategies formed from three practices $\{j, k, l\}$. Then, $g = \{0, 1, ..., 7\}$ and $S_g \equiv s_{j\_l\_k}$, where in which $j, l, k = \{0, 1\}$. For instance, S_0 is $s_{0\_0\_0}$; correspondingly S_1 is $s_{0\_1\_0}$ which implies firms do not practice j, k, but practice l $(j = 0, l = 1, k = 0)$; and so on; finally S_7 is $s_{1\_1\_1}$ $(j = 1, l = 1, k = 1)$. Then, we have:

$$lnTFP_{it} = \sigma_0 + \sigma_1 I_{it} + \sum_{g=0}^{7} \gamma_g S_{git} + Z'_{it}\phi + \varepsilon_{it} \tag{19}$$

In order to estimate the coefficients for panel data robustly, there are two ways: fixed and random effects. Then, the more appropriate model would be selected through Hausman test developed by Griliches and Hausman (1986). In our research, fixed effect models are more appropriate.

For testing complementary of S_g, calling γ is denoted for coefficients of S_g impacts on TFP, we can derive inequalities, for instance with practices j and k, the others are similar, as: $\gamma(10k) + \gamma(01k) \leq \gamma(00k) + \gamma(11k)$

where $k = \{0, 1\}$ and $\gamma(10k) + \gamma(01k)$ stands for the substitute the impacts of practices 1 and 2; meanwhile, $\gamma(00k) + \gamma(11k)$ represents for the complementary impact.

Basing on the matrix of corporate strategies[6], complementarity and substitutability testing can be conducted by basing on the coefficients γ_g in Equation (18) that have to satisfy the following inequality constraint sets which are derived based on the matrix of corporate strategies. First, for complementarity between practice j and l, and $m = \{0, 4\}$:

$$\gamma_{2+m} + \gamma_{1+m} \leq \gamma_{0+m} + \gamma_{3+m} \tag{20}$$

[6]see detail in Appendix A, Table (7)

Next, for complementarity between 1 and 3, $m = \{0, 1\}$, we have:

$$\gamma_{2+m} + \gamma_{4+m} \leq \gamma_{0+m} + \gamma_{6+m} \tag{21}$$

Finally, the following is for testing complementarity between l and k, $m = \{0, 2\}$:

$$\gamma_{1+m} + \gamma_{4+m} \leq \gamma_{0+m} + \gamma_{5+m} \tag{22}$$

Following the method suggested in Kodde and Palm (1986), Mohnen and Röller (2005) and Mothe et al. (2015), we can test strictly *supermodularity* for corporation between (j and l) by the following hypotheses:

Null hypothesis: H_0: $h_0 < 0$ and $h_1 < 0$, and

Alternative hypothesis H_1: $h_0 \geq 0$ or $h_1 \geq 0$

where $h_m = -\gamma_{0+m} + \gamma_{2+m} + \gamma_{1+m} - \gamma_{3+m}$, $m = \{0, 4\}$

By that way, the *submodularity* for practice j and l can be tested based on the inequality system as follows:

Null hypothesis: H_0: $h_0 > 0$ and $h_1 > 0$, and

Alternative hypothesis H_1: $h_0 \leq 0$ or $h_1 \leq 0$

The testing *complementary* and *substitutability* of the remain pair-combinations $j - k$ and $l - k$ of the strategy set S_g can be done in the same way.

If we have 4 practices, g is denoted as corporation strategies from 4 practices $\{j, x, y, k\}$. Then, $g = \{0, 1, ..., 15\}$ and $S_g = s_{j\_x\_y\_k}$, where $j, x, y, k = \{0, 1\}$. For instance, S_0 is $s_{0\_0\_0\_0}$, S_1 is $s_{0\_1\_0\_0}$ which implies firms do not practice j, y, k but practice x ($j = 0, x = 1, y = 0, k = 0$) and so on, and finally S_{15} is $s_{1\_1\_1\_1}$ ($j = 1, x = 1, y = 1, k = 1$).[7] We have the general following function:

$$lnTFP_{gi} = \lambda_0 + \lambda_1 I_{it} + \sum_{g=0}^{15} \gamma_g S_{git} + Z'_{it}\phi\varepsilon_{it} \tag{23}$$

For examining the complementary of j and x, we derive the inequality system as below:

$$\gamma(10yk) + \gamma(01yk) \leq \gamma(00yk) + \gamma(11yk) \tag{24}$$

where $y, k = \{0, 1\}$. One can consider $\gamma(10yk) + \gamma(01yk)$ as the substitute impact of j and x; otherwise $\gamma(00yk) + \gamma(11yk)$ shows the complementary impact.

[7]see the combinations detail in Appendix A, Table (7)

Similarly, for testing supermodularity and submodulartity for this case, using the matrix of corporate strategies (7), the coefficients γ_g need to be satisfied the following inequality constraint system. For instance, firstly, we built up the inequalities for testing complementary and substitutability between practice j and x, as follows:

$$\gamma_{4+m} + \gamma_{8+m} \leq \gamma_{0+m} + \gamma_{12+m} \tag{25}$$

where $m = \{0, 1, 2, 3\}$
For complementary j and y:

$$\gamma_{2+m} + \gamma_{8+m} \leq \gamma_{0+m} + \gamma_{10+m} \tag{26}$$

where $m = \{0, 1, 4, 5\}$
Next, the following is for testing complementary between practices j and k:

$$\gamma_{1+m} + \gamma_{8+m} \leq \gamma_{0+m} + \gamma_{9+m} \tag{27}$$

where $m = \{0, 2, 4, 6\}$
For complementary x and y:

$$\gamma_{2+m} + \gamma_{4+m} \leq \gamma_{0+m} + \gamma_{6+m} \tag{28}$$

where $m = \{0, 1, 8, 9\}$ For complementary x and k:

$$\gamma_{1+m} + \gamma_{4+m} \leq \gamma_{0+m} + \gamma_{5+m} \tag{29}$$

where $m = \{0, 2, 8, 10\}$
Finally, the condition for complementary between y and k can be formed as:

$$\gamma_{1+m} + \gamma_{2+m} \leq \gamma_{0+m} + \gamma_{3+m} \tag{30}$$

where $m = \{0, 4, 8, 12\}$. We denote:

$$h_m = -\gamma_{0+m} + \gamma_{4+m} + \gamma_{8+m} - \gamma_{12+m}, \qquad m = \{0, 1, 2, 3\}. \tag{31}$$

Then, we can derive the hypotheses for testing supermodularity of complementary between j and x as:

Null hypothesis: H_0: $h_0 < 0$, $h_1 < 0$, $h_2 < 0$, $h_3 < 0$, and

Alternative hypothesis H_1: $h_0 \geq 0$ or $h_1 \geq 0$ or $h_2 \geq 0$ or $h_3 \geq 0$

Similarly, the *submodularity* of complementary j and x can be tested based on:

Null hypothesis: H_0: $h_0 > 0$ and $h_1 > 0$, $h_2 > 0$ and $h_3 > 0$, and

Alternative hypothesis H_1: $h_0 \leq 0$ or $h_1 \leq 0$ or $h_2 \leq 0$ or $h_3 \leq 0$

The tests for the remain pairs $\{j-y, j-k, x-y, x-k,\ and\ y-k\}$ can also be conducted by the similar procedures.

For testing the significance of the sets of inequality conditions, we specify the procedure to calculate the Wald test values for detecting the significant levels of super- and sub-modularity estimators. Firstly, basing on the lights of Kodde and Palm (1986), we transform the functions of $h(\gamma)$ into new parameter vectors $\gamma = (\gamma_1', \gamma_2')'$ and $\bar{\gamma} = (\bar{\gamma'}_1, \bar{\gamma'}_2)'$. We denote Ω_0 and Ω_1 are respectively the feasible space for γ under the null hypothesis (H_0) and the alternative hypothesis (H_1). $\tilde{\gamma}$ and $\hat{\gamma}$ are respectively defined as the minimum distance estimators under the restrictions of Ω_0 and Ω_1.

Basing on Kodde and Palm (1986), we can define the Wald test value or distance test, which minimizes the distance between $S\tilde{\gamma}$ and $S\bar{\gamma}$ as:

$$D = D_0 - D_1 \tag{32}$$

where

$$D_0 = \|\bar{\gamma} - \tilde{\gamma}\| \tag{33}$$

which can be solved by $min_{\gamma \in \Omega_0} \|\bar{\gamma} - \gamma\|$, or in the other words, conducting OLS regression. Similarly, we also find:

$$D_1 = \|\bar{\gamma} - \hat{\gamma}\| \tag{34}$$

by $min_{\gamma \in \Omega_1} \|\bar{\gamma} - \gamma\|$. However, because the hypotheses to be tested in our research are composite, supposing $\hat{\gamma} = \bar{\gamma}$, so we just test the hypotheses in space of Ω_0 as:

$$D = \|\bar{\gamma} - \tilde{\gamma}\| \tag{35}$$

where $\bar{\gamma}$ is the vector of consistent estimators, here we find the vector $\tilde{\gamma}$ such that $\tilde{\gamma}$ closest to $S\gamma$ in Ω_0 by applying the method noted in Mohnen and Röller (2005):

$$\min_{\tilde{\gamma}} (S\tilde{\gamma} - S\bar{\gamma})'[Scov(\bar{\gamma})S']^{-1}(S\tilde{\gamma} - S\bar{\gamma}), \qquad s.t.\ S\tilde{\gamma} \leq 0 \tag{36}$$

For the models of three practices, the distances will be compared with the lower- and upper-bound critical values at the significant level 10% of the number of degrees of freedom, say $df = 1$ (1.642) for 'no equality restrictions' and $df = 2$ for 'two inequality restrictions' (3.804). Similarly, the upper bound for 'four inequality restrictions' ($df = 4$) is 7.094. That implies the null hypothesis will be accepted if the Wald test value is below the lower-bound; whereas it is inconclusive for the value between the lower- and upper-bounds (Mothe et al., 2015; Mohnen and Röller, 2005 and Kodde and Palm, 1986).

5 Results

5.1 Estimation of TFP

Table 1: Regression results of Stage 1 (The gam function)

	lnYi	Err.
lnMi	0.3816***	(0.0044)
Constant	2.4758***	(0.0226)
Observations	12550	
Adjusted R^2	0.88	

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

As showed in Table 1, in Stage 1 of ACF method to estimate TFP (Ackerberg et al., 2006), coefficient of material ($lnM_i = 0.382$) is found significantly by programming gam function.[8]

Then in Stage 2 of ACF method, by applying procedure of GMM, we found the significant marginal effects of capital ($bK_i = 0.0668$) and labor ($bL_i = 0.7078$) as in Table 2. After, with fitted value of y, we calculate ω (so-called TFP stochastic). Next, taking log the unbiased TFP and used it as the dependent variable to analyze impacts of interest determinants as well as complementarity and substitutability of these strategies from these strategies between environmental, innovation, and export practices.

[8] See detail in the section of 'Methodology'

Table 2: Results of Stage2 (GMM for estimating coefficients of capital and labor)

Method: twoStep

Kernel: Quadratic Spectral

Coefficients	Estimate	Std. Error	t value	$Pr(>\|t\|)$
bKi	0.0629	3.65e-06	1.72e+04	0.00e+00
bLi	0.703	6.66e-03	1.05e+02	0.00e+00

J-Test: degrees of freedom is 1

	J-test	P-value
Test $E(g) = 0$:	0.327	0.568

Initial values:

bKi=0.075

bLi=0.683

Convergence code = 0

Function eval.= 323

Gradian eval.= NA

5.2 Complementarity versus substituability

Model 1

Table 3: ESC, General innovation and Export (Model 1)

	Coefficients	Err.term
lnInvest	0.059***	(0.003)
$s_{0\_0\_0}$	−0.564***	(0.055)
$s_{0\_1\_0}$	−0.494***	(0.055)
$s_{1\_0\_0}$	−0.400***	(0.057)
$s_{1\_1\_0}$	−0.357***	(0.058)
$s_{0\_0\_1}$	−0.274***	(0.069)
$s_{0\_1\_1}$	−0.228***	(0.062)
$s_{1\_0\_1}$	−0.130*	(0.067)
Location1	0.381***	(0.022)
Cluster1	0.114***	(0.027)
Tech.Sector2	0.120***	(0.021)
Tech.Sector3	0.184***	(0.035)
Observations	12,385	
R^2	0.163	
Adjusted R^2	0.090	
F Statistic	111.232*** (df = 12; 6865)	

Note: *p<0.1; **p<0.05; ***p<0.01

Estimation results came from fixed effect models. The variables s_{jlk}, where $(j, l, k = 0, 1)$ correspond to the eight combinations (j = ESC, l = General innovation, k = Export)

In Model 1, basing on the equation (18), we obtain the consistent estimate of the parameters of the TFP semi-log model examining strategies between ESC (j), General Innovation (l) and Export (k). As results in Table 3, Impacts of complying environment separately ($s_{1\_0\_0}$) is significantly higher than that of firms having no any practices ($s_{0\_0\_0}$) (namely 'The base'), say 16% ($-0.400 - (-0.564)$), in line with previous empirical findings of Hamamoto (2006) which found the positive link with environmental stringent regulations and productivity through R&D induced. Similarly, Piot-Lepetit and Le Moing (2007) which also pointed out the positive correlation between environmental regulation and business efficiency. Therefore, Hypothesis 1 is supported. We also found that effect of pairwise combinations between environmental compliance and innovation ($s_{1\_1\_0}$) is higher than effects of environment ($s_{1\_0\_0}$) and innovation ($s_{0\_1\_0}$) separately, consistent with the previous evidences that imply environmental mechanism may give more incentive for firms innovative activities (Horbach, 2008; Jaffe and Palmer, 1997). This finding is in link with Eiadat et al. (2008) that reveal the moderating effect of environmental regulation on the impacts of innovation on firm's performance. By this finding, our Hypothesis 2 is likely to be also supported. Further, the impact of combination between environment and export ($s_{1\_0\_1}$) is higher than that of Export separately ($s_{0\_0\_1}$), 14.4% (-0.13 - (- 0.27.4)), that supports Hypothesis 3. Finally, the impact of the strategy combining innovation and export ($s_{1\_0\_1}$) is significantly higher than that of isolated-export ($s_{0\_0\_1}$), then Hypothesis 4 is also supported.

Besides, the significantly positive impacts of coefficients of control variables such as Location, Cluster, Tech-sector are also found. For instance, it can be seen that firms located in the cities like Hochiminh City, Hanoi, Haiphong have higher TPF at 38.0% more compared with counterparts located in other provinces. Further, TFP of firms in Cluster is also higher, 11.4%; and the more advanced technical sector enterprises. The higher TFP they have, say 12.0% and 18.4% higher for firms in Low-medium tech-sector and Medium tech-sector, respectively.

For evaluating complementarity and substitutability of the strategies in Model 1, although these results could give clues about the effects of different combinations of the environmental and crucial explanatory variables, the significance levels and signs of the coefficients independently cannot confirm the complementarity of different strategies consistently. Therefore, complementarity and substitutability test need be done with linear inequality restrictions and the joint distribution of several limitations (Mothe et al., 2015; Mohnen and Röller, 2005). For this work, assessing the complementarity of three practices demands joint tests of two inequality constraints for each pairwise comparison.

The null hypothesis H_0 will be rejected if the test statistic is higher than the upper bound, but accepted if the test statistic is lower than the lower bound, and it would be

Table 4: Supermdularity and submodularity tests for Model 1

Wald test	Pair 1-2	1-3	2-3
Suppermodularity	3.655^N	3.706^N	3.867^R
Submodularity	3.814^R	3.813^R	3.840^R

Note: Tests are based on consistence for TFP function (using Fixed effect regression). The lower and the upper bound calculated at the 10% level of significance are 1.642 for df $= 1$ *and 3.808 for df* $= 2$ (Kodde and Palm, 1986)

inconclusive for values between the two bounds. For Model 1 formed from the equation (18), Table 4 reveals that the pattern of complementarity across three practices and test values programmed based on coefficients in Table 3.[9] Actually, we find the inconclusive evidence of complementarity for all strategies. This implies almost impacts of simultaneous pair combinations of these practices are not clear. Briefly, these findings from two models may reflect that implementing such practices simultaneously may not create more benefit and expected complementary effects may not occur.

Model 2

In Model 2, we discuss effects of combined strategies from four practices of ESC, Product, Process innovation and Export. As results mentioned in Table 5, the impacts of ESC on TFP ($s_{1\_0\_0\_0}$) is also keep significantly higher than that of 'The base' ($s_{0\_0\_0\_0}$), say 16.2%.

The combination Environment-Export ($s_{1\_0\_0\_1}$) has the highest impact in all pairwise combinations between these practices. For instance, it higher than those of Environment-Product innovation pair ($s_{1\_1\_0\_0}$), 18.4% and Environment-Process pair ($s_{1\_0\_1\_0}$), 31.9%. In addition, we found that innovations combined with export ($s_{0\_1\_0\_1}$) and ($s_{0\_0\_1\_1}$) have significantly higher impact, say respectively 27.6% and 18.1% compared with innovation separately ($s_{0\_1\_1\_0}$). This finding is in link with the previous findings of Bigliardi et al., 2012 that shows the positive link between export and performance through innovation effects.

[9] We applied methods of Mohnen and Röller (2005), Kodde and Palm (1986) and programmed in R programming to calculate the test value

Table 5: ESC, Product innovation, Process innovation, and Export (Model 2)

	Coefficients	Err.term
lnInvest	0.060***	(0.003)
$s_{0\_0\_0\_0}$	−0.577***	(0.071)
$s_{0\_1\_0\_0}$	−0.501***	(0.071)
$s_{1\_0\_0\_0}$	−0.415***	(0.072)
$s_{1\_1\_0\_0}$	−0.334***	(0.076)
$s_{0\_0\_1\_1}$	−0.328**	(0.164)
$s_{0\_1\_1\_1}$	−0.246***	(0.088)
$s_{1\_0\_1\_1}$	−0.154	(0.146)
$s_{0\_0\_0\_1}$	−0.287***	(0.082)
$s_{0\_1\_0\_1}$	−0.233***	(0.081)
$s_{1\_0\_0\_1}$	−0.150*	(0.078)
$s_{1\_1\_0\_1}$	−0.002	(0.091)
$s_{0\_0\_1\_0}$	−0.575***	(0.078)
$s_{0\_1\_1\_0}$	−0.509***	(0.073)
$s_{1\_0\_1\_0}$	−0.473***	(0.094)
$s_{1\_1\_1\_0}$	−0.403***	(0.079)
Location1	0.380***	(0.022)
Cluster1	0.114***	(0.027)
Tech.Sector2	0.119***	(0.021)
Tech.Sector3	0.183***	(0.035)
Observations	12,385	
R^2	0.164	
Adjusted R^2	0.091	
F Statistic	67.284*** (df = 20; 6857)	

Note: *p<0.1; **p<0.05; ***p<0.01

Estimation results came from fixed effect models. The variables s_{jxyz}, where $(j, x, y, z = 0, 1)$ correspond to the eight combinations (j = ESC, x = Product innovation, y = Process innovation, z = Export)

Table 6: Test Supermodularity and submodularity for Model 2

Wald test	Pair 1-2	1-3	1-4	2-3	2-4	3-4
Model 3						
Suppermodularity	7.588^R	7.639^R	7.870^R	7.646^R	8.324^R	7.844^R
Submodularity	7.667^R	7.723^R	7.525^R	8.149^R	7.230^R	7.556^R

Note: Tests are based on consistence for TFP function (using Fixed effect regression). The lower and the upper bound calculated at the 10% level of significance are 1.642 for df $= 1$ *and 7.094 for df* $= 4$ (Kodde and Palm, 1986)

Until now, by fixed-effects regression, we have obtained significant results that are likely support our hypotheses. However, to confirm that more accurate significantly, we have to do supermodularity and sub-modularity test to point out the existence of complementarity or substitutability in these strategies. As mentioned before, the significant levels and signs of the coefficients individually cannot confirm the complementary and substitute status of different strategies for Model 2. Therefore, we have to apply the supermodularity and submodularity test by following the approach used in (Mothe et al., 2015; Mohnen and Röller, 2005). Basing on Kodde and Palm (1986) with given significant level, 10%. Our test values presented in Table 6 are compared with the lower bound (1.642, $df = 1$) and the upper bound at degree freedom 4 (7.094, $df = 2$). As a result, because test values of all strategies are larger than the upper-bound, we reject all Null-hypotheses (H_0), that means the effects of these strategies are not clear. These findings imply that implementing such practices simultaneously are inclusive and may not create more benefit compared to implementing separately.

6 Conclusion

Our research examines impacts on TFP of ESC, Innovations, Export participating and ISO with taking into account investigating of complementary and substitutability in an attempt to understand whether different mixed practices are complementary or substituted for enhancing productivity. We use supermodularity theory Milgrom and Roberts (1990, 1995) to form the supermodular function and base on the empirical studies as Mothe et al. (2015); Mohnen and Röller (2005) and Kodde and Palm (1986) to calculate the Wald test values for inequality as well as deriving explanations. In our two-step analysis, we first analyzed the conditional correlation among the practices, and then test the impacts of simultaneous combinations of practices measured as a vector of coefficients, γ. In this sense, we investigate two phases of the semi-log regression and supermodularity test. Our empirical study relied on the five bi-annually survey waves on manufacturing SMEs located in provinces of Vietnam. The panel data is carried out in collaboration between the Institute of Labour Studies and Social Affairs (ILSSA) in the Ministry of Labour, Invalids and Social Affairs (MOLISA) of Vietnam and Department of Economics, the University of Copenhagen with funding from DANIDA.

This study is the first to assess the link between firm productivity and environment, especially for SMEs and more in the context of developing countries by analyzing the pattern of complementarity of different strategies between environment and other interest variables like Innovations, Export according to their impacts on TFP. We found some significant results. First, firms complying environmental protection have significantly higher productivity. Second, the impact of the strategy between ESC and Product innovation on TFP is better. Third, the significant implications of the strategy between Export and Process innovation are found be higher than 'The base' and it also greater than that of Export separately. However, basing on results of supermodularity and submodularity test, the significance of these strategies' impacts on TFP are inconclusive. We still can not confirm whether coefficients of these strategies are significant or not. The status of complementarity and substitutability of these link are still not clear.

In conclusion, with the robust empirical approach, our research, if basing on results of fixed effect regression, Hypotheses 1, 2, 3 and 4 are all supported. However, if basing on results of complementarity and substitutability test, Hypotheses 2, 3 and 4 are inconclusive. Our research, although highlighting the controversial outcomes of these effects, with the robust empirical approach, it also has crucial contributions to literature as well as empirical research. In fact, the present research is the first one effort to study environmental issue under the Porter hypothesis, especially to a developing country. It also the prior one combine Super-modularity and Submodularity test and TFP stochastic. Moreover, we first extended empirically the 'Strong version' of Porter hypothesis associated with export participating for the case of SMEs in developing countries, like Vietnam.

Appendix A: Variable description

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

Added value: is measured by real added value. Data are in VND 1,000,000 (1994 price).

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

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

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

Total labours: Firm size: number of full-time employees.

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

Product innovation: Introduce new product or improve existing product. Dummy coded 1 if firm has new product introduced or improve existing product in last two years.

Process innovation: Introduce new process. Dummy coded 1 if firm has produced having any process change in last two years.

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

Export: Export. Dummy coded 1 if firm has exported.

Location: Geographical location. Dummy coded 1 if firm located in the cities belong to the highest level including Ho Chi Minh City (HCMC), Hanoi and Haiphong, 0 for other provinces.

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

Tech.Sector: Sector of firms. Vector of high-tech levels of firms including (i) Low-tech manufacturing Tech.Sector = 1 (ii) Medium low-tech manufacturing Tech.Sector = 2, (iii) Medium high-tech manufacturing Tech.Sector = 3.

Table 7: Matrix of corporate strategies

Strategies	Model 1			Strategies	Model 2			
S_g	(j)	(l)	(k)	S_g	(j)	(x)	(y)	(k)
0	0	0	0	0	0	0	0	0
1	0	1	0	1	0	1	0	0
2	1	0	0	2	1	0	0	0
3	1	1	0	3	1	1	0	0
4	0	0	1	4	0	0	0	1
5	0	1	1	5	0	1	0	1
6	1	0	1	6	1	0	0	1
7	1	1	1	7	1	1	0	1
–	–	–	–	8	0	0	1	0
–	–	–	–	9	0	1	1	0
–	–	–	–	10	1	0	1	0
–	–	–	–	11	1	1	1	0
–	–	–	–	12	0	0	1	1
–	–	–	–	13	0	1	1	1
–	–	–	–	14	1	0	1	1
–	–	–	–	15	1	1	1	1

Appendix B: Descriptive statistics of data set

Table 8: Summary statistics

Variable	**Mean**	Std. Dev.	Min.	**Max.**	N
Revenue	1633.281	23953.714	0.609	2357089.5	12708
Added value	346.883	1743.986	-978.407	106657.961	12595
Material cost	1250.516	22853.765	-206.606	2269122	12630
Physical asset	2111.258	13311.885	0	779213.063	12780
Investment	270.614	1011.433	0	23831.922	6636
Invest_Dummy	0.51	0.5	0	1	13001
Total labor	14.82	38.106	1	1700	12967
ESC*	0.143	0.351	0	1	13004
New product	0.075	0.263	0	1	13005
Improved product	0.304	0.46	0	1	13004
New process	0.107	0.309	0	1	13005
Export	0.062	0.241	0	1	12944
Province	45.204	26.131	1	80	13002
Production zone	3.852	0.64	1	4	13004
Sector	7.958	6.098	0	20	12946
Owners' education	3.206	1.671	1	8	13003
Onwnership	2.23	1.886	1	10	12997

Source: Calculating from data set SMEs

*Environmental standard certificate

Table 9: Descriptive statistics of dummy variables

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

Source: Calculating from data set SMEs

Table 10: Environmental perceptions

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

Source: Calculating from data set SMEs

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

Table 11: Knowledge levels about environmental law

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

Source: Calculating from data set SMEs

Table 12: The most difficult standard in environmental compliance

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

Source: Calculating from data set SMEs

Table 13: The most costly standard in environmental compliance

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

Source: Calculating from data set SMEs

Table 14: Main purposes of investment

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

Source: Calculating from data set SMEs

Table 15: Descriptive statistics in quantile of key indicators, Unit: million VND

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

Source: Calculating from data set SMEs

Table 16: **Statistics of key indicators by sector in 2015, Unit: million VND**

Sector	**Variable**	**N**	**mean**	**p25**	**p50**	**p75**
Food-beverage	Added value	836	175.98	14.13	32.34	84.67
	Total physical asset	838	3155.17	131.80	467.20	2132.00
	Total labor	837	7.24	2	3	5
	Investment capital	342	123.19	2.52	10.20	42.08
Textiles	Added value	86	323.05	28.47	99.36	241.43
	Total physical asset	86	3880.58	570.00	1707.00	5933.55
	Total labor	86	14.88	3	7	15
	Investment capital	38	201.19	6.31	87.10	273.50
Apparel	Added value	141	740.04	61.33	178.86	576.74
	Total physical asset	141	5389.01	760.00	2524.00	5517.69
	Total labor	140	39.68	4	10	34
	Investment capital	51	160.96	7.15	63.12	210.38
Leather	Added value	61	391.37	20.10	79.32	259.83
	Total physical asset	61	3733.59	300.00	1155.00	3350.00
	Total labor	61	21.13	2	5	18
	I Investment capital	28	431.75	3.68	10.52	31.56
Wood	Added value	291	191.18	26.12	61.35	152.01
	Total physical asset	291	2265.99	295.00	760.00	2150.00
	Total labor	290	10.28	2	4	9
	Investment capital	170	134.58	6.31	21.04	63.12
Rubber	Added value	158	1004.61	89.49	205.39	556.28
	Total physical asset	159	9128.70	1620.00	4071.00	8260.50
	Total labor	159	28	5	8	25
	Investment capital	68	394.76	31.56	105.19	420.77
Non-metallic	Added value	98	488.51	50.56	137.21	413.90
	Total physical asset	98	8013.76	790.00	1984.69	5930.00
	Total labor	98	21.45	4	8	20
	Investment capital	58	213.11	10.52	43.55	193.72
Total	Added value	2602	355.41	25.95	71.47	207.46
	Total physical asset	2646	5341.57	285.00	1087.50	3750.00
	Total labor	2640	14.08	2	4	10
	Investment capital	1295	217.04	6.31	21.04	108.35

Source: Calculating from data set SMEs

Table 17: Environment, Innovation, and Export participating by sector in 2015

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

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

References

Ackerberg, D., Caves, K., and Frazer, G. (2006). Structural identification of production functions. Technical report, University Library of Munich, Germany.

Alpay, E., Kerkvliet, J., and Buccola, S. (2002). Productivity growth and environmental regulation in mexican and us food manufacturing. *American Journal of Agricultural Economics*, 84(4):887–901.

Ambec, S. and Barla, P. (2002). A theoretical foundation of the porter hypothesis. *Economics Letters*, 75(3):355–360.

Ambec, S., Cohen, M. A., Elgie, S., and Lanoie, P. (2013). The porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness? *Review of Environmental Economics and Policy*, pages page 0–16.

Anh, N. N., Mai, N. P., Nhat, N. D., and Chuc, N. D. (2011). Trade liberalization and innovation linkages micro-evidence from vietnam sme surveys. *GLOBALIZATION AND INNOVATION IN EAST ASIA*, page 315.

Anton, W. R. Q., Deltas, G., and Khanna, M. (2004). Incentives for environmental self-regulation and implications for environmental performance. *Journal of Environmental Economics and Management*, 48(1):632–654.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C., et al. (1996). Economic growth, carrying capacity, and the environment. *Environment and Development Economics*, 1(01):104–110.

Barbera, A. J. and McConnell, V. D. (1990). The impact of environmental regulations on industry productivity: direct and indirect effects. *Journal of Environmental Economics and Management*, 18(1):50–65.

Becker, R. A. (2011). Local environmental regulation and plant-level productivity. *Ecological Economics*, 70(12):2516–2522.

Berman, E. and Bui, L. T. (2001). Environmental regulation and productivity: evidence from oil refineries. *Review of Economics and Statistics*, 83(3):498–510.

Bernstein, M. A., Feldman, S. L., and Schinnar, A. P. (1990). Impact of pollution controls on the productivity of coal-fired power plants. *Energy Economics*, 12(1):11–17.

Bigliardi, B., Bertolini, M., Doran, J., and Ryan, G. (2012). Regulation and firm perception, eco-innovation and firm performance. *European Journal of Innovation Management*, 15(4):421–441.

Boyd, G. A. and McClelland, J. D. (1999). The impact of environmental constraints on productivity improvement in integrated paper plants. *Journal of Environmental Economics and Management*, 38(2):121–142.

Brännlund, R. and Lundgren, T. (2009). Environmental policy without costs? a review of the porter hypothesis. *International Review of Environmental and Resource Economics*, 3(2):75–117.

Brännlund, R. and Lundgren, T. (2010). Environmental policy and profitability: evidence from swedish industry. *Environmental Economics and Policy Studies*, 12(1-2):59–78.

Carrión-Flores, C. E. and Innes, R. (2010). Environmental innovation and environmental performance. *Journal of Environmental Economics and Management*, 59(1):27–42.

Co, N. T., Hiep, T. D., and Van Huong, V. (2015). What determines export participation of private domestic manufacturing smes in vietnam? *Asian Social Science*, 11(15):70–75.

Cole, M. A., Elliott, R. J., and Shimamoto, K. (2005). Industrial characteristics, environmental regulations and air pollution: an analysis of the uk manufacturing sector. *Journal of Environmental Economics and Management*, 50(1):121–143.

Cole, M. A., Elliott, R. J., and Strobl, E. (2008). The environmental performance of firms: The role of foreign ownership, training, and experience. *Ecological Economics*, 65(3):538–546.

Conrad, K. (2005). Locational competition under environmental regulation when input prices and productivity differ. *The Annals of Regional Science*, 39(2):273–295.

Conrad, K. and Wastl, D. (1995). The impact of environmental regulation on productivity in german industries. *Empirical Economics*, 20(4):615–633.

Costantini, V. and Crespi, F. (2008). Environmental regulation and the export dynamics of energy technologies. *Ecological Economics*, 66(2):447–460.

Costantini, V. and Mazzanti, M. (2012). On the green and innovative side of trade competitiveness? the impact of environmental policies and innovation on eu exports. *Research Policy*, 41(1):132–153.

Costantini, V., Mazzanti, M., and Montini, A. (2013). Environmental performance, innovation and spillovers. evidence from a regional namea. *Ecological Economics*, 89(2013):101–114.

Dieu, T. T. M. (2006). Greening food processing industries in vietnam: Opportunities and constraints. *Environment, Development and Sustainability*, 8(2):229–249.

Domazlicky, B. R. and Weber, W. L. (2004). Does environmental protection lead to slower productivity growth in the chemical industry? *Environmental and Resource Economics*, 28(3):301–324.

Dowell, G., Hart, S., and Yeung, B. (2000). Do corporate global environmental standards create or destroy market value? *Management Science*, 46(8):1059–1074.

Eiadat, Y., Kelly, A., Roche, F., and Eyadat, H. (2008). Green and competitive? an empirical test of the mediating role of environmental innovation strategy. *Journal of World Business*, 43(2):131–145.

Färe, R., Grosskopf, S., and Pasurka, C. A. (2007). Environmental production functions and environmental directional distance functions. *Energy*, 32(7):1055–1066.

Fleishman, R., Alexander, R., Bretschneider, S., and Popp, D. (2009). Does regulation stimulate productivity? the effect of air quality policies on the efficiency of us power plants. *Energy Policy*, 37(11):4574–4582.

Franco, C. and Marin, G. (2014). The effect of within-sector, upstream and downstream energy taxes on innovation and productivity. *NOTA Di LAVORO*, 103(2013).

Frondel, M., Horbach, J., and Rennings, K. (2008). What triggers environmental management and innovation? empirical evidence for germany. *Ecological Economics*, 66(1):153–160.

González-Benito, J. and González-Benito, Ó. (2006). A review of determinant factors of environmental proactivity. *Business Strategy and the Environment*, 15(2):87–102.

Greenstone, M., List, J. A., and Syverson, C. (2012). The effects of environmental regulation on the competitiveness of us manufacturing. Technical report, National Bureau of Economic Research.

Griliches, Z. and Hausman, J. A. (1986). Errors in variables in panel data. *Journal of Econometrics*, 31(1):93–118.

Hamamoto, M. (2006). Environmental regulation and the productivity of japanese manufacturing industries. *Resource and Energy Economics*, 28(4):299–312.

Hansen, H., Rand, J., and Tarp, F. (2009). Enterprise growth and survival in vietnam: Does government support matter? *The Journal of Development Studies*, 45(7):1048–1069.

Hart, S. L. and Ahuja, G. (1996). Does it pay to be green? an empirical examination of the relationship between emission reduction and firm performance. *Business Strategy and The Environment*, 5(1):30–37.

Horbach, J. (2008). Determinants of environmental innovation-new evidence from german panel data sources. *Research Policy*, 37(1):163–173.

Howard, E., Newman, C., Rand, J., and Tarp, F. (2014). Productivity-enhancing manufacturing clusters: Evidence from vietnam. Technical report, WIDER Working Paper.

Jaffe, A. B. and Palmer, K. (1997). Environmental regulation and innovation: a panel data study. *Review of Economics and Statistics*, 79(4):610–619.

Jaffe, A. B. and Stavins, R. N. (1995). Dynamic incentives of environmental regulations: The effects of alternative policy instruments on technology diffusion. *Journal of Environmental Economics and Management*, 29(3):S43–S63.

Kammerer, D. (2009). The effects of customer benefit and regulation on environmental product innovation.: Empirical evidence from appliance manufacturers in germany. *Ecological Economics*, 68(8):2285–2295.

Kodde, D. A. and Palm, F. C. (1986). Wald criteria for jointly testing equality and inequality restrictions. *Econometrica: Journal of the Econometric Society*, pages 1243–1248.

Koźluk, T. and Zipperer, V. (2013). Environmental policies and productivity growth.

Lanoie, P., Ambec, S., Cohen, M. A., and Elgie, S. (2010). The porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness? *CIRANO-Scientific Publications 2010s-29*.

Lanoie, P., Patry, M., and Lajeunesse, R. (2008). Environmental regulation and productivity: testing the porter hypothesis. *Journal of Productivity Analysis*, 30(2):121–128.

Leeuwen, G. v. and Mohnen, P. (2013). Revisiting the porter hypothesis: An empirical analysis of green innovation for the netherlands. *CIRANO-Scientific Publications Research Paper*, (2013s-02).

Levinsohn, J. and Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies*, 70(2):317–341.

Lewis, J. I. (2007). Technology acquisition and innovation in the developing world: Wind turbine development in china and india. *Studies in Comparative International Development*, 42(3-4):208–232.

Lin, R.-J., Tan, K.-H., and Geng, Y. (2013). Market demand, green product innovation, and firm performance: evidence from vietnam motorcycle industry. *Journal of Cleaner Production*, 40:101–107.

López-Gamero, M. D., Molina-Azorín, J. F., and Claver-Cortes, E. (2009). The whole relationship between environmental variables and firm performance: Competitive advantage and firm resources as mediator variables. *Journal of Environmental Management*, 90(10):3110–3121.

Martino, R. and Nguyen-Van, P. (2014). Labour market regulation and fiscal parameters: A structural model for european régions. Technical report, Bureau d'Economie Théorique et Appliquée, UDS, Strasbourg.

Milgrom, P. and Roberts, J. (1990). The economics of modern manufacturing: Technology, strategy, and organization. *The American Economic Review*, pages 511–528.

Milgrom, P. and Roberts, J. (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of accounting and economics*, 19(2):179–208.

Minh, N. K. and Long, G. T. (2009). Efficiency estimates for the agricultural production in vietnam: a comparison of parametric and non-parametric approaches. *Agricultural Economics Review*, 10(2):62.

Mohnen, P. and Röller, L.-H. (2005). Complementarities in innovation policy. *European Economic Review*, 49(6):1431–1450.

Mothe, C., Nguyen-Thi, U. T., and Nguyen-Van, P. (2015). Complementarities in organizational innovation practices: evidence from french industrial firms. *Economics of Innovation and New Technology*, 24(6):569–595.

Newman, C. and Narciso, G. (2009). The role of technology, investment and ownership structure in the productivity performance of the manufacturing sector in vietnam.

Newman, C., Rand, J., Talbot, T., Tarp, F., et al. (2014a). Technology transfers, foreign investment and productivity spillovers: evidence from vietnam. *Institute for International Integration Studies, Trinity College Dublin. Mimeo.*

Newman, C., Rand, J., Tarp, F., and Anh, N. T. T. (2014b). Exporting and productivity: The role of ownership and innovation in the case of vietnam. Technical report, WIDER Working Paper.

Olley, G. S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6):1263–1297.

Piot-Lepetit, I. and Le Moing, M. (2007). Productivity and environmental regulation: the effect of the nitrates directive in the french pig sector. *Environmental and Resource Economics*, 38(4):433–446.

Porter, M. (1991). April 1991 america's green strategy. *Scientific American*, 264(4).

Porter, M. E. and Van der Linde, C. (1995a). Green and competitive: ending the stalemate. *Harvard Business Review*, 73(5):120–134.

Porter, M. E. and Van der Linde, C. (1995b). Toward a new conception of the environment-competitiveness relationship. *The Journal of Economic Perspectives*, pages 97–118.

Prakash, A. and Potoski, M. (2006). Racing to the bottom? trade, environmental governance, and iso 14001. *American Journal of Political Science*, 50(2):350–364.

Rennings, K. and Rammer, C. (2011). The impact of regulation-driven environmental innovation on innovation success and firm performance. *Industry and Innovation*, 18(03):255–283.

Rubashkina, Y., Galeotti, M., and Verdolini, E. (2015). Environmental regulation and competitiveness: Empirical evidence on the porter hypothesis from european manufacturing sectors. *Energy Policy*, 83:288–300.

Russo, M. V. and Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. *Academy of Management Journal*, 40(3):534–559.

Shadbegian, R. J. and Gray, W. B. (2005). Pollution abatement expenditures and plant-level productivity: a production function approach. *Ecological Economics*, 54(2):196–208.

Shadbegian, R. J. and Gray, W. B. (2006). Assessing multi-dimensional performance: environmental and economic outcomes. *Journal of Productivity Analysis*, 26(3):213–234.

Simpson, R. D. and Bradford III, R. L. (1996). Taxing variable cost: environmental regulation as industrial policy. *Journal of Environmental Economics and Management*, 30(3):282–300.

Tuan, N. P., Chi, T. H., and Ha, N. T. (2012). Impact of firm's environmental performance on its financial performance: Empirical evidence from vietnam's small and medium manufacturing firms.

Vu, V. H. (2012). Private manufacturing smes survival and growth in vietnam: The role of export participation.

Wagner, M. (2003). *The Porter hypothesis revisited: a literature review of theoretical models and empirical tests*. CSM.

Wagner, M. (2008). Empirical influence of environmental management on innovation: evidence from europe. *Ecological Economics*, 66(2):392–402.

Worrell, E., Price, L., Martin, N., Hendriks, C., and Meida, L. O. (2001). Carbon dioxide emissions from the global cement industry 1. *Annual Review of Energy and The environment*, 26(1):303–329.

Yang, C.-H., Tseng, Y.-H., and Chen, C.-P. (2012). Environmental regulations, induced r&d, and productivity: Evidence from taiwan's manufacturing industries. *Resource and Energy Economics*, 34(4):514–532.

Zhang, C., Liu, H., Bressers, H. T. A., and Buchanan, K. S. (2011). Productivity growth and environmental regulations-accounting for undesirable outputs: Analysis of china's thirty provincial regions using the malmquist–luenberger index. *Ecological Economics*, 70(12):2369–2379.