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Essays on environmental performance and productivity of firms: Applications to Vietnamese SMEs

presented by

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Chapter 1

General introduction

This thesis consists of three empirical essays on the Porter hypothesis analysis at firm level and a theoretical essay on the relationship between emission tax, firm's environmental compliance, bribery and political connection.

1.1 Motivation

Environmental compliance and economic performance at firm level is arguably a key component in environmental management. Firms comply with environmental regulations based on their own different utility functions that are not always consistent with environmental management objectives. Governments can issue these regulations to control firm's behaviors. Conventional views argue that there is a trade-off between firm's economic performance and environmental quality, i.e. more stringent environmental regulations can entail a decrease in economic performance (Palmer et al., 1995; Simpson and Bradford III, 1996; Simpson et al., 2004). These views are criticized as they are too static and overlook the influence of environmental compliance in improving innovation (see Porter, 1991 and Porter and Van der Linde, 1995). Meanwhile, revisionists support such regulations under well-designed policy framework because they can encourage firms to recheck and improve the efficiency of resource usage and production. As a result, innovation capacity is improved, which in turn enhances their productivity and competitiveness. The debate gives rise to the conflicting literature on the so-called "Porter hypothesis" (henceforth PH). Most related studies on this relationship have focused on the cases of developed countries while little attention has been paid to the context of developing countries. Three empirical essays in this thesis aim to address the impact of the environmental compliance on firm's economic performance in Vietnam, one of the most prominent emerging countries in the last three decades. In addition, in order to explore the nature of firm's behavior in environmental compliance, this thesis proposes a model showing the impacts of tax on firm's amount of emissions and firm's efforts to commit bribery and maintain political connection.

Productivity is viewed as the most crucial driver of economic growth. Krugman (1994, p.13) propounded that "Productivity is not everything, but in the long run it is almost everything." A substantial number of studies on the relationship between environmental compliance and productivity have been carried out.[1] These studies mainly applied reduced-form models by controlling several relevant factors (Anton et al., 2004; Cole et al., 2008; Carrión-Flores and Innes, 2010). One drawback of existing studies is that total factor productivity (TFP) is assumed deterministic and estimated as the Solow residual of the production function, which could generate biased results due to regressor endogeneity (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Wooldridge, 2009; Ackerberg et al., 2015). The latter is due to the correlation between TFP and inputs of production function.

In addition, beside improving innovation and productivity, environmental compliance may also help firms increase export capacity. For instance, Holladay (2016) found that exporters frequently correspond with more productive firms and use newer facilities than non-exporters. They are likely to have good public images and involve in environmental protection activities. Despite a majority of these studies focus on the impacts of environment and innovation on productivity (see Hamamoto, 2006; Rubashkina et al., 2015; Van Leeuwen and Mohnen, 2017), few studies examine the role of export activities in combining innovation and environmental compliance to enhance TFP. Hence, there would be significant relationships between environmental compliance, innovation, and export activities in explaining firm's productivity.

[1] See Ambec et al. (2013), Brännlund and Lundgren (2009), and Cohen and Shimshack (2016) for a review

Furthermore, Aw et al. (2005) and Esteve-Pérez et al. (2018) found a positive link between firm's productivity and survivability, implying a potential link between environmental compliance and firm survival. Existing studies in this field showed that there is a wide spectrum of determinants affecting firm's survivability. These determinants can be classified into three main sub-categories: firm's internal capacity (Audretsch, 1995; Audretsch, 1997; Yang et al., 2017), owner/top manager's characteristics (see Boyer and Blazy, 2014; Mas-Verdú et al., 2015; Ugur et al., 2016), and external conditions such as interest rate, inflation, regulations (see Manjón-Antolín and Arauzo-Carod, 2008; Yang et al., 2012; Fajnzylber et al., 2009). Particularly, innovation, which can be improved by environmental compliance, is known as a key factor of enhancing firm survival (see Baumol, 2002; Colombelli et al., 2016 and Ugur et al., 2016). Several studies have examined the role of export in firm survival (Wagner, 2013; Mas-Verdú et al., 2015). However, there has been no study examining the impacts of the combination between environmental compliance, innovation, and export on firm's survivability. In this respect, a part of this thesis provides insights into the Porter hypothesis by investigating the link between environmental compliance and firm survival.

According to Krugman (1994), the capacity to improve the standard of living of a nation depends upon its productivity growth. In this way, less productive countries, regions, industries, or enterprises can catch up with higher productive ones, which is summarized by the well-known β- convergence (Barro and Sala-i Martin, 1992, 1997). Studying firm's TFP convergence is important because it allows firms to identify key drivers which help not only to enhance their performance but also catch up with higher productive firms. A considerable volume of research has been conducted on productivity convergence. Several determinants affecting productivity convergence have been found, such as corporate taxes, policies, institutions (McMillan and Rodrik, 2012), international technology transfer (Cameron et al., 2005), and business cycles (Escribano and Stucchi, 2014). Firm's productivity is also affected by micro indicators such as expenditure on R&D, innovation (Gemmell et al., 2016), human resources, and international trading activities (Ding et al., 2016). However, studies investigating productivity convergence at firm level, especially in developing countries is still limited. Environmental compliance could affect firm convergence because it can help firms to increase innovation and productivity. These results can create positive impact on productivity growth, influencing productivity convergence. However, almost all of these studies overlooked the impact of environmental compliance on firm's productivity convergence.

Moreover, firms respond to environmental activities and regulations based on different utility functions. Adherence to these regulations increases environmental gain but it also increases production cost and reduces profit. Hence, firms may want to avoid emission tax by bribing inspectors to under-report emissions. In order to detect the breach of regulations, audit mechanism can be adopted, but it is impossible to audit all firms. Audit is then performed on randomly selected firms. Damania et al. (2004) and Wilson and Damania (2005) proposed a model in which a firm and an inspector cooperate to violate regulations for avoiding taxes. However, in their model, the function of the probability of being audited which is assumed depends merely on the level of underreported emissions. This model ignored the potential impacts of firm's political connection. We therefore propose a theoretical model to show the impacts of emission tax (in the presence of audit and political connection) on firm's environmental emissions.

This thesis focuses on the case of manufacturing SMEs in Vietnam, using bi-annually panel data in the period 2005-2015. Studying SMEs in Vietnam is interesting because SMEs play a crucial role in economic development, particularly in GDP and employment creation. For example, between 2007 and 2009, SMEs accounted for 97% of total enterprises, contributed more than 40% of GDP, and used approximately 51% of the labor force (Phan et al., 2015). SMEs however are also facing difficulties and challenges such as inefficiency in resource utilization, credit and financial constraints, and the obstacles from the regulatory environment (Brandt et al., 2016, p.9). In Vietnam According to Reuters (2015), a considerable number of SMEs have exited in recent years. For instance, although a large of number of new SMEs were established (76,955 new ones in 2013 and 74,842 in 2014), the number of SMEs exiting the market has remarkably increased: 54,277 enterprises collapsed in 2012, 60.737 in 2013, and 67,800 in 2014. Most SMEs are small-scale and used outdated technology. They are also concerned as a main contributor of serious environmental degradation because of unregulated structures and the lack of supervision (Hsu and Zomer, 2015).[2] This environmental degradation has almost reached the climax and could threaten Vietnam's long-term growth (Report of WorldBank, 2016). For instance, Vietnam's environmental performance index (EPI) in 2016 ranked 131 on 190 evaluated countries and territories, belonging to the lowest group in ASEAN (Report of YaleUniversity, 2016).[3] Therefore, empirically, examining the role of environmental practices, innovation, and export in enhancing firm's economic performance is necessary.

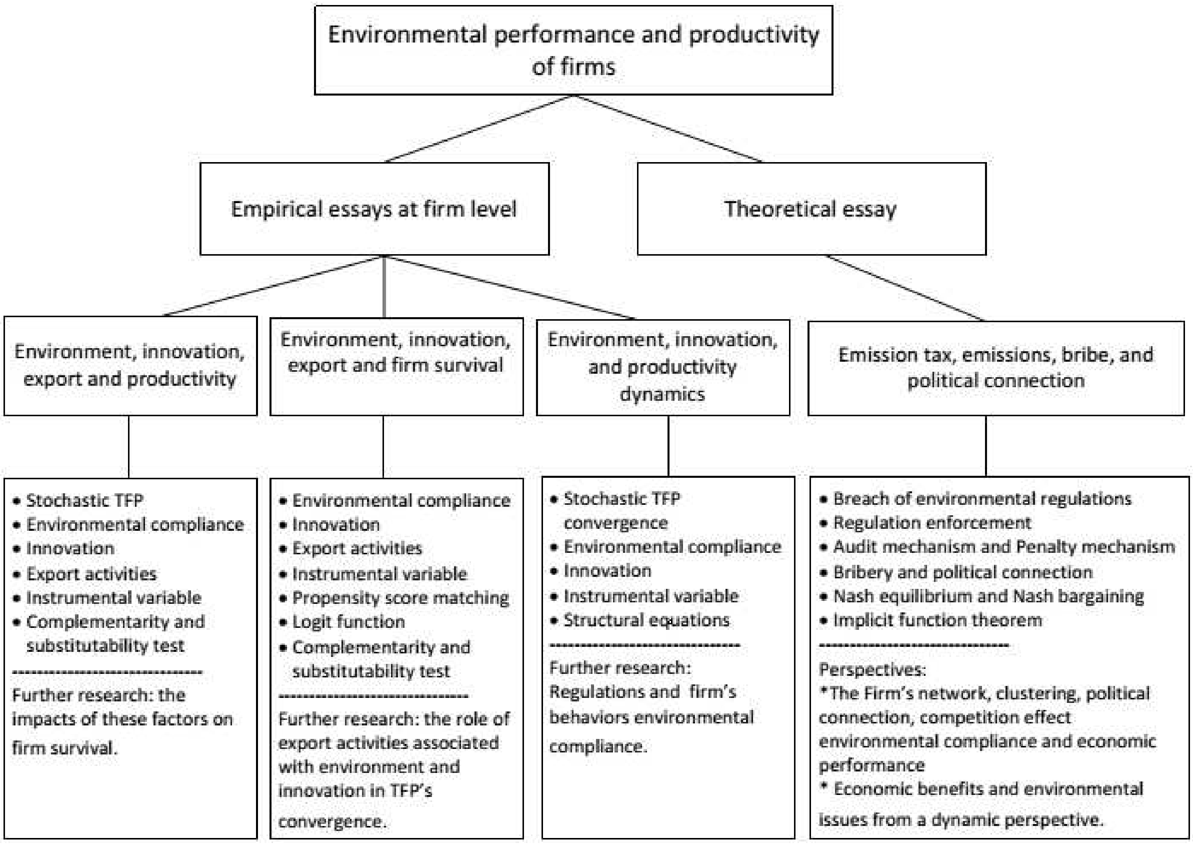

Figure 1.1: An overview of the thesis

[2]Official statistics in 2011 shows that there are more than 1300 villages in Vietnam, in which more than 3200 accredited craft villages operated. They are considered as the firms which use outdated technology and could generate serious environmental pollution by discharging heavy metal wastes like lead, zinc, and aluminium oxides (Hsu and Zomer, 2015).

[3]EPI of Singapore 14/190, Malaysia 63, The Philippines 66, Thailand 91, Brunei 98, Indonesia 107, Vietnam 131, Timor-Leste 138, Cambodia 146, and Laos 148/190 (Yale Environmental Performance Index Report, 2016)

1.2 An overview of the thesis

The thesis includes topics represented in Figure 1.1, which is organized as follows. Chapters 2, 3, and 4 present three empirical essays; Chapter 5 reports theoretical study. Finally, in Chapter 6, concluding remarks and perspectives are synthesized.

Chapter 2 addresses a new approach to studying the Porter hypothesis in a developing country. It first estimates the stochastic TFP and uses an instrumental variable to solve the issue of endogeneity; then complementarity/substitutability test on determinants of TFP is conducted. This chapter provides robust firm-level evidence on the role of firm's environmental compliance in explaining firm's TFP. One of the key findings is that the relationship between environmental compliance and product innovation is complementary. Importantly, export activities can affect the link between this compliance and innovation in explaining firm's productivity.

Chapter 3 looks at the impact of environmental compliance, innovation, and export activities on firm survival. Firstly, the propensity score matching (PSM) is applied to solve the right-truncated issue in panel data. Then, logit model regression is used to estimate the coefficients of interest variables on hazard rate. Finally, the complementarity/substitutability test is conducted to analyze complementary or substitute relationship between these variables in explaining firm survival. One key finding of this chapter is that environmental compliance can enhance firm survival which is also improved if firms implement separated innovation and export activities. The second key finding is that adopting both environmental compliance and product innovation may not help improve firm's survivability. Interestingly, the combination between environmental compliance and export can induce firm's survivability. These findings suggest that appropriate environmental regulations should be combined with other complementary policies such as incentive programs for innovation and/or export. In addition, these regulations should correspond to international environmental standards.

Chapter 4 aims to assess the impacts of *ESC* and environmental treatment on firm's productivity convergence and on firm's innovation performance. In order to provide compelling evidence, the stochastic TFP by accounting regressor endogeneity is estimated, which is used to analyze TFP convergence. Instrumental variable technique is used to solve the endogeneity of the variable *Innovation*. This chapter finds the evidence of a β-convergence for SMEs' productivity. Environmental compliance is unlikely to directly affect TFP convergence. This impact is merely matter once this compliance is combined with innovation.

In **Chapter 5**, we develop a model showing the impacts of tax on firm's environmental emissions, and their efforts to commit bribery and maintain political connection. This study shows that that firms are more likely to commit more bribery when emission tax is higher than a certain threshold. The extended model including political connection shows that this connection can affect the efficiency of emission tax on environmental compliance. Precisely, too high emission tax may encourage firms to maintain political connection. As a result, emission may increase beyond the expected level; and corruption maybe increased. By analyzing firm's and inspector's behaviors in a two-stage bargaining game, this chapter proposes a theoretical framework which can be generalized to explain the mechanism of breaching environmental regulations to avoid emission tax.

Introduction générale

Cette thèse comprend trois essais empiriques en rapport avec l'hypothèse de Porter, ainsi qu'un essai théorique sur la relation entre une taxe sur les émissions, la conformité environnementale de la firme (à travers quoi nous entendons le respect des régulations environnementales mises en place par les autorités publiques), la corruption et les connexions politiques.

Motivation

Il est très souvent avancé qu'il existe un arbitrage entre la performance économique des firmes et la qualité de l'environnement: des régulations environnementales plus fortes entraîneraient une réduction de la performance économique (Palmer et al., 1995; Simpson and Bradford III, 1996; Simpson et al., 2004). Cette vision est critiquée pour son approche statique de l'économie, ainsi que pour sa non prise en compte des potentiels effets des régulations environnementales sur la capacité d'innovation des firmes (see Porter, 1991 and Porter and Van der Linde, 1995). En effet, certains réformateurs supportent ces régulations, dans la mesure où elles encouragent les firmes à améliorer la qualité de leur processus de production et à être plus compétitives. L'idée est que les firmes les moins productives ou les plus inertes se voient obligées d'innover ou d'améliorer leur compétitivité à la suite de ces régulations (qui ont pour effet notamment d'augmenter les coûts de production) si elles ne veulent pas avoir à quitter le marché (remplacées par d'autres firmes qui utilisent leurs ressources de façon plus efficace).

Ce débat a été le déclencheur d'une littérature abondante sur ce qui est aujourd'hui communément appelé "l'hypothèse de Porter" (HP). La plupart des études sur la relation entre les régulations environnementales et la performance économique des firmes se sont concentrées sur le cas des pays développés, alors que peu d'attention a été consacrée aux pays en développement. Les trois essais empiriques compris dans cette thèse ont pour objectif d'analyser la relation entre la conformité environnementale des firmes et leur performance économique, dans un des principaux pays émergents de ces trente dernières années, le Vietnam. De plus, afin d'explorer les déterminants de la conformité environnementale au niveau de la firme, cette thèse comprend un modèle théorique étudiant l'impact d'une taxe environnementale sur le montant d'émissions de la firme, et les incitations que cela pourrait engendrer en terme de corruption ou de connexions politiques.

La productivité est perçue comme étant le principal facteur expliquant la croissance économique. Krugman (1994, p.13) a notamment fameusement avancé que "la productivité n'est pas tout, mais sur le long terme c'est presque tout". Comme souligné auparavant, un grand nombre d'études a été mené sur la relation entre la conformité environnementale de la firme et sa productivité économique.[4] Ces études ont principalement analysé des modèles à équations simultanées, en contrôlant pour certains facteurs standards (Anton et al., 2004; Cole et al., 2008; Carrión-Flores and Innes, 2010). Une potentielle faiblesse de ces études est qu'elles assument que la productivité totale des facteurs (PTF) est déterministique, et donc estimée en tant que "résidu de Solow" de la fonction de production, ce qui peut entraîner de sévères problèmes d'endogénéité (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Wooldridge, 2009; Ackerberg et al., 2015). L'endogénéité peut notamment provenir de la corrélation entre les facteurs de production et la PTF.

Ensuite, en plus d'améliorer la productivité et les incitations à l'innovation, les régulations environnementales pourraient aussi améliorer la capacité des firmes à exporter. Par exemple, Holladay (2016) a trouvé que les firmes exportatrices sont en moyenne plus productives et utilisent des facteurs de production de meilleure qualité que les firmes qui n'exportent pas leurs produits. Les firmes exportatrices ont aussi souvent une bonne image au sein de l'opinion publique, et ont tendance à être engagées dans des activités liées à la protection de l'environnement. Alors que bon

[4] Voir Ambec et al. (2013), Brännlund and Lundgren (2009), et Cohen and Shimshack (2016) pour une revue de la littérature.

nombre d'études se sont concentrées sur l'impact des régulations environnementales et de l'innovation sur la productivité (see Hamamoto, 2006; Rubashkina et al., 2015; Van Leeuwen and Mohnen, 2017), peu d'études ont combiné cette approche avec une analyse détaillée de leur impact sur les activités d'exportation des firmes. Il pourrait ainsi y avoir une relation importante entre la conformité environnementale, l'innovation, les capacités d'exportation et la PTF des firmes.

De plus, Aw et al. (2005) and Esteve-Pérez et al. (2018) ont trouvé une relation positive entre la productivité des firmes et leur probabilité de survie, impliquant ainsi un lien potentiel entre la conformité environnementale des firmes et leur survie sur le marché. Plusieurs études ont montré que la survie des firmes sur le marché est dépendante d'un grand nombre de facteurs. Ces déterminants peuvent être classés en trois principales sous-catégories: la capacité interne des firmes (Audretsch, 1995; Audretsch, 1997; Yang et al., 2017), les caractéristiques du manager/dirigeant (see Boyer and Blazy, 2014; Mas-Verdú et al., 2015; Ugur et al., 2016), et les conditions externes telles que le taux d'intérêt, l'inflation, ou les régulations (see Manjón-Antolín and Arauzo-Carod, 2008; Yang et al., 2012; Fajnzylber et al., 2009). Particulièrement, l'innovation, qui peut potentiellement être affectée par les régulations environnementales, est reconnue comme un facteur clé expliquant la survie des firmes sur le marché (see Baumol, 2002; Colombelli et al., 2016 and Ugur et al., 2016). De nombreuses études ont étudié l'influence des activités d'exportation des firmes sur leur survivabilité (Wagner, 2013; Mas-Verdú et al., 2015). Cependant, il n'y a, à ma connaissance, aucune étude ayant examiné l'impact de la combinaison entre la conformité environnementale des firmes, l'innovation, et leurs activités d'exportation sur leur probabilité de survie. A cet effet, une partie de cette thèse essaye d'apporter de nouvelles idées sur l'hypothèse de Porter, en investiguant le lien entre la conformité environnementale des firmes et leur survie sur le marché.

D'après Krugman (1994), la capacité d'une nation à améliorer la niveau de vie général de sa population dépend de la croissance de sa productivité. L'idée conventionnelle est que les nations, régions, industries ou firmes les moins développées verront leur productivité croître davantage que celle des nations, régions, industries ou firmes les plus développées, leur permettant ainsi d'entamer un processus de convergence économique, bien connu sous le nom de "beta-convergence" (Barro and Sala-i Martin, 1992, 1997). Etudier la convergence de la PTF au niveau des firmes est essentiel, dans la mesure où cela peut nous permettre d'identifier les composantes clés qui permettent aux firmes non seulement d'améliorer leur propre performance économique, mais aussi de rattraper les firmes les plus productives. Un grand nombre d'études a analysé la convergence des productivités des firmes. Plusieurs facteurs affectant cette convergence ont été avancés, tels que l'impôt sur les sociétés, les institutions (McMillan and Rodrik, 2012), le transfert technologique (Cameron et al., 2005), ainsi que les cycles économiques (Escribano and Stucchi, 2014). La productivité des firmes dépend évidemment aussi de facteurs davantage microéconomiques, tels que l'investissement en R&D, l'innovation (Gemmell et al., 2016), les ressources humaines, ou encore les activités commerciales de la firme (Ding et al., 2016). Cependant, le nombre d'études examinant la convergence de la PTF des firmes dans les pays en développement est très limité. Nous pourrions penser que la conformité environnementale des firmes peut affecter la convergence de la PTF, dans la mesure où ceci peut notamment pousser les firmes les moins productives à innover davantage. Ce potentiel effet a été très largement négligé dans la littérature sur ce sujet.

Les firmes répondent aux régulations environnementales d'après la nature de leur fonction d'utilité. L'adhérence et la conformité à ces régulations augmente le gain environnemental au niveau de la société, mais augmente aussi les coûts de production des entreprises, et de ce fait, tend à réduire leur profits. Ainsi, il est possible que les firmes décident d'essayer d'éviter la taxe sur les émissions en versant des pots-de-vin aux inspecteurs, ou encore en faussant le rapport sur leurs véritables émissions. Afin de détecter ces potentielles brèches, un mécanisme d'audit peut être mis en place par les autorités publiques. Il est cependant impossible d'auditer toutes les firmes. L'audit est ainsi performé sur un échantillon de firmes de façon aléatoire. Damania et al. (2004) and Wilson and Damania (2005) ont proposé un modèle dans lequel une firme et un inspecteur coopérent afin de contourner les régulations environnementales dans le but d'éviter la taxe. Cependant, dans leur modèle, la probabilité d'une firme d'être auditée dépend seulement du niveau de sous-déclaration des véritables émissions. Leur modèle ignore les potentiels effets des connexions politiques que la firme peut développer. Ainsi, cette thèse contient un modèle théorique visant à analyser l'effet d'une taxe sur les émissions, en présence d'une possibilité d'audit et de connexions politiques, sur la décision des firmes d'adhérer ou non aux régulations environnementales.

Cette thèse se concentre sur le cas des Petite et Moyenne Entreprises (PME) manufacturières au Vietnam, utilisant une base de données bi-annuelle en panel, sur la période 2005-2015. Etudier les PME au Vietnam est particulièrement intéressant, dans la mesure où ces dernières jouent un rôle crucial dans le processus de développement économique, notamment à travers la création d'emplois. Par exemple, entre 2007 et 2009, les PME représentaient 97% de l'ensemble des firmes, et contribuaient à plus de 40% du PIB, et utilisaient environ 51% de la force de travail (Phan et al., 2015). Les PME font cependant aussi face à des difficultés liées notamment à l'utilisation inefficace des ressources, aux contraintes de crédit et de financement, ainsi qu'à des obstacles provenant des régulations environnementales (Brandt et al., 2016, p.9). Selon Reuters (2015), un nombre considérable de PME au Vietnam a quitté le marché ces dernières années. Par exemple, bien qu'un large nombre de nouvelles PME a été créé (76.955 en 2013 et 74.842 en 2014), le nombre de PME ayant quitté le marché a remarquablement augmenté : 54.277 en 2012, 60.737 en 2013 et 67.800 en 2014 (reference). La plupart des PME opèrent à une petite échelle et utilisent des technologies obsolètes. Il y a ainsi une inquiétude croissante liée à l'opération de ces PME, notamment concernant leur adhérence aux régulations environnementales, dans la mesure où les structures de supervision de leurs activités sont quasiment inexistantes (Hsu and Zomer, 2015).[5] La dégradation de l'environnement au Vietnam a atteint des niveaux inégalés, et pourrait compromettre la croissance à long terme (le rapport de WorldBank, 2016). En effet, le Vietnam est classé 131ème sur 190 pays et territoires dans le monde en 2016 selon l'Index de Performance Environnementale (IPE) (le rapport de YaleUniversity, 2016). Ainsi, étudier empiriquement l'effet de la conformité environnementale, de l'innovation et des activités exportatrices des firmes sur leur performance économique est un sujet important et d'actualité.

[5]Les statistiques officielles en 2011 montrent qu'il existe plus de 1300 villages au Vietnam au sein desquels plus de 3200 artisans accrédités opèrent. Ces derniers sont susceptibles de générer une énorme pollution environnementale en déchargeant dans la nature des métaux lourds tels que du plomb, du zinc ou des oxydes d'aluminium (Hsu and Zomer, 2015).

Plan de la thèse

Cette thèse comporte les sujets présentés dans la Figure 1.1, et est organisée comme suit. Les chapitres 2, 3 et 4 présentent trois essais empiriques; le chapitre 5 reporte un modèle théorique, alors que le chapitre 6 tire certaines conclusions et énumère de possibles nouvelles perspectives de recherche.

Le chapitre 2 a pour ambition d'évaluer l'impact de l'ESC et des régulations environnementales Vietnamiennes sur la convergence des productivités des firmes, ainsi que sur leurs capacités à innover. Afin d'apporter des résultats convaincants, nous avons estimé la PTF stochastique en prenant en compte l'endogénéité des régresseurs, ce qui nous permet d'analyser la convergence de la PTF entre les firmes. La technique des variables instrumentales est utilisée afin de corriger pour l'endogénéité de la variable *Innovation*. Les résultats laissent à penser qu'il y a eu une certaine "beta-convergence" des productivités pour les PME. La conformité environnementale n'affecte pas directement la convergence de la PTF. La conformité environnementale semble affecter cette convergence seulement si l'on prend aussi en compte ses effets sur l'innovation.

Le chapitre 3 utilise une approche nouvelle destinée à étudier l'hypothèse de Porter dans un pays en développement. Nous estimons d'abord la PTF stochastique, et nous utilisons une variable instrumentale pour corriger les problèmes d'endogénéité. Un test de complémentarité/substituabilité sur les déterminants de la PTF est ensuite conduit. Ce chapitre fournit des résultats robustes quant au rôle de la conformité environnementale des firmes sur leur PTF. Un des principaux résultats est la complémentarité entre la conformité environnementale et l'innovation de produit. De façon importante, les activités d'exportation peuvent influencer le lien entre l'adhérence aux régulations environnementales et l'innovation de produit, affectant ainsi directement la PTF des firmes.

Le chapitre 4 étudie l'impact de la conformité environnementale, de l'innovation, ainsi que des activités d'exportation sur la survivabilité des firmes. D'abord, la technique du *Propensity Score Matching* (PSM) est utilisée dans l'optique de corriger le problème de troncation à droite dans la base de données en panel. Ensuite, une régression de type logit est utilisée afin d'estimer les coefficients des variables d'intérêt sur le taux de survivabilité. Enfin, un test de complémentarité/substituabilité est conduit afin d'analyser la relation entre ces variables d'intérêt sur la probabilité de survie d'une firme. Un résultat important est que la conformité environnementale peut augmenter la probabilité de survie des firmes. De façon similaire, implémenter séparément des innovations ou des activités d'exportation peut augmenter la survivabilité. Ensuite, un second résultat important est que les firmes qui, simultanément, adhèrent aux régulations environnementales et innovent, n'ont pas une probabilité de survie plus élevée. De façon intéressante, la combinaison entre la conformité environnementale et les activités d'exportation des firmes peut augmenter leur survivabilité. Ces résutats suggèrent que les régulations environnementales devraient être combinées avec d'autres politiques, par exemple une incitation pour les entreprises à innover et à exporter. Enfin, ces régulations doivent être en accord avec les standards environnementaux internationaux.

Dans le chapitre 5, nous développons un modèle théorique montrant l'effet d'une taxe sur les émissions sur les incitations qu'ont les entreprises à payer des pots-de-vins ou à développer des connexions politiques avec les autorités publiques. Cette étude montre que les firmes sont davantage incitées à payer des pots-de-vin lorsque la taxe sur les émissions dépasse un certain palier. L'extension du modèle, incluant de potentielles connexions politiques, montre que ces connexions peuvent diminuer l'efficacité d'une taxe sur les émissions, en réduisant la conformité environnementale des firmes. De façon plus précise, une taxe sur les émissions trop élevée peut encourager les firmes à développer des connexions politiques. Les émissions des firmes, dans ce cas, pourraient même augmenter au-delà du niveau attendu, tout comme le niveau de corruption. En analysant le comportement des firmes et des inspecteurs dans un jeu de négociation à deux étapes, nous développons un modèle théorique pouvant être généralisé afin d'expliquer les mécanismes par lesquels les firmes et les inspecteurs se mettent d'accord pour contourner les régulations environnementales.

Chapter 2

Synergy effects of environmental compliance, innovation, and export on firm productivity[1]

Abstract

Although numerous studies examining the impacts of environmental compliance and innovation on firm's economic performance, the role of export activities in this nexus has remained unanswered. In order to investigate this issue, we propose and test a modified Porter hypothesis which accounts for four major strategies of firms (environmental compliance, product innovation, process innovation, and export activity). We estimate firm stochastic total factor productivity to investigate the existence of synergy between these strategies. Synergy is found for the following pairs of strategies: environmental compliance and product innovation, process innovation and export activity, and environmental compliance and export activity. The effectiveness of environmental regulations on firm's productivity economic performance should be analyzed with respect to not only innovation, but also export activities.

[1]This chapter is based on a joint work with Phu Nguyen-Van.

2.1 Introduction

From 1990s, a vast literature has been devoted to the impacts of environmental regulations and innovation on firm economic performance. Conventional views argue that an increase in the stringency of these regulations could increase production cost, leading to a decrease in economic performance (Simpson and Bradford III, 1996). These views have been criticized as they are too static and overlook the spillover effects of these regulations on innovation. Meanwhile, revisionists proclaim that such regulations may pressurize firms to increase the efficiency of resources usage and investment in environmentally friendly technologies (see Hamamoto, 2006; Rubashkina et al., 2015; Yang et al., 2012). As a result, innovation capacity could be improved, which in turn enhances firm productivity (Porter, 1991; Porter and Van der Linde, 1995). The debate gives rise to the conflicting literature on the so-called "Porter hypothesis" (henceforth PH).

The majority of studies on the PH have applied reduced-form models by controlling for several relevant factors (Cole et al., 2008; López-Gamero et al., 2009; Van Leeuwen and Mohnen, 2017). One drawback of these studies is that TFP was assumed to be deterministic and was estimated as the Solow residual of the production function. Those results hence may be biased due to endogeneity (Ackerberg et al., 2015; Levinsohn and Petrin, 2003; Olley and Pakes, 1996; Wooldridge, 2009). The latter is due to the correlation between TFP and the inputs of production function.

In addition, almost all of existing studies in this topic have ignored complementarity or substitutability tests in analyzing the impacts of interaction terms. As a consequence, the results may be biased since each independent variable can appear in more than one interaction term. For example, Van Leeuwen and Mohnen (2017) conducted the complementarity/substitutability test to analyze the synergy of different types of innovation on firm TFP in the Netherlands. Mohnen and Röller (2005) and Mothe et al. (2015) also respectively applied this method to examine the complementarity of firm's innovation in European countries and France.

Furthermore, these studies have solely focused on the impacts of the environment and innovation on productivity (see Ambec et al., 2013; Hamamoto, 2006; Rubashkina et al., 2015). The literature has overlooked the role of export activities albeit their important role in explaining firm TFP, especially when they are associated with environmental compliance and innovation. Indeed, export activities may motivate firms to increase environmental compliance if the international market requires higher environmental standards. Exporters also have a good public image and are prone to act on environmental protection (Holladay, 2016).

Finally, most existing research have studied the cases of developed countries such as the US, the European countries and OECD (see Ambec et al., 2013;Brännlund and Lundgren, 2009; Rubashkina et al., 2015), while few studies have examined the case of developing countries (Jha and Whalley, 2015). Obviously the characteristics and capacity of firms in developing countries are different from those in developed countries. Most of these enterprises often lack financial resources, technologies, management skills and environmental perception. Therefore, the PH would not be appropriate in the context of developing countries.

This chapter aims to unveil the synergy of environmental compliance, product innovation, process innovation, and export activities in explaining firm productivity. We use the data of manufacturing small and medium-sized enterprises (SMEs) in Vietnam. We estimate firm stochastic TFP, and then conduct the complementarity/substitutability test to analyze the impacts of pair synergies on firm TFP. We find that the synergy of environmental compliance and product innovation is complementary. Importantly, export activities can affect the link between environmental compliance and innovation in explaining firm productivity. This chapter contributes to the existing literature by combining estimating firm stochastic TFP with the complementarity/substitutability test to evaluate the modified Porter hypothesis. It also enriches knowledge of the Porter hypothesis for the case of a developing country.[2]

[2]Vietnam is a good context for revisiting the validity of the PH, especially for the case of SMEs. SMEs play an important role in economic development. They account for approximately 97% of total enterprises, contributes more than 40% GDP, and uses more 51% labor forces (Phan et al., 2015). They are however facing difficulties and challenges such as inefficiency in resource utilization, credit and financial constraints, and the obstacles from regulatory environment (Brandt et al., 2016). SMEs are also concerned as the main contributor of increasingly environmental degradation (WorldBank, 2016). For instance, in 2016, Vietnam's environmental performance

The remaining parts of Chapter 2 is organized as follows. Section 2.2 begins by laying out a new conceptual framework and the empirical background. The data sources and descriptive statistics are elaborated in Section 2.3. Section 2.4 discusses the methodology. Section 2.5 analyzes the results in light of the relevant literature. Finally, Section 2.6 provides concluding remarks with respect to the modified Porter hypothesis and policy implications.

2.2 A new concept framework for synergy of environment, innovation, and export activities

The traditional Porter hypothesis argues that under a well-designed policy, more stringent environmental regulations may have a positive impact on economic performance. The latter may be through environmentally induced innovation. It might be affected by export activities because the global market requires firms to follow international environmental standards. Joining this market improves firm's innovation capacity and efficiency in resources usage, leading to an increase in productivity. However, for less productive firms, more expenditure on abatement might not improve economic performance (Gray and Shadbegian, 2003) and export performance (Sankar, 2007). Hence, the question is whether there would be significant synergies of environmental compliance, innovation, and export in explaining firm's productivity. We propose a new conceptual framework to test a modified Porter hypothesis by taking into account export activities (see Figure 2.1).

Environmental regulations can boost innovation capacity, which in turn increases firm productivity. Well-designed and flexible regulations are likely to motivate both innovation and environmental performance (Eiadat et al., 2008; Jaffe and Palmer, 1997). For example, Carrión-Flores and Innes (2010) found that the most important drivers of toxic emission reduction in the U.S were as a reaction to these regulations. These positive effects may come from the adaptation of new energy-saving technology (Zhang et al., 2011), and then increase firm's market value (Dowell

index ranked 131 on 190 evaluated countries and territories, belonging to the lowest group in ASEAN (YaleUniversity, 2016).

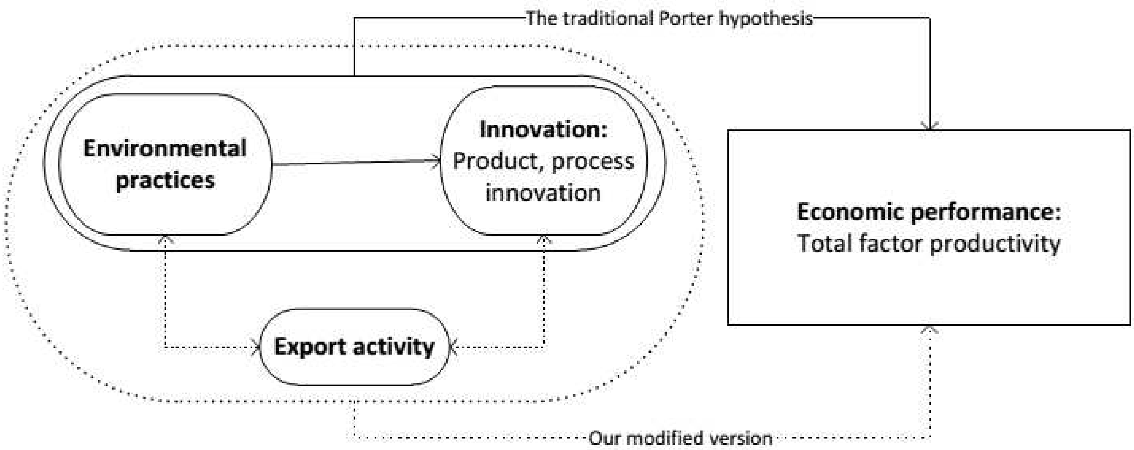

Figure 2.1: A new conceptual framework for the modified Porter hypothesis

et al., 2000). However, the effectiveness of environmental investment may lag in the subsequent years (Hart and Ahuja, 1996) and depends on its nature (Rennings and Rammer, 2011).

The relationship between such regulations and innovation may be influenced by export activities. Anecdotally, these regulations might be complementary with export activities to enhance firm productivity through their positive spillovers on innovation, which in turn increase exports. Indeed, exporters are commonly larger, have a good public image, and release lower emissions per unit than non-exporters (Batrakova and Davies, 2012; Bernard and Jensen, 2004; Cui et al., 2012). In addition, export activities can motivate firms to follow environmentally friendly strategies, encouraging exporters to focus on long-term responsibilities with their present emissions and to be involved in environmental protection activities (Holladay, 2016). They are also expected to comply with international regulations, which can enhance their innovation capacity and productivity (Bigliardi et al., 2012; Costantini et al., 2013; Porter and Van der Linde, 1995). Meanwhile, non-exporters or smaller companies seem to focus on their survivability and profitability, rather than environmental issues.

In addition, exporters show lower emissions per sale value than non-exporters in same industries. For instance, Cui et al. (2012) showed that being an exporter could help Irish manufacturing firms improve pollution abatement and increase investment in new technologies. Such effects can vary across industrial sectors; for example, exporters in low-energy intensive industries often increase energy consumptions, while those in high-energy intensive industries tend to consume less (Batrakova and Davies, 2012). In the U.S., exporters reduce their emissions by 9-13% on average compared to non-exporting firms (Holladay, 2016). Indian exporters in the leather industry follow international environmental standards; their environmental performance depends on the imposition of these standards (Batrakova and Davies, 2012). Therefore, firms tending to export activities often achieve a higher environmental performance; this pair strategy is viewed as a key factor for productivity improvement (Galdeano-Gómez, 2010).

Furthermore, productive firms frequently adopt more efficient technologies to save energy and increase exports more than less productive firms. This comparison might hint a significant link between productivity, environmental performance, and export activities. In fact, highly productive firms pay more attention to environmental issues since their expected business life is longer. Meanwhile, less productive firms may have a lower survivability and do not seriously worry about what environmental consequences caused by their present emission (Konar and Cohen, 1997). Additionally, exporters also have better managerial skills than non-exporters (Melitz, 2003), which can support them in reducing emissions and in increasing innovation and export activities, leading to an increase in productivity (Frankel and Rose, 2005; Roy, 2012).

2.3 Data

For empirical analysis, this chapter relies on a data set of manufacturing SMEs in Vietnam over the period 2007-2015. The data come from bi-annually survey waves which were carried out as the collaboration between the Institute of Labor Studies and Social Affairs (ILSSA) of the Ministry of Labor, Invalids and Social Affairs (MOLISA) and the Department of Economics, University of Copenhagen and funded by the Royal Embassy of Denmark in Vietnam (DANIDA). The surveys were conducted in ten provinces and provided general information about firms (e.g., characteristics, production, economic performance, investment, innovation, export, bureaucracy and informality).[3] After eliminating responses with missing observations, we have a large sample of 4,430 firms and 12,369 firm observations.

Table 2.1: Descriptive statistics

Variables	Definition	Mean	Std.	Min.	Max.
Environmental compliance	Environmental standard certificate (=1 if the firm has the certificate, 0 otherwise.)	0.140	0.347	0	1
Product innovation	Product innovation (= 1 if firm implements a product innovation, 0 otherwise.)	0.357	0.479	0	1
Process innovation	Process innovation (= 1 if firm implements a process innovation, 0 otherwise.)	0.107	0.309	0	1
Export	Export (=1 if the firm has doing export, 0 otherwise.)	0.060	0.238	0	1
KEL	Knowledge about environmental law (= 1 if knowledge level is average and good, 0 if this level is bad and do not concern.)	0.187	0.390	0	1
lnAbacost	Abatement cost (log of cost spending on abatement activities.)	0.299	0.719	0.000	7.956
Firmsize	Firm size (=1 if the firm has less than 9 workers, =2 if there are 9 to 49 workers and =3 for 49 to 300 workers.)	1.365	0.594	1	3
TechSector	Technological sector (= 1 for a low technological, 2 for medium low technological, and 3 for medium high technological firm, respectively.)	1.404	0.595	1	3
Industrialzone	Industrial zone (= 1 if firm located in industrial zone, or processing zone, or economic special zone, 0 otherwise.)	0.051	0.221	0	1
Y	Valued added (1 million VND)	326	1,416	-978	87,178
K	Total physical asset (1 million VND)	1,165	4,157	0	158,485
L	Labor	14	27	0	300
M	Material cost (1 million VND)	1,224	22,903	-207	2,269,122

[3] Provinces: Ha Noi, HCMC, Long An, Lam Dong, Hai Phong, Binh Dinh, Khanh Hoa, Nghe An, Binh Duong

Table 2.1 and 2.2 show that firms following environmental compliance (*ESC*) accounted for a small ratio in total firms (less than 14% on average), in line with the low level of knowledge of environmental law. For instance, the majority of owners or responsible decision makers had poor knowledge of or do not care about environmental law (around 80%), while the number of firms having good and average levels is modest (18.74%). These figures suggest that SMEs might not focus on environmental concerns, but pay more attention to economic performance. In addition, the sample had large variations in the indicators on economic accounts and employment. The majority of the sample consists of micro-scale firms (1-9 employees) accounting for 69.49%, while small firms (10-49 employees) and medium-sized firms (50-300 employees) accounted for respectively 24.48%, and 6.03% of the sample (see Table 2.2). These figures imply that merely a small proportion of the samples could afford spending on environmental compliance and R&D. Furthermore, the technological level of most of SMEs was rather low; firms in low-tech sectors accounted for the highest ratio (65.29%), while the rates of those in medium and high-tech sectors were 28.92% and 5.68% respectively. Only a small ratio of them had a plant located in an industrial zone or a special processing zone (5.13%), which might cause difficulties for the government in monitoring environmental regulations.

In order to analyze the pair synergy between *ESC*, *Process innovation*, *Product innovation*, and *Export*, we define the set of combinations between these strategies. There are 16 combinations in total (S_g or s_{abcd}, where a,b,c,d are *ESC*, *Product innovation*, *Process innovation* and *Export*, respectively). Let $a, b, c, d = \{0, 1\}$, the distribution of these strategies as presented in Table 2.3.

More than 50% of SMEs followed none of the strategies which are viewed as the reference category, and the majority of the sample did not have *ESC* (85.97%) while only 14.02% obtained *ESC*. These figures in Table 2.3 show that firm environmental perception was weak, which is consistent with the small rate of owners/responsible who have good or average knowledge on environmental law (18.74%). Most innovative firms prefer *Product innovation* (22.80%) to *Process innovation* and both *Product-Process innovation* (1.92% and 5.26%). The percentage of the synergy was negatively small, firms combined *ESC* with *Process innovation* accounted for 0.54%; this might because that the majority of firms being of micro-scale and employing

Table 2.2: Distribution of variables in 2007 - 2015

Indicators	2007	2009	2011	2013	2015	Average
ESC (%)	8.73	13.56	16.13	19.04	12.95	14.03
Knowledge on environmental law						
Good and average	18.35	18.85	21.35	18.79	16.52	18.74
Poor and not concern	81.65	81.15	78.65	81.21	83.48	81.26
Innovation						
Product innovation	45.91	42.21	40.58	16.83	32.62	35.72
Process innovation	15.16	13.91	13.12	6.42	4.90	10.68
Export	5.30	5.81	5.98	6.25	6.80	6.03
Firmsize						
1 - 9 employees	66.77	67.11	68.58	71.96	72.98	69.49
10 - 49 employees	26.69	26.36	25.41	22.46	21.27	24.48
50 - 299 employees	6.27	6.52	6.02	5.58	5.75	6.03
Technical sector						
Low-Tech	63.99	64.70	65.40	65.96	66.41	65.29
Medium-Teach	29.43	29.76	28.88	28.38	29.03	28.92
High-low-Tech	6.59	5.53	5.73	5.67	4.90	5.68
Industrialzone	6.31	5.18	4.76	5.42	4.00	5.13
Number of observations	2,474	2,530	2,393	2,400	2,572	12369

Table 2.3: Distribution of synergy strategies

Strategies		Mean	St. Dev.	Min.	Max.	Obs.	Freq.(%)
s_0000	S_0	0.521	0.500	0	1	6,450	52.15
s_0001	S_1	0.014	0.118	0	1	175	1.41
s_0010	S_2	0.019	0.137	0	1	238	1.92
s_0011	S_3	0.001	0.035	0	1	15	0.12
s_0100	S_4	0.228	0.420	0	1	2824	22.83
s_0101	S_5	0.016	0.126	0	1	198	1.60
s_0110	S_6	0.053	0.223	0	1	650	5.26
s_0111	S_7	0.007	0.082	0	1	84	0.68
s_1000	S_8	0.070	0.256	0	1	870	7.03
s_1001	S_9	0.010	0.098	0	1	121	0.98
s_1010	S_{10}	0.005	0.073	0	1	67	0.54
s_1011	S_{11}	0.001	0.035	0	1	15	0.12
s_1100	S_{12}	0.028	0.164	0	1	344	2.78
s_1101	S_{13}	0.005	0.073	0	1	66	0.53
s_1110	S_{14}	0.015	0.120	0	1	180	1.46
s_1111	S_{15}	0.006	0.076	0	1	72	0.58
Number of observations						12,369	
Number of firms						4.430	

low levels of technology (65.29% on average). SMEs' innovation strategies therefore focused on developing new products and improving existing product lines rather than on processes. Their export capacity was low, accounting for the lowest portion in separated practices (6.03%), and approximately 1.0% implemented *Export* and *ESC* simultaneously.

2.4 Methodology

We first estimated firm stochastic TFP, then examined the impacts of *ESC*, *Product innovation, Process innovation*, and *Export* on the TFP by using different estimators: Fixed effects (FE), Random effects (RE), Instrumental variable - fixed effects (FE-IV), and Hausman-Taylor (HT), in which the Hausman-Taylor was selected as the best estimator. We finally conducted the complementarity/substitutability test on these four strategies.

2.4.1 TFP estimation

We use the method proposed by Wooldridge (2009) to estimate firm stochastic TFP. The specification begins with the production function:[4]

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it} \tag{2.1}$$

where y_{it}, k_{it}, l_{it} are respectively value added, capital stock, and total regular employees of firm $i (i = 1, ..., N)$ at period $t\,(t = 1, ..., T)$. TFP corresponds to ω_{it}. As ω_{it} is non-parametric, β_0 is not separately identified and merged with ω_{it}. We follow Wooldridge (2009) to derive the orthogonal conditions for $u_{it}, t = 2, 3, ..., T$ as:

$$E\left(u_{it} \mid k_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{i1}, k_{i1}, m_{i1}\right) = 0 \tag{2.2}$$

where $u_{it} \equiv \xi_{it} + \varepsilon_{it}$. Then, we apply the GMM to solve condition (2.2) to find β_l, β_k and firm's stochastic TFP (in log) is estimated as[5]

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

[4]See detail specification in Appendix 2.B.

[5]In Stata, command *prodest* allows to estimate the stochastic TFP by the method proposed by Wooldridge (2009), which is developed by Mollisi and Rovigatti (2017).

2.4.2 Test for complementarity/substitutability

Suppose that TFP is affected by choosing strategies S_g, where $g = \{1, 2, ..., n\}$ which are the combined strategies. TFP of firm i at time t can be defined as $TFP(S_g, w_{it})$. Then firm i aims to choose one in the set of strategies $\{S_g\}_{g=0}^{g=15}$ such that

$$\max_g \Psi_{it}(S_g, w_{it})$$

where $\Psi_{it} \equiv \ln TFP_{it}$

Firm implements one of the strategies formed from four practices including *ESC* denoted as (a), *Product innovation* (b), *Process innovation* (c), and *Export activity* (d); g is defined as the composites formed from these practices $(abcd)$, where $a, b, c, d = \{0, 1\}$. Then, $S_0 = s\_0000$, $S_1 = s\_0001$, $S_2 = s\_0010, ...$, $S_{15} = s\_1111$.[6] In which, $S_0 = s\_0000$ means that firms do nothing. $S_1 = s\_0001$ means that firms do not implement practices a, b, c but practice d $(a = 0, b = 0, c = 0, d = 1)$ and so on. Finally $S_{15} = s\_1111$ $(a = 1, b = 1, c = 1, d = 1)$ implies that firms conduct four practices simultaneously. The regression function is as follows:

$$\Psi_{it} = \sigma_0 + \sum_{g=0}^{15} \gamma_g S_g + X_{it}'\theta + Z_i'\delta + \mu_i + \varepsilon_{it} \tag{2.3}$$

where S_g is the vector of the strategies; X_{it}' is a set of time-varying control variables such as log of abatement cost and firm size, Z_i' is a set of time-invariant control variables such as technological sector, and industrial zone; i and t are individual firm and time effects; μ_i and ε_{it} are individual and time-specific unobservable effect. We use several methods FE, RE, IV-FE, and HT estimator to ensure the robustness of the results.

The model fixed effect with instrumental variable (IV-FE) is likely to be inconsistent to estimate Eq.(2.3) because of a possibility of endogeneity on the main variable *ESC*. In fact, firms following *ESC* may be more productive. Although this issue can be solved by examining the effect merely for the group of firms who follow *ESC* by law (Brandt et al., 2016), we still believe that there would be omitted

[6] $S_0 = s\_0000, S_1 = s\_0001, S_2 = s\_0010, S_3 = s\_0011, S_4 = s\_0100, S_5 = s\_0101, S_6 = s\_0110, S_7 = s\_0111, S\_8 = s_1000, S_9 = s\_1001, S_{10} = s\_1010, S_{11} = s\_1011, S_{12} = s\_1100, S_{13} = s\_1101, S_{14} = s\_1110, S_{15} = s\_1111.$

variable bias. For instance, the level of pollution that each firm emitted was unable to control for because it was not mentioned in the survey. The legal basis for following *ESC* was vague in what kinds of pollutants need to be abated (Brandt et al., 2016). Due to its inability to control for this, it can be certain that a naive OLS estimator of the impacts of *ESC* on productivity could be biased. Therefore, we propose 'Knowledge about environmental law' *(KEL)* as an instrumental variable (IV) for *ESC*. *KEL* is encoded as a dummy which equals 1 if firm's owner/top manager has either good or average knowledge of the environmental law, 0 if they have either poor knowledge or are not concerned. The IV is valid for two assumptions: relevance and exclusion restriction conditions. With respect to the relevance, *KEL* is significantly correlated with *ESC*, which was checked by the first stage of IV regression on *ESC* (see Table 2.7). In reference to the exclusion restriction, *KEL* could have only indirect impact on TFP through *ESC*. This approach makes perfect sense since no one can argue that TFP affects *KEL*, and otherwise the latter seems unable to influence TFP.

In addition to IV-FE, we propose the Hausman-Taylor estimator as an alternative to the IV-FE because of its advantages. The HT estimator allows us to control for both time-constant and time-varying variables that could correlate with the individual-specific unobservable effect μ_i. More precisely, we use X'_{it} as a set of time-varying control variables such as log of abatement cost and firm size and Z'_i as a set of time-invariant control variables such as technological sector, and industrial zone. The HT estimator would be more efficient than others if there exist correlations between S_g, X_{it}, Z_{it} and μ_i, $E(\mu_i|S_g, X_{it}, Z_{it}) \neq 0$. In order to select the best estimator, Hausman test is used to compare efficient and consistent performance for each two of these four estimators.

For testing complementarity and substitutability, we draw on the plausible guidance in Mothe et al. (2015), Mohnen and Röller (2005), Van Leeuwen and Mohnen (2017). The test aims to examine whether the relationship between these practices in the pair synergy are complementary or substitute in terms of enhancing firm's TFP.[7]

[7] In this study, we examine four strategies: *ESC*, *Product innovation, Process innovation* and *Export*.

For examining the complementarity of a and b, the inequality system is derived as follows:

$$\gamma(10cd) + \gamma(01cd) \leq \gamma(00cd) + \gamma(11cd)$$

where $c, d = \{0, 1\}$; $\gamma(10cd) + \gamma(01cd)$ is the substitute impact of a and b; otherwise $\gamma(00cd) + \gamma(11cd)$ shows the complementary impact. Then, the inequalities are derived for complementarity test of the combined strategies. For instance, considering the complementarity test between practice a and b:

$$\gamma_{4+m} + \gamma_{8+m} \leq \gamma_{0+m} + \gamma_{12+m}, \qquad m = \{0, 1, 2, 3\}.$$

For practice a and c:

$$\gamma_{2+m} + \gamma_{8+m} \leq \gamma_{0+m} + \gamma_{10+m}, \qquad m = \{0, 1, 4, 5\}.$$

Next, the following is for testing complementarity between practices a and d:

$$\gamma_{1+m} + \gamma_{8+m} \leq \gamma_{0+m} + \gamma_{9+m}, \qquad m = \{0, 2, 4, 6\}.$$

For practice b and c:

$$\gamma_{2+m} + \gamma_{4+m} \leq \gamma_{0+m} + \gamma_{6+m}, \qquad m = \{0, 1, 8, 9\}.$$

For practice b and d:

$$\gamma_{1+m} + \gamma_{4+m} \leq \gamma_{0+m} + \gamma_{5+m}, \qquad m = \{0, 2, 8, 10\}.$$

Finally, the inequality for complementarity test the combined strategy between c and d can be formed as:

$$\gamma_{1+m} + \gamma_{2+m} \leq \gamma_{0+m} + \gamma_{3+m}, \qquad m = \{0, 4, 8, 12\}.$$

Denoting

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

We derive the hypotheses for testing complementarity between a and b as:

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

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

Similarly, the substitutability of the combination between a and b can be tested as follows:

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

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

Complementarity and substitutability of the remaining pairs (a and b, a and c, a and d, b and c, b and d, c and d) are conducted in the similar way. We used the Wald test developed by Kodde and Palm (1986) to assess the test(see Appendix 2.C and 2.D).

2.5 Estimated results

2.5.1 Determinants of TFP

Table 2.4 presents the estimated results, using the FE-IV and Hausman-Taylor estimators, those of other estimators (FE, RE) and tests are presented in Table 2.8 in Appendix 2.A. The coefficient associated with *ESC* (s_1000) is statistically significant (p-value < 0.05) and 15.6% higher than that of the reference category.[8] This result is in line with some previous studies. For example, Berman and Bui (2001) found the positive relationship between air regulations and firm TFP in South California. The regulations on water discharge could improve technical efficiency in Frech pig sector (Piot-Lepetit and Le Moing, 2007). However, some others found no significant evidence for this link, including the case of the U.S. pulps and mills, oil refineries, steel mills sectors (Shadbegian and Gray, 2005), manufacturing firms in the U.S. (Becker, 2011), and in 17 European countries (Rubashkina et al., 2015).

In addition, firms separately implement *Product innovation* (s_0100) can improve their productivity (8.0%, $p - value < 0.01$) higher than that of reference category (s_0000). The result is consistent with some studies; for example, Hamamoto (2006) postulated that environmentally-induced R&D, which can improve product innovation, leading to a significant impact on the positive link between environmen-

[8] The reference category S_0 (or s_0000)

Table 2.4: Determinants of TFP

		IV-FE		Hausman-Taylor	
		Coefficients	Std. Error	Coefficients	Std. Error
Intercept				1.704***	0.018
s_0001	S_1	0.283**	0.093	0.412***	0.073
s_0010	S_2	0.096	0.068	0.049	0.048
s_0011	S_3	0.449*	0.178	0.472**	0.181
s_0100	S_4	0.089**	0.033	0.080***	0.018
s_0101	S_5	0.310***	0.078	0.420***	0.064
s_0110	S_6	0.111*	0.052	0.095**	0.032
s_0111	S_7	0.405***	0.108	0.542***	0.087
s_1000	S_8	0.572	0.042	0.156***	0.033
s_1001	S_9	0.436*	0.193	0.449***	0.083
s_1010	S_{10}	0.494*	0.230	0.304***	0.090
s_1011	S_{11}	0.895***	0.266	0.900***	0.195
s_1100	S_{12}	0.532	0.375	0.231***	0.046
s_1101	S_{13}	0.467*	0.186	0.556***	0.108
s_1110	S_{14}	0.334	0.233	0.158**	0.060
s_1111	S_{15}	0.552**	0.196	0.584***	0.106
ln Abatement cost		0.007	0.019	0.059***	0.012
Firm size (10 - 49 employees)		−0.021	0.026	0.392***	0.018
Firm size (50 - 299 employees)		−0.054	0.053	0.546***	0.036
Medium Tech				0.177***	0.017
High-low Tech				0.196***	0.031
Industrial zone				0.111***	0.030
Year 2009		0.067***	0.024	0.092***	0.018
Year 2011		0.170***	0.030	0.190***	0.020
Year 2013		0.156***	0.044	0.204***	0.021
Year 2015		0.205***	0.028	0.230***	0.022
Number of observations		12,369		12,369	
Number of firms		4,430		4,430	
F Statistic		1.396 (*df* = 22; 7922)		399.99*** (*df* = 25; 12343)	

Notes: Estimation based on the Hausman-Taylor estimator. The dependent variable is $\ln TFP$. Significance level: *p < 10%, **p < 5%, ***p < 1%.

tal stringency and firm productivity. Examining the case of European countries, Rubashkina et al. (2015) found significant evidence supporting the positive impact of environmental compliance on innovation.

Finally, *Export activity* also plays an important role in explaining firm productivity. Its impact is highest among separated strategies, higher than the reference category (41.2%). This result is aligned with Galdeano-Gómez (2010)'s finding that export activities can enhance productivity indirectly through their positive spillovers on environmental performance.

2.5.2 Complementarity and substitutability test

The synergy of *ESC* and *Product innovation* (a and b) is complementary since supermodularity is accepted and submodularity is inconclusive (see Table 2.5). This finding implies that following the combination between *ESC* and *Product innovation* can help firms enhance TFP. This finding is in line with that of some previous studies even if they did not employ the complementarity/substitutability test. For instance, environmental regulations could motivate firms to increase their innovation capacity (Horbach, 2008; Jaffe and Palmer, 1997; Rubashkina et al., 2015) and consequently influence the link between innovation and firm economic performance (Eiadat et al., 2008).

Table 2.5: Complementarity/substitutability test

Pair synergy	a and b	a and c	a and d	b and c	b and d	c and d
Supermodularity (complementarity)	0.518^A	3.060^N	0.380^A	0.090^A	0.013^A	3.537^N
Submodularity (substitutability)	4.706^N	1.837^N	1.271^A	7.805^R	1.428^A	0^A

Notes: The Kodde-Plam test statistics are computed based on the results of the Table 2.4. The practice *a, b, c,* and *d* stand for environmental compliance (*ESC*), *Product innovation, Process innovation* and *Export activity*, respectively. 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).

The synergy of *ESC* and *Process innovation* (a and c) is inconclusive because the test shows that submodularity and supermodularity are both inconclusive. This finding indicates that the combination between environmental compliance and process innovation might not help firms have higher productivity than that of adopting separate strategies, environmental compliance, and process innovation. It is in line with Kammerer (2009) who found that the environmental issue was not always a key factor for innovation.

Meanwhile, the synergy between *Product innovation* and *Process innovation* should be accompanied to increase the effectiveness of innovation on TFP because their synergy is complementary (b and c). The finding agrees with Mothe et al. (2015), who pointed out a complementarity between product and process innovation in explaining firm performance in France.

The synergy of *ESC* and *Export* (a and d) is complementary because the supermodularity is accepted. Surprisingly, the submodularity is also accepted, i.e. their relationship in enhancing TFP is substitute. These results imply that the role of export activities in this link might be influenced by innovation. This ambigous relationship could be explained by the substitutability of the synergy of *Process innovation* and *Export* (c and d). This finding seems to be inconsistent with Roy (2012) and Holladay (2016) who found that complying with environmental regulations, exporters could increase their export volume. Similarly, Cui et al. (2012) proclaimed that participating export activities can motivate firms to invest in new technologies and environmental compliance, which in turn may increase firm productivity. The role of export activities in the synergy with environmental compliance should be analyzed with the role of innovation.

2.6 Conclusion

This research is among the first examining the impacts of environmental compliance, innovation, and export activities on a firm productivity. We combine the estimation of firm stochastic productivity and the complementarity/substitutability test to analyze the synergy of these practices on firm's TFP. The chapter accounts for the endogeneity of several factors and its findings partially support the Porter hypothesis. Environmental compliance can be complementary with product innovation in enhancing firm TFP, while its compatibility with process innovation is ambiguous. Process innovation seems not to be efficient in this case because its combination with export activities might not improve firm TFP (their synergy is substitute). This finding may be a reason for the ambiguity in the relationship between environmental compliance and export activities in explaining firm productivity.

These results may provide policy implications. For instance, policies aiming at promoting firm's environmental compliance should be accompanied by policies that encourage firms to strengthen product innovation as well as foster process innovation. Meanwhile, export activities should be promoted in correspondence with an innovation prompting program.

This study contributes to the existing literature in three ways. It is an original study investigating the synergies of environmental compliance, innovation, and export activities in explaining firm's productivity. We propose a new perspective on the Porter hypothesis by including a new variable, *export activity*, in firm's productivity analysis. In addition, we combined the estimation of stochastic TFP and the administration of complementarity/substitutability test to analyze the influences of the synergy. Finally, Chapter 2 enriches our knowledge of this nexus which can be viewed as a modified Porter hypothesis, particularly in a developing country.

2.7 Appendix

Appendix 2.A: Empirical results

Table 2.6: Wooldridge's estimation of the production function

	Coef.	Std. Err.
ln L	0.711	0.007
ln K	0.172	0.005
Hansen's J statistics	385.71	
Hansen's J p-value	0.00	
Number of observations	12427	
Number of firms	4430	

Table 2.7: First-stage IV estimation for ESC

	Coef.	Std. Err.
Knowledge on environmental law	0.032^{***}	0.007
Product innovation	-0.012^{*}	0.006
Process innovation	-0.002	0.009
Export	0.072^{***}	0.018
ln Abatement cost	0.055^{***}	0.005
Firm size (10 - 49 employees)	0.018^{*}	0.011
Firm size (50 - 299 employees)	0.041^{*}	0.022
Year 2009	0.058^{***}	0.007
Year 2011	0.072^{***}	0.008
Year 2013	0.115^{***}	0.008
Year 2015	0.067^{***}	0.008
Number of observations	12,369	
Number of firms	4,430	
Adjusted R^2	-0.457	
F Statistic	50.677^{***} (df = 12; 7933)	

Notes: Estimation for First stage IV regression. The dependent variable is ESC. Significance level: *p < 10%, **p < 5%, ***p < 1%.

Table 2.8: Determinants of TFP, using various estimators

		FE		RE	
		coef.	std.err	coef.	std.err
s_0001	S_1	0.204**	0.067	0.376***	0.053
s_0010	S_2	0.031	0.044	0.120**	0.041
s_0011	S_3	0.377*	0.165	0.467**	0.159
s_0100	S_4	0.069***	0.016	0.123***	0.015
s_0101	S_5	0.248***	0.059	0.366***	0.049
s_0110	S_6	0.058*	0.029	0.178***	0.027
s_0111	S_7	0.316***	0.080	0.542***	0.071
s_1000	S_8	0.073*	0.030	0.147***	0.025
s_1001	S_9	0.218**	0.077	0.399***	0.064
s_1010	S_{10}	0.229**	0.082	0.309***	0.077
s_1011	S_{11}	0.656***	0.178	0.767***	0.163
s_1100	S_{12}	0.134**	0.042	0.234***	0.037
s_1101	S_{13}	0.275**	0.100	0.457***	0.085
s_1110	S_{14}	0.057	0.055	0.181***	0.049
s_1111	S_{15}	0.344***	0.098	0.505***	0.083
ln Abatement cost		0.026*	0.011	0.088***	0.010
Firm size (10 - 49 employees)		−0.011	0.024	0.338***	0.017
Firm size (50 - 299 employees)		−0.042	0.051	0.495***	0.034
Medium Tech				0.169***	0.018
High-low Tech				0.183***	0.032
Industrial zone				0.115***	0.030
Year 2009		0.087***	0.016	0.109***	0.016
Year 2011		0.198***	0.018	0.203***	0.017
Year 2013		0.205***	0.019	0.239***	0.018
Year 2015		0.228***	0.020	0.266***	0.018
Constant				1.688***	0.017
Number of observations		12,369		12,369	
Number of observations		4,430		4,430	
Adjusted R^2		-0.501		0.240	
F Statistic		14.564*** (df = 22; 7922)		157.066*** (df = 25; 12343)	

Notes: Estimation based on FE, RE, IV-FE estimator. The dependent variable is lnTFP. Significance level: *p < 10%, **p < 5%, ***p < 1%.

Appendix 2.B: TFP estimation method

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

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} \tag{2.4}$$

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

Taking logarithm of Eq.(2.4) gives:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it}. \tag{2.5}$$

where $\beta_0 = \ln A_0, \ln Y = y, \ln K = k$ and $\ln L = l$. In addition, the productivity function could be derived as:

$$\omega_{it} = \omega(k_{it}, m_{it}) \tag{2.6}$$

where m_{it} is intermediate inputs.

Assume that

$$E(\varepsilon_{it} \mid l_{it}, k_{it}, m_{it}) = 0, \quad t = 1, \ldots, T. \tag{2.7}$$

Then we have the following regression function:

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

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

To identify β_l, we need three assumptions. The first concerns ε_{it} such that Eq.(2.7) could be derived as:

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

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

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

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

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

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

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

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

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

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

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

and

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

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

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

Estimating β_k and β_l requires investigating the unknown function $f(.)$ and $\omega(.)$. Following Wooldridge (2009), these functions are specified as:

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

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

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

from where the production function can be rewritten as:

$$y_{it} = \zeta_0 + \beta_k k_{it} + \beta_l l_{it} + c_{it}\gamma + \varepsilon_{it}, \quad t = 1, \ldots, T. \tag{2.8}$$

and

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \rho_1(c_{i1}\gamma) + \cdots \rho_n(c_{it-1}\gamma)^n + u_{it}, \quad t = 2, \ldots, T. \tag{2.9}$$

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

Following Wooldridge (2009), the GMM is performed to estimate Regressions (2.8)-(2.9).[9] Once β_k, β_l and β_l are estimated, the firm's TFP (in log) is computed as:

$$\omega_{it} = y_{it} - \beta_k k_{it} - \beta_l l_{it} - \beta_m m_{it} \tag{2.10}$$

Appendix 2.C: Complementarity/substitutability test

Following Mohnen and Röller (2005) and Mothe et al. (2015), we let $\hat{\boldsymbol{\gamma}}$ be the consistent estimator of $\boldsymbol{\gamma}$ and $\tilde{\boldsymbol{\gamma}}$ be the estimator closest to $\boldsymbol{\gamma}$ under the null hypothesis. The Wald test statistic is defined as the minimum of the distance D between $\boldsymbol{S}\tilde{\boldsymbol{\gamma}}$ and $\boldsymbol{S}\hat{\boldsymbol{\gamma}}$. It can be calculated as:

$$\min_{\tilde{\boldsymbol{\gamma}}} (\boldsymbol{S}\tilde{\boldsymbol{\gamma}} - \boldsymbol{S}\bar{\boldsymbol{\gamma}})'[\boldsymbol{S}cov(\bar{\boldsymbol{\gamma}})\boldsymbol{S'}]^{-1}(\boldsymbol{S}\tilde{\boldsymbol{\gamma}} - \boldsymbol{S}\bar{\boldsymbol{\gamma}}), \qquad s.t.\ \boldsymbol{S}\tilde{\boldsymbol{\gamma}} \leq 0. \tag{2.11}$$

D follows a $\chi^2(df)$, $df = 1$ and $df = 4$. The value of D 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 $df = 4$ for 'four inequality restrictions' (7.094). If D is non-negative and greater than the critical value, we reject to null hypothesis, while, the null hypothesis will be accepted if the Wald test value is below the lower-bound; and if the value between the lower- and upper-bounds, it is inconclusive.

Appendix 2.D: Specification test

The regression results are presented in Table 2.8. The first two columns of Table 2.8 are the simple fixed effect models without IV and random effect; the IV-FE is notified in Column 2 in Table (2.4). For FE and RE, the test shows that $\chi^2(22) = 629.24$, $p-value < 2.2e-16 < 0.1$; the null hypothesis H_0 hence is rejected at 1% significant level, and FE is supported to be consistent. For selecting FE and IV-FE, the test shows that $\chi^2(22) = 1.5546$, $p-value = 1 > 0.1$; H_0 could not be rejected at 10% significant level, and FE is better. Next, for selecting FE and Hausman-Taylor estimators, the result shows that $\chi^2(22) = 549.89$, $p-value <$

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

$2.2e - 16 < 0.1$, which rejects H_0 and the Hausman-Taylor estimator is preferred. Finally, the best one is Hausman-Taylor estimator and its coefficients are employed to conduct complementarity and substitutability test.

Chapter 3

Environmental compliance and firm survival: Evidence of Vietnam

Abstract

Several existing studies have examined the role of environmental regulations in enhancing firm economic performance. Yet, the question 'whether environmental regulations can be complementary with innovation and export to strengthen firm survival' has not been adequately responded to. In order to investigate this issue, we propose a modified Porter hypothesis which accounts for the impacts of the synergies of environmental compliance, innovation, and export activities on firm survival. This study shows that environmental compliance can be complementary with process innovation and export to foster firm survival. By contrast, the synergy of environmental compliance and product innovation is substitute in explaining firm survival. Environmental policies should be designed in the way that can motivate innovation and export to foster firm's survivability.

3.1 Introduction

Conventional views argue that these regulations may cause a negative impact on firm economic performance because of an increase in compliance costs. In contrast to this view, Porter (1991) and Porter and Van der Linde (1995) propounded that under a well-designed policy framework, regulations can pressurize firms to use resources more efficiently. As a result, their innovation capacity will be increased, which in turn improves their economic performance. This is the so-called Porter hypothesis (PH).

Environmental compliance may be complementary with innovation and export in enhancing firm productivity. However, whether these combinations can increase firm survival remains underexplored. On the one hand, there is a large number of studies revealing that the synergy is complementary, supporting the PH (e.g. Hamamoto, 2006; Rubashkina et al., 2015; and Yang et al., 2012 among others). On the other hand, some existing studies on this link found negative relationships and also insignificant evidence (Becker, 2011; Palmer et al., 1995; Simpson et al., 2004 among others). In addition, proposing and testing the modified Porter hypothesis by taking into account export activity, Chapter 2 pointed out that the synergy between environmental regulations and export activity on firm productivity might be complementary and substitute. Although firm productivity and survival are positively correlated (Aw et al., 2005, Esteve-Pérez et al., 2018), the existing literature has not explored the relationship between firm survival and the pair-synergies from the strategies of environmental compliance, innovation, and export activities.

The nature of these impacts can be heterogeneous across different research contexts geographically, i.e. developed countries versus developing countries. It is worth accounting for this perspective in analyzing the PH. However, the majority of studies on this domain at firm-level have been conducted mainly in the context of developed countries such as the U.S., European countries, OECD (see Ambec et al., 2013; Brännlund and Lundgren, 2009; Rubashkina et al., 2015). Meanwhile, rather little research concerns the context of developing countries (Jha and Whalley, 2015). This chapter aims to provide further knowledge to modify the PH by examining the impacts of the pair-synergies between environmental compliance, innovation, and export activities on firm survival in Vietnam, one of the most prominent developing countries in last three decades. There are four research questions: (i) Is there positive impact of environmental compliance on firm survival? (ii) In term TFP enhancing, whether the synergy between environmental compliance and export activities is complementary? (iii) Whether firms can increase their survivability if they implement both strategies of environmental compliance and innovation? and finally (iv) Is there a synergy between innovation and export activities in increasing firm's survivability?

We use the dataset of manufacturing SMEs in Vietnam in the period 2007-2015, applied attrition treatment, propensity score matching and a log-log hazard models to investigate the determinants of firm survival. The complementarity/substitutability test is also conducted to examine the synergy between these practices in explaining firm survival. The research shows that the synergy of compliance with environmental compliance *(ESC)*.[1] If *ESC* is combined with process innovation, the synergy can improve firm survival. In contrast, if *ESC* is combined with product innovation, the synergy may not improve firm survival. In addition, *ESC* may be complementary with export activity in enhancing the chance of firm survival.

The remaining parts of this chapter are organized as follows. Section 3.2 begins by laying out the empirical background from which hypotheses are derived. The data sources and a treatment for truncation issues are elaborated in Section 3.3. Section 3.4 discusses the methodology. Section 3.5 analyses the results in light of the relevant literature. Finally, Section 3.6 provides concluding remarks regarding of the modified Porter hypothesis and policy implications.

[1]The compliance with environmental compliance of firms is proxied by obtaining *ESC*. *ESC* is formed under official legal documents such as: the Law on Environmental Protection issued from 2005, Decree 80/2006 and Decree 29/2011 instruct how to implement the Law. *ESC* is adopted for some certain sectors. Firms in these sectors have to own *ESC* by adapt full of criteria in environment investment assessment (EIA) that instituted at Degree 29/11. While, firms which are not in these sectors are not obligated owing *ESC*, but they are also required to sign an environment protection commitment (Brandt et al., 2016).

3.2 A new conceptual framework on firm survival

Chapter 2 found that the modified Porter hypothesis included the role of export activity associated with the environment and innovation in analyzing firm productivity. Some studies also reveal a positive relationship between firm's productivity and survivability. Hence, there would be a significant impact of environmental compliance associated with innovation and export on firm survival, which will be analyzed in correspondence to the following conceptual framework (Figure 3.1).

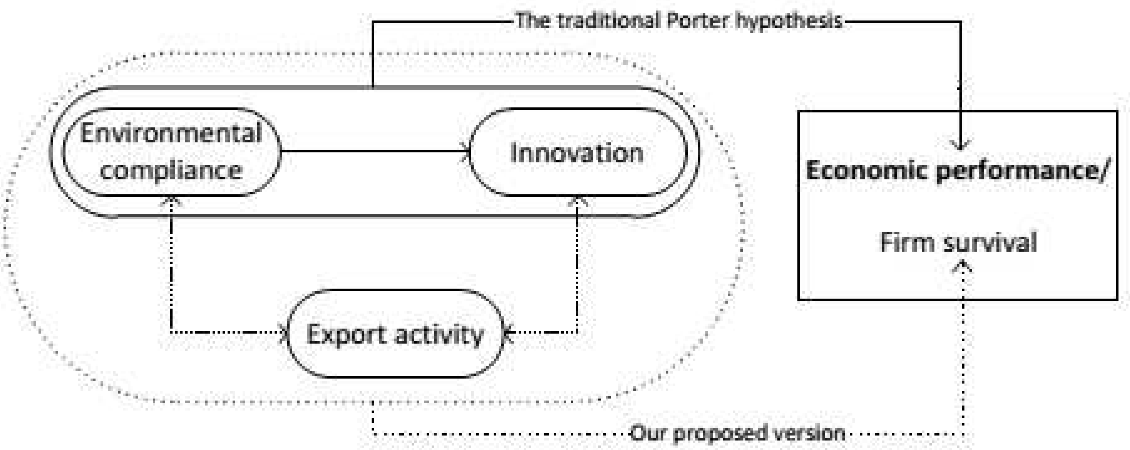

Figure 3.1: A conceptual framework on environmental compliance and firm survival

3.2.1 Environmental compliance and firm survival

A "win-win" relationship proposed by Piot-Lepetit and Le Moing (2007) revealed that investment in environmental compliance can be off-set by economic performance. However, such compliance might increase production cost and reduce profitability and productivity growth. Most of firms think that environmental compliance has negative influence on their business performance because compliance cost may not be integrated into the added value of products. Only few of them gain competitive advantages from this compliance (Simpson et al., 2004). The direct effect of environmental regulations on productivity depends on allocating resources for abatement, while its indirect effects can increase or reduce firm TFP (Barbera and McConnell, 1990). For instance, albeit the U.S. enterprises located in the regions where compliance cost is higher may have higher productivity, the average impact on manufacturing enterprises may be negative across regions (Becker, 2011). Likewise, Shadbegian and Gray (2006) proclaimed that spending more on pollution treatment may reduce firm's efficiency.

Environmental regulations may have a positive pressure on firm environmental compliance through an increase in technological investment and production process. As a result, innovation capacity is increased, which in turn enhances economic performance. This view is supported through empirical evidences which were pointed out in severy studies (see Hamamoto, 2006, Berman and Bui, 2001; Yang et al., 2012; and Piot-Lepetit and Le Moing, 2007). In addition, such improvement of productivity and competitiveness can support firms to increase their survivability (Aw et al., 2005; Esteve-Pérez et al., 2018; and Hiller et al., 2017). Firm's survivability is one of the most important indicators to evaluate economic performance; it could be affected by several determinants which are categorized into three groups. The first consists of the product life cycle, industrial growth, economic scale (see Manjón-Antolín and Arauzo-Carod, 2008; Yang et al., 2017); government support, credit access ability, legal formality (Fajnzylber et al., 2009). The second consists of age, gender, education, and professional experience of owner/responsible (see Boyer and Blazy, 2014; Ejermo and Xiao, 2014; Mas-Verdú et al., 2015; Ugur et al., 2016 for a review), location and legal ownership structure, or other affecting to managerial capacity of firms (Hansen et al., 2009). The third includes firm size, operation experience, ownership structure, technological level, innovation, and export activity, and other internal factors (Audretsch, 1995; Audretsch, 1997; Yang et al., 2017). This review shows that there would be a significant relationship between environmental compliance and firm survival. However, studies on this link are still underexplored.

3.2.2 Environmental compliance and innovation

Following the seminal papers of Porter (1991) and Porter and Van der Linde (1995), the role of environmental regulations associated with innovation on firm economic performance has been considerably examined. Regulations can motivate firms to reduce inefficient output and use environmentally friendly technologies (Eiadat et al., 2008). As a result, innovation capacity is improved, leading to an increase in productivity (Hamamoto, 2006; Rubashkina et al., 2015; Yang et al., 2012) which, in turn, can improve firm survival (Aw et al., 2005; Esteve-Pérez et al., 2018; Hiller et al., 2017). Hence, there would be significant impacts of the synergy between environmental regulations and innovation on firm survival.

The success of innovation however is not always linear; its impact depends on several factors. For example, Reid and Smith (2000) pointed out that implementing the strategy of innovation might sometimes slow down firm development. This impact varies across firm's amplitude of innovation strategies (Holmes et al., 2010), and following a major innovation plan might reduce firm survival (Buddelmeyer et al., 2009). In addition, the impact of innovation varies according to environmental regulations (Carrión-Flores and Innes, 2010; Eiadat et al., 2008). Under such regulations, firms can increase R&D expenditure which can improve innovation capacity, leading to an improvement in firm survival (Rexhäuser and Rammer, 2014; Ugur et al., 2016; Vismara and Signori, 2014). However, the impact of innovation might be heterogeneous across different measurements of innovation (Cefis and Marsili, 2005). The latter therefore can be categorized into product and process innovation in analyzing its impacts on firm survival with respect to environmental regulations.

3.2.3 Environmental compliance, innovation, and export

The impact of environmental regulations on firm survival may vary across export activities. For instance, Galdeano-Gómez (2010) proclaimed that firms tending to export are likely to align with higher environmental performance which may also increase their survivability. In Germany, Wagner (2013) however pointed out that following a separate export strategy might not help firms enhance their survival. Exporters are different from non-exporters in several aspects such as having larger scales and adopting newer and environmental friendly technologies (Melitz, 2003). As a result, they have better public image and lower emissions per output (Bernard and Jensen, 2004; Cui et al., 2012; Holladay, 2016).

In addition, participating export activities can help firms to be complementary with environmental regulations. For example, export activities are expected to be more compatible with international environmental standards, which in turn boost innovation capacity, brand name, and productivity (Costantini et al., 2013; Porter and Van der Linde, 1995). Therefore, exporters may have higher productivity and are frequently located in places where these regulations are stricter. In such conditions, exporters are required to have better managerial skills in order to increase their innovation capacity and reduce emissions. This effect may come from the spillover of managerial and technological innovation (Frankel and Rose, 2005), and be fostered if export activity is associated with R&D expenditure (Inui et al., 2017). Consequently, in association with environmental regulations, export activity can increase its role in strengthening firm survival.

Finally, countries with more stringent environmental regulations are likely to become surplus exporters of pro-environmentally new technologies (Costantini and Melitz, 2008). The combination between innovation and environmental compliance can strengthen export capacity. International trade also motivates firms to comply with global environmental standards, particularly in trading with countries where these standards are more stringent (Prakash and Potoski, 2006). For example, a decline in export volume is viewed as the signal of increasing in the probability of hazard of Danish manufacturing enterprises. Similarly, productive exporters found are likely to maintain their export market longer than less productive ones (Hiller et al., 2017; Farinas and Ruano, 2005; Wagner, 2010, 2013). Lacking innovation could be threaded, causing firm's hazard (Atkeson and Burstein, 2010; Costantini and Crespi, 2008). Hence, innovation associated with export activities may have a significant influence on firm's survivability.

3.3 Data

3.3.1 Data sources

This chapter relies on the data of manufacturing SMEs in Vietnam over the period 2007 - 2015. The data includes bi-annual survey waves was carried out as the collaboration between the Institute of Labor Studies and Social Affairs (ILSSA) in the Ministry of Labor, Invalids and Social Affairs (MOLISA) of Vietnam and

Department of Economics, the University of Copenhagen, and was financially funded by DANIDA. From 2007, each wave used as many repeated firms in the previous survey as possible, and firms dropping out would be replaced. The issue of attrition may have appeared because we did not know actual reasons why firms withdrew from the study.[2] Because data on information about the environment were available from 2007, the 2007 wave was used as the base and to observe the survival of firms in the 2007 wave and their survival over time. Since survivors repeated over time and could be viewed as the independent observations, we constructed these observations as the pool panel data (Singer and Willett, 1993, 2003).

3.3.2 Treatment for truncation

There were a number of firms that dropped out of the sample. We do not know exactly whether they were actually died, merged, changed the location, or were even unwilling to respond to the survey. Here, the issue of right-truncation appeared. Hence, regression would be biased without truncated treatment because of an overestimation of the exiting rate (Hansen et al., 2009; Wennberg and Lindqvist, 2010). There are some approaches to solving this issue. For example, Hansen et al. (2009) conducted deep interviews with owners whose firms dropped out and asked them the actual reasons for the withdrawal. As an alternative, Dorsett (2010) replaced survey dropouts by using propensity score matching technique (PSM), which was also adopted by Austin (2014).

PSM is applied to solve the issue. We relied on the information such as firm's performance, innovation, and competition that uncensored firms have in the previous wave $(t-1)$ to predict the probability of their survival in wave t. First, we used the wave $(t-1)$ to define censored and uncensored firms in wave t. Next, the sample of wave t was divided into 2 groups: Group 1 included survivors which were available in wave $(t-1)$ and t; Group 2 included those surviving in wave $(t-1)$, but dropped out of the sample of wave t. Then, the PSM is applied to the two groups

[2] The sample was selected based on legal ownerships such as household business and private, partnership, limited liability, and joint-stock companies. Sector codes were linked with international standard industrial classification (ISIC) codes; and the ratio of these sectors was correspondent to sector distribution in 2004 and 2007 reported by GSO (CIEM et al. 2012)

to detect observations in Group 2 which had identical propensity score to those in Group 1 (Austin, 2014; Dorsett, 2010). Those matched observations were viewed as those having higher survival probability in wave t. As a result, we had some clues about those observations that dropped out of wave t and were not matched. Finally, we predicted that they had probably exited.

We applied two matching techniques to the PSM: exact matching and neighborhood matching with caliper = 0.001. First, the exact matching allowed matching individual in Group 2 to Group 1 with the exact propensity score using information at $(t-1)$. For example, Table (3.1) shows that there were 7 matching observations in Group 2, implying that these observations had high probability of surviving in wave t. This procedure was also used for other waves; as a result, the number of detected observation in wave 2009, 2011, 2013 were 12, 3, and 0 respectively. These observations were included into Group 1 to create the 'Exact matched' sample.

Second, following Austin (2014), we used the 'nearest neighborhood matching' to predict the probability of survival of observations that dropped at t, using their information at $(t-1)$. Unlike exact matching, the NNM with caliper allowed us to detect those in Group 2 and Group 1 with quite similar propensity scores. In this case, we chose the caliper level 0.001, which means that the difference in propensity scores between Groups 1 and 2 was allowed to be lower than 0.1%. The NNM gave us more number of observations compared to the exact matching. Table 3.1 shows that 274 observations in Group 2, which had identical propensity scores to Group 1 (for the 2007 survey), are detected. Similarly, the detected observations in waves 2009, 2011, 2013 were 203, 121, and 98 respectively. These observations were included in Group 1 to create the 'Nearest neighborhood matched' sample (NNM), which is viewed as the reflexive image of the survey in wave t.[3]

3.3.3 Descriptive statistics of main variables

Table 3.5 in Appendix 3.A shows that the number of firms having an *ESC* account for a small ratio (14.5%), implying that environmental perception of the

[3]The result of difference in mean for nearest neighbourhood matching is presented in Table 3.4 in Appendix 3.A.

Table 3.1: Samples before and after matching

Indicators	Before matching		Exact matching		NNM with caliper = 0.001	
	Survived	Dropped	Survived	Dropped	Survived	Dropped
2007	2,012	462	2004	455	1,738	188
2009	1599	401	1,585	389	1,396	198
2011	1,283	262	1,279	259	1,162	141
2013	1081	201	1081	201	983	103
Total	6157	1,326	5,949	1,034	5,624	630

SMEs is weak. Most of them focus on improving economic performance through fostering innovation, rather than environmental issues. For instance, firms implementing product innovation account for the largest ratio (38.4%), while only a small ratio of those follow process innovation (12.3%). These figures show that SMEs tend to prefer developing new products. Meanwhile, export capacity of Vietnamese SMEs is still low; in this sample, exporters account for only a modest part (roughly 6.1% in average over years). These figures can be partially explained that because most of SMEs are in the industries using low technology. The definition of variables used in the regression model and the descriptive statistics of other variables are also presented in Table 3.5 in Appendix 3.A.

3.4 Methodology

The conventional maximum likelihood estimation is used for discrete time data to estimate the conditional odds of death at each wave t (Cox, 1972). The simple conventional Cox hazard model is proposed as follows:

$$h(t_j|X_i) = \frac{1}{1 + exp(-[\sum_{k=1}^{J} \sigma_k T_{kit} + \sum_{m=1}^{n} \beta_m X'_{mi} + \sum_{k=1}^{n} Z'_{li} w_l])}, \quad (3.1)$$

where $[T_{1it}, T_{2it}, ..., T_{Jit}]$ is a dummy vector including the values of indexing time periods (waves) $(t_{1it}, t_{2it}, ..., t_{Jit})$; J is a last period observed in the sample. Take the log-transformation of Eq.(3.1):

$$log_e(\frac{h(t_j|X_i)}{1-h(t_j|X_i)}) = \sum_{k=1}^{J} \sigma_k T_{kit} + \sum_{m=1}^{n} \beta_m X'_{mi} + \sum_{k=1}^{L} Z'_{li} w_l \,. \quad (3.2)$$

The logistic regression is used to estimate the impacts of these explanatory variables on the hazard rate (Singer and Willett, 1993, 2003). The firm's objective now is to follow the most appropriate one in the set of strategies S_g (where $g = 1, 2, ..., 16$) such that survival likelihood could be maximized. The discrete time hazard model via standard logistic regression is derived:

$$log_e(\frac{h(t_j|X_i)}{1-h(t_j|X_i)}) = \sum_{k=1}^{J} \sigma_k T_{kit} + \sum_{g=1}^{16} \delta_g S_{git} + \sum_{l=1}^{L} Z'_{li} w_l \,. \quad (3.3)$$

where S_g is the vector of the synergies from four practices; Z_{it} is a set of control variables; i and t are individual firms and time effects.[4]

The synergies are correlated because each practice may be in more than one synergies. Hence, a complementarity/substitutability test needed to be conducted to examine the synergy between these practices in explaining firm survival. Firms can choose one of the synergies formed from four practices (environment compliance (a), product innovation (b), process innovation (c), and export activities (d)); g is denoted as the combinations composed of the practices ($abcd$), where $a, b, c, d = \{0, 1\}$. Then, $S_0 = s\_0000$, $S_1 = s\_0001$, $S_2 = s\_0010$, ..., $S_{15} = s\_1111$.[5] $S_0 = s\_0000$ means that firm did nothing. $S_1 = s\_0001$ means that firms did not implement practice a, b, c but implement practices d ($a = 0, b = 0, c = 0, d = 1$) and so on. Finally $S_{15} = s\_1111$ ($a = 1, b = 1, c = 1, d = 1$), implies that firms conducted simultaneously four practices.[6]

We followed the method used in Mohnen and Röller (2005), Van Leeuwen and Mohnen (2017), and Mothe et al. (2015) to conduct the complementarity/substitutability test. To examine the complementarity between a and b, the inequality system is derived as follows:

$$\delta(10cd) + \delta(01cd) \leq \delta(00cd) + \delta(11cd),$$

[4]See the detail specification in Appendix 3.B.

[5]$S_0 = s\_0000, S_1 = s\_0001, S_2 = s\_0010, S_3 = s\_0011, S_4 = s\_0100, S_5 = s\_0101, S_6 = s\_0110, S_7 = s\_0111, S\_8 = s_1000, S_9 = s\_1001, S_{10} = s\_1010, S_{11} = s\_1011, S_{12} = s\_1100, S_{13} = s\_1101, S_{14} = s\_1110, S_{15} = s\_1111.$

[6]See distribution of s in Table 3.4 in Appendix 3.A.

where $c, d = \{0, 1\}$; $\delta(10cd) + \delta(01cd)$ is the substitute impact of a and b; otherwise $\delta(00cd) + \delta(11cd)$ is the complement impact. Then, we derived the inequalities for complementarity test. For the latter test between practices a and b:

$$\delta_{4+m} + \delta_{8+m} \leq \delta_{0+m} + \delta_{12+m}, \qquad m = \{0, 1, 2, 3\}.$$

Similarly, for practices a and c:

$$\delta_{2+m} + \delta_{8+m} \leq \delta_{0+m} + \delta_{10+m}, \qquad m = \{0, 1, 4, 5\}.$$

For practices a and d:

$$\delta_{1+m} + \delta_{8+m} \leq \delta_{0+m} + \delta_{9+m}, \qquad m = \{0, 2, 4, 6\}.$$

For practices b and c:

$$\delta_{2+m} + \delta_{4+m} \leq \delta_{0+m} + \delta_{6+m}, \qquad m = \{0, 1, 8, 9\}.$$

For practices b and d:

$$\delta_{1+m} + \delta_{4+m} \leq \delta_{0+m} + \delta_{5+m}, \qquad m = \{0, 2, 8, 10\}.$$

And finally, for practice c and d is formulated as:

$$\delta_{1+m} + \delta_{2+m} \leq \delta_{0+m} + \delta_{3+m}, \qquad m = \{0, 4, 8, 12\}.$$

Defining

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

Then, the hypotheses for testing the synergy between a and b is:

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

H_1: $h_0 \geq 0$ or $h_1 \geq 0$ or $h_2 \geq 0$ or $h_3 \geq 0$.

While, the hypotheses for testing substitutability between a and b is formed as follows:

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

H_1: $h_0 \leq 0$ or $h_1 \leq 0$ or $h_2 \leq 0$ or $h_3 \leq 0$.

The complementarity/substitutability test of the remaining pairs (a and c, a and d, b and c, b and d, c and d) are conducted by the similar procedures. We follow Wald test developed by Kodde and Palm (1986) to determine whether these hypotheses are rejected or accepted.[7]

[7] See Appendix 2.C and 2.D

3.5 Estimated results

The regression is processed with three samples: completing, exact matched, and NNM sample; these results are presented in Columns 1, 2, 3 in Table 3.7 respectively. The complementarity/substitutability test was conducted based on the results of the regression on NNM sample, reported in Table 3.2. These results show that the impacts of four separated practices and pair-synergies on firm survival. The first finding reveals that firms obtaining *ESC (s_1000)* can help themselves reduce hazard rate, but this rate is lower than the reference category *(s_0000)*, 8.4% v.s. 21.2%. However, it is unnecessary that the efficiency of *ESC* is lower than that of the reference category because the efficiency of *ESC* may be allocated into its synergies with other practices. In addition, the impact of the separate innovation on firm survival varies across its different measurements. For instance, *Product innovation (s_0100)* has a stronger impact than *Process innovation (s_0010)*, 12.6% v.s. 7.8%. Finally, among the separate practices, *Export activity (s_0001)* has the smallest impact (7.2%).

In order to analyze the synergy between these four practices, we conducted the complementarity/substitutability test. Test results are presented in Table 3.3. Firms implementing both *ESC* and *Product innovation* cannot improve their survivability (the synergy between *ESC* and *Product innovation* (a and b) is substitute in enhancing firm survival).[8] Such findings do not seem to be in line with Porter and Van der Linde (1995), who argued that more stringent environmental regulations may have positive impacts on economic performance through innovation. However, it is likely to align with Conrad and Wastl (1995) and Simpson et al. (2004), who showed the negative influence of environmental compliance on firm performance. It is also consistent with Buddelmeyer et al. (2009) who proclaimed that innovation might not always be successful.

In contrast, environmental regulations may be complementary with process innovation because according to the test, their synergy (a and c) is complementary

[8] In Table 3.3, a complementary relation in explaining firm hazard rate is equivalent to a substitute relation in explaining firm survival.

Table 3.2: Determinants of firm hazard rate

		NNM sample	
s_0000	S_0	-0.212^{***}	(0.019)
s_0001	S_1	-0.072^{***}	(0.004)
s_0010	S_2	-0.078^{***}	(0.004)
s_0011	S_3	-0.069^{*}	(0.011)
s_0100	S_4	-0.126^{***}	(0.008)
s_0101	S_5	-0.077^{***}	(0.004)
s_0110	S_6	-0.085^{***}	(0.004)
s_0111	S_7	-0.081^{***}	(0.003)
s_1000	S_8	-0.084^{***}	(0.005)
s_1001	S_9	-0.070^{***}	(0.005)
s_1010	S_{10}	-0.073^{***}	(0.005)
s_1011	S_{11}	-0.044	(0.024)
s_1100	S_{12}	-0.079^{***}	(0.004)
s_1101	S_{13}	-0.072^{***}	(0.005)
s_1110	S_{14}	-0.073^{***}	(0.004)
s_1111	S_{15}	-0.076^{***}	(0.004)
Environmental treatment		-0.034^{*}	(0.015)
ln Abatement cost		0.001	(0.002)
ln Added value		-0.002	(0.003)
Firm size (10 - 49 employees)		-0.001	(0.009)
Firm size (50 - 299 employees)		-0.002	(0.018)
Medium-Tech		-0.008	(0.007)
High-low-Tech		0.047^{***}	(0.016)
Location (City v.s Province)		0.063^{***}	(0.008)
Difficult to sell		-0.006	(0.007)
Constraint to growth		-0.031^{***}	(0.007)
D2		0.022^{**}	(0.009)
D3		0.036^{**}	(0.012)
D4		$0.023^{\cdot}$	(0.013)
Number of observations		7,301	

Notes: Estimation based on logit model. The dependent variable is dropout of SMEs. NNM is denoted for Nearest neighbourhood matched sample. Significance level: $^{+}p < 10\%$, $^{*}p < 5\%$, $^{**}p < 1\%$, $^{***}p < 0.1\%$.

in explaining firm survival. Such a combination may help firms increase the likelihood of survival. A possible explanation is that the investment in environmental compliance of SMEs has not been efficient and created any significant results in environmental performance to foster innovation capacity. Firms might also be unable to absorb the positive impact of process innovation to enhance their productivity and survivability.

Interestingly, environmental regulations can be complementary with export activities in improving firm survival (the synergy of a and b is complement). It means that combination between these two practices may help firms to increase their survivability. That is because the positive spillovers of the environment to innovation or/and export activities can be improved if firms follow international environmental standards. However, this impact might be heterogeneous across innovation types, technical-based levels, firm-size, and cultural contexts (Cefis and Marsili, 2005; Mas-Verdú et al., 2015; Rosenbusch et al., 2011). This implies that these regulations can enhance the competitiveness of exporters and should be considered in designing export promoting policies.

Table 3.3: Test complementarity and substitutability for matched sample using NNM

Pair synergy	a and b	a and c	a and d	b and c	b and d	c and d
Suppermodularity (complementarity)	0.072^{A}	4.057^{N}	2.266^{N}	0.961^{A}	0^{A}	2.511^{N}
Submodularity (substitutability)	1.826^{N}	0^{A}	0^{A}	4.549^{N}	9.510^{R}	4.081^{N}

Note: The Kodde-Plam test statistics are computed based on the results of the Cloglog model. The practice a, b, c, and d stand for Environmental compliance, Product innovation, Process innovation and Export activity, respectively. 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)

Finally, the combination between *Product innovation* and *Export activity* might not help firms improve survivability (the synergy of b and d is substitute in explaining firm survival). This result is in line with Boyer and Blazy (2014) and Buddelmeyer et al. (2009), who pointed out that innovative firms might have lower survivability than non-innovative firms. Whereas, it seems to be efficient if following both *Product innovation* and *Process innovation* (the synergy of b and c is substitute in explaining firm's survivability).

3.6 Conclusion

This chapter investigates the impacts of the synergies of environmental compliance, innovation, and export activities on firm survival, using the panel data of manufacturing SMEs in Vietnam. It drew on the discrete hazard model to derive the logistic regression model and applied the complementarity/substitutability test to analyze the synergies of these strategies on firm survival.

Complying with environmental regulations can be complementary with process innovation in increasing firm survival. Meanwhile, the synergy of environmental compliance and product innovation is substitute. Importantly, SMEs can improve their survivability if they follow both strategies of compliance and export activities. These results may provide policy implications. First, in general, appropriate environmental policies should be combined with other complement policies such as incentive programs for innovation and/or export. Second, policies should focus on improving product innovation. Additionally, an incentive program is necessary for fostering process innovation. Environmental regulations should conform to international standards and be associated with export promoting programs. In such circumstances, governments may provide favorable conditions to encourage firms to obtain international environmental certificates.

In conclusion, the contribution of this chapter to the existing literature is twofold. First, it is an original study that examines the compatibility or substitutability of environmental compliance with innovation and export in improving firm survival. We propose a new perspective on the Porter hypothesis by taking into account *Export activity* with respect to a firm survival analysis. Second, this research enriches knowledge of the Porter hypothesis in the context of developing countries.

3.7 Appendix

Appendix 3.A: Descriptive statistics and empirical results

Table 3.4: Difference in mean for NNM with caliper = 0.001

Indicators	**2007**	**2009**	**2011**	**2013**
ln Added value	-0.137	0.136	0.084	-0.154
Export activity	-0.004	-0.020	-0.008	-0.041
Product innovation	0.058	-0.010	0.058	0.010
Process innovation	-0.029	0.025	0.033	-0.041
Difficult to sell product	-0.022	0.015	0.117	-0.020
Constraint to growth	0.004	0.000	0.050	0.000
Technological sector Medium-Tech	0.000	-0.025	-0.058	0.010
High-low-Tech	0.029	-0.015	0.017	-0.010
Location (City v.s. Province)	-0.025	0.017	-0.010	0.031

Table 3.5: Descriptive statistics of main variables

Variables	Definition	N	Mean	Std	Min	Max
ESC	Environmental standard certificate (=1 if the firm has the certificate, 0 otherwise.)	7,301	0.145	0.352	0	1
Export activity	=1 if the firm has export activity, 0 otherwise	7,301	0.061	0.239	0	1
Product innovation	= 1 if firm implements product innovation, 0 otherwise	7,301	0.384	0.486	0	1
Process innovation	= 1 if firm implements process innovation, 0 otherwise	7,301	0.123	0.329	0	1
ln Added-value	Log of added value.)	7,301	4.289	1.578	−1.274	11.376
ln Abatement-cost	Log of expenditure on abatement activities.)	7,301	1.320	3.093	0.000	16.118
Technological sector	= 1 for a low technology, 2 for medium technology, and 3 for medium high technology firm, respectively	7,301	1.412	0.599	1	3
Location	= 1 if firms located in Hanoi, Hochiminh City, or Hai Phong, = 0 in other provinces	7,301	0.401	0.490	0	1
Firm size	=1 if the firm has less than 9 workers, =2 if there are 9 to 49 workers and =3 for 49 to 300 workers	7,301	1.362	0.588	1	3
Environmental treatment	=1 if the firm has environmental treatment activity, 0 otherwise	7,301	0.194	0.395	0	1
Constraint to growth	= 1 if firms encounter some constraint in operate or expand business, 0 if not	7,301	0.184	0.388	0	1
Difficult to sell	=1 if the firm has difficulties in selling their products, 0 otherwise	7,301	0.712	0.453	0	1
D1	Dropout in 2007 (=1 if the firm are still survive, 0 otherwise.)	7,301	0.339	0.473	0	1
D2	Dropout in 2009 (=1 if the firm are still survive, 0 otherwise.)	7,301	0.274	0.446	0	1
D3	Dropout in 2011 (=1 if the firm are still survive, 0 otherwise.)	7,301	0.212	0.408	0	1
D4	Dropout in 2013 (=1 if the firm are still survive, 0 otherwise.)	7,301	0.176	0.380	0	1

Table 3.6: Distribution of synergy strategies

Strategies		N	Mean	St. Dev.	Min	Max	Obs.	Freq.
s_0000	S_0	7,301	0.492	0.500	0	1	3,592	49.20
s_0001	S_1	7,301	0.013	0.114	0	1	96	1.31
s_0010	S_2	7,301	0.020	0.141	0	1	148	2.03
s_0011	S_3	7,301	0.001	0.031	0	1	7	0.10
s_0100	S_4	7,301	0.240	0.427	0	1	1,750	22.97
s_0101	S_5	7,301	0.018	0.133	0	1	132	1.81
s_0110	S_6	7,301	0.061	0.240	0	1	449	6.15
s_0111	S_7	7,301	0.009	0.095	0	1	66	0.9
s_1000	S_8	7,301	0.073	0.261	0	1	536	7.34
s_1001	S_9	7,301	0.008	0.088	0	1	57	0.78
s_1010	S_{10}	7,301	0.007	0.083	0	1	51	0.70
s_1011	S_{11}	7,301	0.001	0.037	0	1	10	0.14
s_1100	S_{12}	7,301	0.028	0.166	0	1	207	2.84
s_1101	S_{13}	7,301	0.004	0.064	0	1	30	0.41
s_1110	S_{14}	7,301	0.017	0.129	0	1	124	1.70
s_1111	S_{15}	7,301	0.006	0.079	0	1	46	0.63

Table 3.7: The impacts of the synergies on firm's survivability

		Competing sample		Exact matched sample		NNM sample	
		(1)		(2)		(3)	
s_0000	S_0	−0.209***	(0.020)	−0.218***	(0.020)	−0.212***	(0.019)
s_0001	S_1	−0.107***	(0.020)	−0.110***	(0.018)	−0.072***	(0.004)
s_0010	S_2	−0.147***	(0.011)	−0.146***	(0.010)	−0.078***	(0.004)
s_0011	S_3	−0.097	(0.064)	−0.100	(0.060)	−0.069*	(0.011)
s_0100	S_4	−0.174***	(0.014)	−0.177***	(0.013)	−0.126***	(0.008)
s_0101	S_5	−0.139***	(0.012)	−0.140***	(0.012)	−0.077***	(0.004)
s_0110	S_6	−0.154***	(0.009)	−0.154***	(0.009)	−0.085***	(0.004)
s_0111	S_7	−0.146***	(0.013)	−0.147***	(0.012)	−0.081***	(0.003)
s_1000	S_8	−0.127***	(0.012)	−0.130***	(0.012)	−0.084***	(0.005)
s_1001	S_9	−0.116***	(0.022)	−0.119***	(0.021)	−0.070***	(0.005)
s_1010	S_{10}	−0.129***	(0.019)	−0.130***	(0.018)	−0.073***	(0.005)
s_1011	S_{11}	0.010	(0.103)	−0.001	(0.097)	−0.044	(0.024)
s_1100	S_{12}	−0.142***	(0.011)	−0.144***	(0.010)	−0.079***	(0.004)
s_1101	S_{13}	−0.123***	(0.026)	−0.125***	(0.024)	−0.072***	(0.005)
s_1110	S_{14}	−0.134***	(0.014)	−0.137***	(0.012)	−0.073***	(0.004)
s_1111	S_{15}	−0.150***	(0.015)	−0.150***	(0.014)	−0.076***	(0.004)
Environmental treatment		−0.022	(0.025)	−0.023	(0.024)	−0.034*	(0.015)
ln Abatement cost		−0.004	(0.003)	−0.004	(0.003)	0.001	(0.002)
ln Added value		−0.004	(0.005)	−0.002	(0.005)	−0.002	(0.003)
Firm size (10 - 49 employees)		−0.0004	(0.014)	−0.002	(0.014)	−0.001	(0.009)
Firm size (50 - 299 employees)		−0.008	(0.026)	−0.012	(0.025)	−0.002	(0.018)
Medium-Tech		0.007	(0.010)	0.010	(0.010)	−0.008	(0.007)
High-low-Tech		0.033·	(0.021)	0.035*	(0.021)	0.047***	(0.016)
Location (City v.s Province)		0.063***	(0.011)	0.063***	(0.011)	0.063***	(0.008)
Difficult to sell		−0.005	(0.010)	−0.007	(0.010)	−0.006	(0.007)
Constraint to growth		−0.038**	(0.011)	−0.035***	(0.011)	−0.031***	(0.007)
D2		0.010	(0.012)	0.008	(0.011)	0.022**	(0.009)
D3		0.006	(0.015)	0.007*	(0.015)	0.036**	(0.012)
D4		−0.013	(0.016)	−0.010	(0.016)	0.023·	(0.013)
Number of observations		7,301		7,301		7,301	

Notes: Estimation based on logit model. The dependent variable is dropout of SMEs. NNM is denoted for Nearest neighbourhood matched sample. Significance level: $^{+}$p < 10%, *p < 5%, **p < 1%, ***p < 0.1%.

Appendix 3.B: Logistic hazard function

Following Singer and Willett (1993, 2003), we let T be an event that firm exits from the market. The probability of exit at time t is assumed as the cumulative distribution derived as:

$$F(t) = Pr(T \leq t) = \begin{cases} \sum_{k=0}^{t} Pr(T = k), & \text{if } T \text{ is discrete} \\ \int_0^t f(s)ds, & \text{if } T \text{ is continuous} \end{cases} \tag{3.4}$$

where $f(s)$ is the probability density function; t and s are the realization of T. The survival function can be formed as:

$$S(t) = 1 - F(t) = Pr(T \geqslant t), \text{ where } S(0) = 1 \tag{3.5}$$

The hazard probability at period t, denoted as $h(t)$, is a conditional probability that an individual experiences the event T at period t, given that the event has not already occurred in any earlier time period $\{T \geq t\}$. Then, the function of hazard-rate is derived as:

$$h(t) = Pr(T = t|T \geqslant t) = \frac{f(t)}{S(t)} \tag{3.6}$$

The hazard model allows us to introduce the predictors into the model. Suppose X_{mi} as a vector of covariates of firm i and Z_{li} as a vector of control variables, then Eq.(3.6) can be reformed as:

$$h(t_j|X_i) = Pr[T_i = t_j|T_i \geq t_j, X_{mi} = x_{mi}, Z_{li} = z_{li}] \qquad \text{where m = 1, 2, ..., n predictors} \tag{3.7}$$

It is possible to apply the conventional maximum likelihood estimation for discrete time data to estimate the conditional odds of dying at each wave t (Cox, 1972). The simple conventional Cox hazard model is proposed as follows:

$$h(t_j|X_i) = \frac{1}{1 + exp(-[\sum_{k=1}^{J} \sigma_k T_{kit} + \sum_{m=1}^{n} \beta_m X'_{mi} + \sum_{k=1}^{n} Z'_{li} w_l])} \tag{3.8}$$

where $[T_{1it}, T_{2it}, ..., T_{Jit}]$ is a dummy vector including the values of indexing time periods (waves) $(t_{1it}, t_{2it}, ..., t_{Jit})$; J is a last period observed in the sample. Take the log-transformation of Eq.(3.8):

$$log_e(\frac{h(t_j|X_i)}{1 - h(t_j|X_i)}) = \sum_{k=1}^{J} \sigma_k T_{kit} + \sum_{m=1}^{n} \beta_m X'_{mi} + \sum_{k=1}^{L} Z'_{li} w_l \tag{3.9}$$

This logistic regression is applied to estimate the impacts of these explanatory variables on the hazard rate (Singer and Willett, 1993, 2003). If we estimate Eq.(3.9) without truncation treatment, the results might be biased. Hence, two regressions are conducted using the 'completing sample' 'exact matched sample' and 'nearest neighborhood matched' sample. By this way, we can do a sensitivity analysis, and select the most appropriate regression (Hansen et al., 2009; Glewwe et al., 2004).

The objective of the firm now is to follow the most appropriate one in the set of strategies S_g (where $g = 1, 2, ..., 16$) such that survival likelihood could be maximized. The discrete time hazard model via standard logistic regression is derived:

$$log_e(\frac{h(t_j|X_i)}{1 - h(t_j|X_i)}) = \sum_{k=1}^{J} \sigma_k T_{kit} + \sum_{g=1}^{16} \delta_g S_{git} + \sum_{l=1}^{L} Z'_{li} w_l \qquad (3.10)$$

where S_g is the vector of the synergies; Z_{it} is a set of control variables; i and t are individual firm and time effects.

Chapter 4

Environmental compliance, innovation, and productivity convergence of firms [1]

Abstract

There is a large body of research examining the impacts of environmental compliance either on firm's economic performance (the strong version of Porter Hypothesis) or on firm's innovation (the weak version of Porter Hypothesis) through a single equation. In contrast, we use structural equations to investigate the nexus between environmental compliance, innovation and firm's total factor productivity convergence. This chapter reveals that there is a strong correlation between innovation and environmental treatment, implying the significant impact of environmentally induced innovation on firm's total factor productivity convergence.

[1]This chapter is based on a join work with Thanh Tam Nguyen-Huu and Minh Nguyen-Khac. WIDER Working Paper 92/2017, UNU-WIDER.

4.1 Introduction

Productivity is viewed as the most crucial driver of economic growth. According to Krugman (1994, p.13), "Productivity is not everything, but in the long run it is almost everything. A country's ability to improve its standard of living overtime depends almost entirely on its capacity to raise its output per worker." In this way, entities like countries, regions, industries, or enterprises with lower productivity could catch up with those which have higher productivity, which is called β-convergence (Barro and Sala-i Martin, 1992, 1997). Much of the existing literature on productivity convergence focuses on a β-convergence at country, region and/or industry level,[2] while the TFP convergence at firm level has remained under-explored. Investigating determinants of firm's TFP convergence is of importance because it allows firms to define key drivers that help them not only to enhance their performance but also catch up to higher productivity firms. Several determinants affecting TFP convergence are frequently examined, such as corporate taxes, policies and institutions (McMillan and Rodrik, 2012), international technology transfer (Cameron et al., 2005), business cycles (Escribano and Stucchi, 2014), expenditure on R&D, innovation (Gemmell et al., 2016), human resources, international trading activities (Ding et al., 2016).

Recently, the environment has emerged as one of the most important factors in economic development. However, there is the trade-off between economic growth and environmental quality and whether more stringent 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, critiques argue that the conventional views are static and do not account for the dynamic influence of environmental factors on innovation which can enhance productivity as well as productivity growth (Porter, 1991; Porter and Van der Linde, 1995). The latter shows that environmental compliance and its

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

spillover effects to innovation capacity can influence firm's productivity convergence.

Although, the literature on productivity convergence abounds, there is comparatively little known about such regulations on productivity in the context of developing countries. Moreover, the literature seems to overlook the role of environmental factors in enhancing TFP convergence. This chapter aims to fill this gap by investigating the relationship between environmental compliance, innovation, and productivity convergence of SMEs in Vietnam. Two questions are raised: (i) Is there evidence of a β-convergence in firm's TFP? (ii) How firm's environmental compliance and innovation affect the convergence? Vietnam is an interesting case study for at least two reasons. On the one hand, it is a developing country with a high GDP growth rate. On the other hand, SMEs play a crucial role in economic development, especially in terms of contributing to GDP and creating employment. For instance, 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).

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

This chapter is organized as follows. Section 4.2 provides a review of relevant literature. Section 4.3 describes the data and variables, followed by the econometric specifications. Section 4.4 presents the main findings. Conclusion and policy implications are reported in Section 4.5.

4.2 Background on environmental compliance, innovation, and firm productivity convergence

4.2.1 Environmental compliance, 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 impacts of environment regulations on innovation and productivity.[3] According to the strong version of Porter's hypothesis (henceforth 'strong PH'), as environmental regulations become more stringent, they encourage firms to reduce their reliance on energy-intensive inputs and improve productivity as the way of controlling cost and strengthening their competitiveness. In addition, firms will be more environmentally conscious and creative in investment in new technology. Consequently, as firms expand on innovation capacity, their economic performance is likely to be enhanced - a phenomenon known as 'weak PH' version of PH (Porter, 1991; Porter and Van der Linde, 1995; Jaffe and Palmer, 1997).[4] The casual links between environmental regulations and firm's innovation and productivity is shown in Figure 4.1.

For instance, 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, the impacts of environmental stringency on firm's economic performance are found to be negative or insignificant in Quebec (Lanoie et al., 2008) and 17 European countries Rubashkina et al. (2015).[5] Likewise, examining the

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

[4]The Porter hypothesis consists of several tenets. First, well-designed environmental regulations create a fair business environment; it can prevent firms taking advantage from non-compliant activity. Second, these regulations may help firms to reevaluate the efficiency of resource usage and to explore potential additional capacities. Third, firms can raise corporate awareness to share information and knowledge, which helps them improve human resources and reduce production costs. As a result, innovation may be prompted, thereby enhancing productivity (Porter, 1991; Porter and Van der Linde, 1995).

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

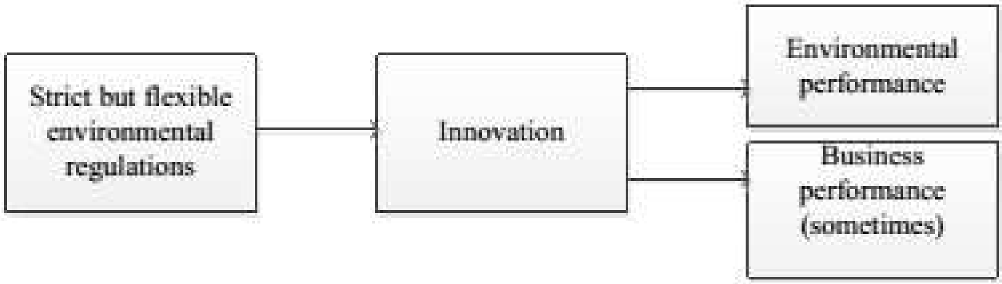

Figure 4.1: Casual links of PH

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

case of manufacturing firms in the Netherlands, Van Leeuwen and Mohnen (2017) found no significant evidence to support the 'strong PH'. In addition, spending more on pollution abatement may decrease firm's efficiency in terms of both production and emission (Shadbegian and Gray, 2006). This impact also varies over regions within a country; for example, the oil refineries in Los Angeles, where environmental regulations are more stringent, have higher TFP than those in other states in the U.S. (Berman and Bui, 2001).

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

Sanchez and McKinley, 1998; Jaffe and Palmer, 1997)

To sum up, the aforementioned literature shows no conclusive evidence supporting the strong or weak PH version. Furthermore, most studies on this topic have been conducted for the cases of developed countries, while only few studies examine the cases of developing countries.[6] Most importantly, they have almost investigated the strong or weak PH version by relying on reduced-form model but not the whole Porter chain of causality described in Figure 4.1, except Lanoie et al. (2011) and Van Leeuwen and Mohnen (2017). Our study contributes to filling this gap by examining both strong and weak PH versions, but with respect to productivity convergence in the context of a developing country.

4.2.2 β-convergence and its determinants

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, an unconditional (or absolute) β-convergence reveals that the income per capita growth rate of a poor country tends to exceed that of a rich one. In addition, when some factors appear to influence the convergence speed, there is a conditional convergence. For example, the beta-convergence tends to be higher in open economies because of capital and technology transfer from richer to poorer countries.

Following the seminal paper of Barro et al. (1991) and Barro and Sala-i Martin (1995), substantial literature on productivity convergence has been conducted but almost at the level of countries, regions, or industries. Empirically, the labor productivity convergence can be heterogeneous across different technological levels

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

and sectors among countries (Bernard and Jones, 1996c). In addition, capital intensity can affect the speed of convergence. These impacts are small in services sector, high in manufacturing one, and vary across sectors (Gouyette and Perelman, 1997). The speed of convergence is also different across regions as in India (Bernard and Durlauf, 1996) or in the U.S. (Bernard and Jones, 1996b). This speed may be affected by other factors including 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).[7]

There is a small research investigating the beta-convergence at firm level. Particularly, the potential nexus between environmental compliance and innovation on firm's productivity convergence has not been explored yet. For instance, Nishimura et al. (2005) found significant evidence of productivity convergence of Japanese firms. Such convergence can be affected by corporate taxation because reducing tax may encourage firms to expand their production by increasing investment and expenditure on R&D (Gemmell et al., 2016). In the same vein, Bournakis and Mallick (2017) found a negative impact of corporate taxation on TFP growth rate. The convergence is also influenced by internal characteristics such as firm's political affiliation, ownership, firm age, export behavior, geographic location (Ding et al., 2016). For the case of Mexican firms, enhancing firm's technological capacity plays an important role in catching up with the global frontier, but not for the domestic frontier (Iacovone and Crespi, 2010). Similarly, information technology and globalization may affect productivity convergence, which is stronger for the most productive firms (Chevalier et al., 2012). Firms in the high-technology group have

[7] Escribano and Stucchi (2014) examined the case of Spanish manufacturing factor and found an existence of convergence in productivity in business recessive period because followers with scale advantages could reduce cost and be more productive. In contrast, no convergence is found in business expansive periods because firms with high productivity frequently have higher innovation performance compared to those with lower productivity. Cameron et al. (2005) used a panel of 14 manufacturing sectors in United Kingdom and the U.S and found the evidence that lower productivity industries have higher productivity growth rate; R&D impacts on productivity growth indirectly through innovation, and human capital does give significant additional impact on productivity growth.

higher convergence speed, which can be affected by size, technical capacity and spatial effects (Val et al., 2009).

4.3 Data and methodology

4.3.1 Data

Data used in this chapter are from the bi-annual survey on Vietnamese SMEs over the period 2007-2015. After deleting firms with missing data, we obtain a sample of 4,584 observations on manufacturing SMEs.

Figure 4.2 shows that the SMEs experienced on average a steady increase in TFP over the period 2007-2015.

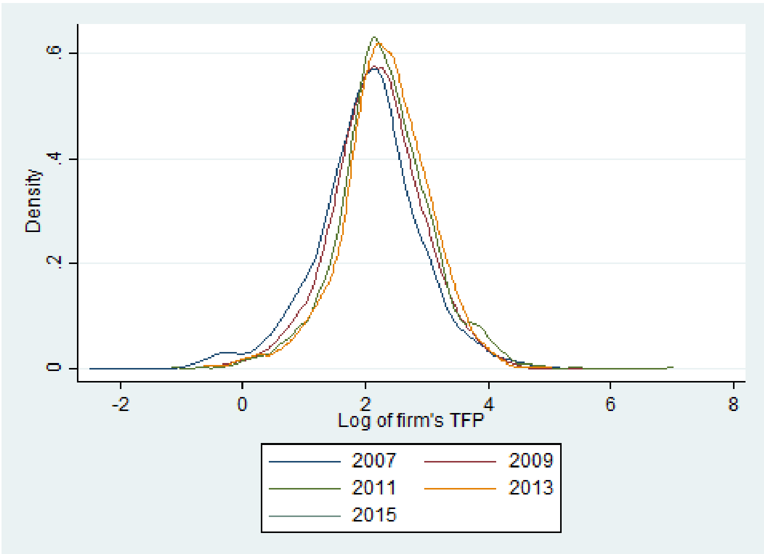

Figure 4.2: Distribution of firm's TFP (in log)

Table 4.1 presents the definition of main variables used in this research. Two measures of firm's environmental practices are available in the data. 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, all responses are grouped into a sole category of having at least an ET.

Table 4.1: Definition of variables

Variable		Definition	Type
TFP		The firm's TFP obtained from Eq.(4.3)	Continuous
Environmental and innovation practices			
ET		Environmental treatment. $ET = 1$ if the firm has a treatment for environmental pollution (air quality, fire, waste disposal, etc.)	Dummy
ESC		1 if the firm has Certificate for registration of satisfaction of environmental standards	Dummy
Knowledge about Environmental Law			Discrete
	1	if Good or Average	
	2	if Poor	
	3	if No	
Innovation			Discrete
	1	if no innovation	
	2	if either a process or product innovation	
	3	if both innovations	
Firm characteristics			
Share of Professional Workers		The share of professional workers over the firm's total employees	Continuous
Investment		The firm's total level investment of firm	Continuous
Industrial characteristics			
Capital intensity of industry		Total industrial stock of capital/Total industrial employees	Continuous

Table 4.2: Descriptive statistics

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

Main variables descriptive statistics are reported in Table 4.2. Those firms cover about 25% of our sample. Second, firm is asked to confirm whether it has a "Certificate for registration of satisfaction of environmental standards" (ESC). About 13% of firms have such certificate. In this chapter, ESC and ET are used as proxies for firm's compliance with environmental regulations.[8]

With respect to firm innovation, the questionnaire contains three questions: (i) Has the firm introduced new product groups (since last survey)? (ii) Has the firm implemented any improvements of existing products or changed specification? and (iii) Has the firm introduced new production process/new technology? Overall, 55% of the firms in the sample reported no innovation while 35% reported either a product or process innovation. Only 10% of them reported both types of innovation. Other control variables are also included in this chapter, including total investment, share of professional workers and the capital intensity of the industries.

[8]Environmental compliance is proxied by obtaining an environmental standard certificate (ESC). ESC is formed under official legal documents such as the Law on Environmental Protection issued from 2005, Decree 80/2006 and Decree 29/2011 which instructs how to implement the Law. ESC is adopted for some certain sectors. Firms in these sectors have to own ESC by adapting full criteria in environment investment assessment (EIA) instituted Degree 29/2011. Firms which are not in these sectors are not constrained to have an ESC, but are also required to sign an environment protection commitment (Brandt et al., 2016).

4.3.2 Methodology

TFP estimation strategy: A stochastic approach

To estimate firm's TFP, we start with the Cobb-Douglass production function:[9]

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} \tag{4.1}$$

where Y_{it} is output of firm i ($i = 1, ..., N$) at period t ($t = 1, ..., T$), and A_{it}, K_{it}, L_{it} are TFP, capital stock and labor, respectively. The firm TFP can be expressed as $A_{it} = A_0 exp(\omega_{it} + \varepsilon_{it})$ where ε_{it} is the error term and ω_{it} the stochastic productivity shock.

Taking logarithm of Eq.(4.1) gives:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it} \tag{4.2}$$

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

Failure to control for the unobservable productivity shock ω_{it}, using the panel fixed effects (FE) or random effects (RE) model to estimate Eq.(4.2) may lead to biased results. This issue is firstly solved by Olley and Pakes (1996), in which investment is used as an appropriate instrument for inputs. However, investment information, sometimes, is not available, particularly in the case of SMEs. To deal with this problem, Levinsohn and Petrin (2003) used material cost as an intermediate input instead of investment. LP estimator however suffers from three major limits. The first is associated with the functional dependence. More precisely, all variables are supposed occur at the same time by using the unconditional intermediate input demands. That could lead to a collinearity problem because material would normally be chosen after labor (Ackerberg et al., 2015). Second, the LP estimator overlooks the probability of the correlation of error terms in the moments. Third, it could not be efficient because of serial correlation or heterogeneity (Wooldridge, 2009).

In this chapter, we follow Wooldridge (2009) to estimate firm's TFP. Indeed, to correct these limitations of the LP method, the author proposes the GMM estimator because it could improve efficiency by using the cross-equation correlation and the

[9]See detail specification of TFP estimation in Appendix 2.B.

optimal weighting matrix. Once β_k and β_l are estimated, the firm's TFP (in log) is computed as:

$$\omega_{it} = y_{it} - \beta_k k_{it} - \beta_l l_{it} - \beta_m m_{it} \tag{4.3}$$

Estimation strategy for β-convergence

(i) Environmental practices and β-convergence

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

$$\left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1 \omega_{i,t} + \theta H_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \tag{4.4}$$

where the dependent variable refers to the TFP growth rate, and ω is log of the TFP obtained in Eq.(4.3). H is a vector of covariates capturing environmental practices (ET and ESC). X is a vector of control variables including the firm and industrial characteristics. Eq.(4.4) can be estimated by using the panel fixed effects method. However, such estimation could be biased since ESC and ET might be potentially endogenous as they could be affected by unobserved factors. To overcome this issue, we introduce both the 'variable addition test' and the 'instrumental variables estimation with panel data' proposed by Wooldridge (2005, 2014). Eq.(4.4) then is rewritten as:

$$\text{First stage:} \quad ET_{i,t} = \theta_1 KEL_{i,t} + \theta_2 \omega_{i,t} + \theta_3 X_{i,t} + \epsilon_{i,t} \tag{4.5a}$$

$$ESC_{i,t} = \gamma_1 KEL_{i,t} + \gamma_2 \omega_{i,t} + \gamma_3 X_{i,t} + u_{i,t} \tag{4.5b}$$

$$\text{Second stage:} \quad \left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1 \omega_{i,t} + \theta H_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \tag{4.5c}$$

and the estimated procedure is as follows:

(i.1) In the first step, RE probit models are performed for *ET* and *ESC*. These variables are instrumented with a categorical variable measuring firm's knowledge of the environmental law (*KEL*): *1* if good or average knowledge, *2* if poor knowledge, and *3* if no knowledge. *KEL* could be validated as an instrumental variable (IV) for two reasons. On the one hand, there should be a strong correlation between *KEL* and environmental practices (e.g. the potential endogenous variables). On the other hand, it is hardly difficult that *KEL* may impact the firm's TFP growth rate.

(i.2) For each regression of the first step (Eq.4.5a and 4.5b), we compute the associated generalized residuals and the latter are introduced to Eq.(4.5c). The full specification is then estimated by the usual FE model.

(i.3) Finally, a robust test is performed in which *ESC* and *ET* are exogenous. According to Koné et al. (2017), this test is called *robust* because it is based on robust standard errors.

(ii) Innovation and β-convergence

It is possible that environmental practices do not directly affect TFP convergence but indirectly through *Innovation*. To assess this indirect impact, we estimate the following regression model:

$$Innovation_{i,t} = \beta_1\omega_{i,t} + \kappa H_{i,t} + \gamma_1 X_{i,t} + u_{i,t} \quad (4.6a)$$

$$\left(\frac{\omega_{i,t+k}}{\omega_{i,t}}\right) = \alpha_i + \beta_1\omega_{i,t} + \delta Innovation_{i,t} + \gamma_2 X_{i,t} + \epsilon_{i,t} \quad (4.6b)$$

To estimate Eq.(4.6a) and (4.6b), the 'variable addition test' and the 'instrumental variables estimation with panel data' are performed. In the first stage, *Innovation* is instrumented with *ESC* and *ET* in an RE ordered probit model, taking into consideration the potential endogeneity of the two environmental variables. We then compute the related generalized residuals and introduce them to Eq.(4.6b). Finally, we test whether the coefficient associated with these residuals equals to zero. The null hypothesis means the exogeneity of *Innovation*. Environmental practices are here expected to have significant impacts on *Innovation* but not on TFP convergence. Consequently, they may be used as excluded IV at the first stage.

If the strong version of PH obtained from estimating Eq.(4.4) is supported, estimation of both Eq.(4.6b) becomes irrelevant. In this case, we will merely focus on how environmental practices impact *Innovation* (Eq.4.6a).

(iii) Speed of convergence and half-life time

Once Eq.(4.5c) and Eq.(4.6b) are estimated, the sign of the estimated coefficient $\hat{\beta}_1$ allows us to confirm the existence of a β-convergence. If the sign is positive, there is a β-divergence. By contrast, if that sign is negative, a β-convergence is found as follows:

$$\beta = -\frac{\ln(1+\frac{\hat{\beta}_1}{k})}{T} \quad (4.7)$$

and the associated speed of convergence can be computed. The half-life time (hl) is:

$$hl = \frac{\ln 2}{\beta} \tag{4.8}$$

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 chapter, it is the necessary time for firm's TFP in the associated year to be halfway between the initial and the steady-state value.

4.4 Empirical findings

4.4.1 Environmental compliance and TFP convergence

Table 4.3 reports the estimated results for the firm TFP convergence taking into account the potential endogenous of ET and ESC (Eqs. 4.5a-4.5c) .

Table 4.3: Impacts of ESC and ET on firm's TFP convergence

	Stage 1				Stage 2	
Dependent variable	*ET*		*ESC*		*dlnTFP*	
Estimator	RE Probit		RE Probit		FE	
	Est.	Mar. effect	Est.	Mar. effect		
	(1)	(2)	(3)	(4)	(5)	(6)
TFP (in log)	0.344***	0.105***	0.434***	0.036***	-1.147***	-1.145***
	(0.029)	(0.009)	(0.073)	(0.006)	(0.023)	(0.022)
Environmental practices						
ESC					0.035	
					(0.056)	
ET					-0.078+	
					(0.043)	
Firm and industrial characteristics						
Firm's investment (in log)	-0.267*	-0.082*	0.634**	0.052**	0.009	
	(0.109)	(0.033)	(0.209)	(0.017)	(0.074)	
Share of professional workers	-0.010	-0.003	-0.168	-0.014	-0.008	
	(0.030)	(0.009)	(0.132)	(0.011)	(0.021)	

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Table 4.3: Impacts of *ESC* and *ET* on firm's TFP convergence (continued)

	Stage 1				Stage 2	
Dependent variable	*ET*		*ESC*		*dlnTFP*	
Estimator	RE Probit		RE Probit		FE	
	Est.	Mar. effect	Est.	Mar. effect		
	(1)	(2)	(3)	(4)	(5)	(6)
Capital intensity of industry	0.526***	0.161***	0.337**	0.028**	0.101**	
	(0.054)	(0.017)	(0.127)	(0.010)	(0.035)	
Generalized residuals of *ET*					0.095**	
					(0.029)	
Firm fixed effects	-	-	-	-	Yes	Yes
Constant	-4.302***		1.388***		2.130***	2.593***
	(0.601)		(0.120)		(0.157)	(0.050)
Excluded IV						
Knowledge about the environmental law(Reference: Good or average knowledge)						
Poor knowledge	-0.082	-0.027	-0.749***	-0.076***		
	(0.057)	(0.019)	(0.119)	(0.013)		
No knowledge	-0.284***	-0.089***	-1.224***	-0.111***		
	(0.054)	(0.018)	(0.124)	(0.013)		
Observations	4,584	-	4,584	-	4,584	4,584
Number of firms	1,941	-	1,941	-	1,941	1,941
R-squared					0.574	0.572
Test for endogeneity	-	-	-	-	10.41***	-
Beta-convergence (%)	-	-	-	-	10.59	10.62
Half-life time (years)	-	-	-	-	6.54	6.52

Robust standard errors in parentheses.

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

Starting with the first stage of the estimated procedure, the results are shown in columns 1-4 of Table 4.3. The two first columns present the estimation and the associated marginal effect for *ET* and the two following columns for *ESC*. Recall that *KEL* is used as excluded instruments for the two potential endogenous variables. As expected, this variable is shown to be strongly correlated with either *ESC* or

ET. Compared to firms having *good or average knowledge*, firms with *no knowledge* are 8.9% less likely to exert an *ET*. The influence of *KEL* on *ESC* even is more pronounced; firms with *good or average knowledge* of the environmental law are 7.6% and 11.1% more likely to obtain an *ESC* than those with *poor knowledge* and those with *no knowledge*, respectively.

Turning to the second stage, testing for endogeneity suggests that only *ET* is endogenous, but not *ESC*. Column 5 reports the estimated results of Eq.(4.5c) with endogeneity of *ET* and exogeneity of *ESC*. Interestingly, Column 5 shows a significant and negative estimated coefficient of the TFP variable, indicating the presence of a β-convergence for the SMEs during the period 2007-2015. The speed of convergence is 10.6% and the half-life time is 6.5 years. With respect to the role of environmental practices, *ESC* has a positive but insignificant impact on the TFP growth rate. By contrast, the coefficient of *ET* is negative and significant at 10% level. As for other firm characteristics, only *capital intensity of industry* has a negative and significant impact on the TFP growth rate.

To have a deeper insight on the impacts of environmental variables on TFP convergence, we refer to the unconditional convergence. The estimation is shown in Column 5 of Table 4.3. The estimated coefficient of TFP is similar to the one reported in Column 5 (-1.145 vs -1.147), indicating that environmental practices have a negligible effect on the TFP convergence. These findings are in line with empirical studies which do not support the strong version of PH. For example, Rubashkina et al. (2015) found a non-significant impact of environmental regulations on sectoral TFP growth of 17 European countries. Likewise, Van Leeuwen and Mohnen (2017) found no evidence to support that impact in the Netherlands.

In summary, there is a $\beta-$convergence for Vietnamese manufacturing SMEs over the period 2007-2015. However, this convergence is unlikely to be influenced by the environmental practices. The negligible impact of *ET* raises a question about the amount of expenditures associated with *ET*. In our sample, the average value of this expenditure is about 2 million VND (equivalent to 100 U.S. dollars). This expenditure is not sufficiently high to have a non-negligible impact on firm TFP convergence. Indeed, the level of investment should exceed a threshold to have a significant impact on the economy (Bruno et al., 2009). On the other hand, the insignificant impact of *ESC* could be related to the firm motivation to obtain such certificate. In fact, 64% of the firms in our sample reported that they obtained *ESC* because it was required by local authorities while only less than 10% cited a reduction in the long run production cost or environmental protection as the main reason for spending on *ESC*. Since the motivation comes from an obligation imposed by local authorities rather than from their strategic behavior, it is not surprising that *ESC* does not have a significant impact on TFP convergence.

4.4.2 The nexus between environmental compliance, innovation and TFP convergence

Since *ESC* and *ET* are not correlated with the TFP convergence, it is possibly that the impact is indirect through *Innovation*. To examine this issue, we perform the estimations of Eq.(4.6a) and (4.6b) by using the two environmental variables as excluded IV.

While estimating Eq.(4.6a), both *ET* and *ESC* are found to be exogenous. Additionally, *ESC* has no significant impact on *Innovation*. Table 4.4 reports the estimated results Eq.(4.6a) and (4.6b) with exogeneity of *ET* as the sole excluded IV for *Innovation*.

Table 4.4: Environmental practices, Innovation and TFP convergence

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

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Table 4.4: Environmental practices, Innovation and TFP convergence (continued)

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

Robust standard errors in parentheses.

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

Column 1 of Table 4.4 presents the estimated results of Eq.(4.6a) and Eq(4.6b); columns 2-4 show the marginal effects for the three categories of *Innovation* (*'No innovation'*, *'Process or Product innovation'*, and *'Both innovations'*). *ET* appears to be strongly correlated with *Innovation*. In fact, having an *ET* increases the probability of having *No innovation* by 14% and decreases the probability of having *'Process or Product innovation'* by 7.5% and of *'Both Process and Product innovation'* by 6.5%. Since *ET* is likely to discourage firms to innovate, it is possible that introducing both *Innovation* and *ET* are costly for firms, particularly when most of them lack capital and face credit constraints, forcing them to choose between either *ET* or *Innovation*. As a result, firms practicing *ET* are less likely to innovate. These findings are thus consistent with the negative impact of *ET* on *Innovation* displayed in Column 1 of Table 4.4.

The existence of a negative correlation between *ET* and *Innovation* makes our research different to other studies supporting the weak PH version. 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, stricter environmental regulations might stimulate firms to invest in new technology (Hamamoto, 2006) or increase its expenditure on R&D and pollution abatement (Yang et al., 2012).

Column 5 of Table 4.4 displays the estimated results of Eq.(4.6b). The test for endogeneity of *Innovation* is statistically significant at 5% level, implying that innovation is endogenous in our sample. Compared to firms having *'No-innovation'*, the TFP growth rate of those with *'both Product and Process innovation'* is 16% higher. Most importantly, Column 4 displays a β-convergence of 10.8% leading to a half-life time of 6.4 years. This rate is higher than that of the unconditional convergence reported in Column 5 of Table 4.3. In the absence of *Innovation*, the speed of convergence slightly declines to 10.7% (Column 6 of Table 4.4). Overall, a comparison of the β-convergence in Table 4.4 to that of Table 4.3 indicates that there is a conditional convergence and firms having *Innovation* and/or belonging to capital intensive industries exhibit higher speed of convergence than those do not.

4.5 Conclusion

Chapter 5 investigates the nexus between environmental compliance, innovation and TFP convergence for Vietnamese manufacturing SMEs over the period 2007-2015. We find that firm's environmental compliance has a marginal effect on its TFP convergence. However, this impact is indirect though innovation, implying that environmental treatment on firms may discourage them to innovate with negative consequences for this convergence. This chapter makes two contributions to the literature. First, unlike most empirical studies that investigate the role of environmental regulation on firm's performance using a single-equation framework, we apply a structural modeling framework to assess both strong and weak PH versions. Second, in contrast to the country or sectoral level analysis of the existing literature, we use firm-level data to assess the impacts of environmental regulations on the TFP convergence of SMEs in a developing country.

Some policy recommendations can be drawn from these results. First, since *KEL* positively affects firm's environmental practices, information about environmental awareness should be disseminated on a large scale. This is of great importance considering that only 3% of the firms in the sample reported having good knowledge of the environmental law while most of them (52%) expressing no concerns about it. Training activities to enhance environmental awareness might be another solution. Second, the finding that firm's capital intensity is positively associated with innovation and TFP convergence suggests that policy measures aimed at encouraging investment in physical capital should also contribute to the TFP convergence.

This chapter suggests future research as follows. First, a study of the environmental behaviors of large firms, which are less financed constraints than SMEs, might shed light on the mediating role of credit constraint on the nexus between environmental practices, innovation and TFP convergence. Second, a focus on firms in polluted industries may also shed light on both strong and weak version of PH.

Chapter 5

Emission tax and environmental compliance of firms: Effects on bribery and political connection

Abstract

Stringent emission tax may encourage firm's environmental compliance. Yet whether such a policy may motivate firms to commit bribery and maintain political connection has remained unanswered. This chapter proposes a model to investigate emission tax efficiency in the presence of audit and penalty mechanism. We find that political connection could affect this efficiency, depending upon the parameters of the functions of profit, audit and penalty. In addition, the impacts of tax on political connection is non-monotonous and contingent on these parameters, the levels of tax magnitude and underreported emissions. These findings provide the insight that despite its crucial role in public management, tax adoption should be deliberate due to the trade-off of bribery and political connection.

5.1 Introduction

Corruption may be a key factor causing environmental degradation in developing countries (Wilson and Damania, 2005). For instance, receiving benefits from special interest groups of local officials and bureaucrats could reduce the efficiency of efforts in environmental protection and natural resource reserve, especially in some countries having largest tropical forests as Brazil, Indonesia, and Congo (Burgess et al., 2012). These authors also suggest that reducing the motivation to participate in illegal activities of these officials and bureaucrats plays a key role in these efforts. Such a political connection between these groups and these officials could affect environmental compliance and cause serious environmental degradation. The probability of well-connected enterprises being investigated and fined relevant to environmental non-compliance is lower than that of non-connected counterparts. In China, the rate of environmental penalty imposed on politically connected firms is 15% lower than that of unconnected firms. Chinese firms can use political connection to relax the enforcement of environmental regulations. For example, politically well-connected firms can be easily successful in disclosing information of worker's death due to their own environmental non-compliance (Fisman and Wang, 2015).

Political connection and bribery are frequently appeared in tax and environmental regulation enforcement. For example, although the tax system has gained significant improvement, the probability of bribery and corruption between firms and tax inspectors in Vietnam has still been high (Nguyen et al., 2017). The tax system in Vietnam is organized at three levels: (i) General Department of Taxation (GDT), (ii) Provincial agencies, and (iii) District tax offices. Tax is relied on taxpayer's self-reporting. In order to reduce bribery and corruption, tax authorities investigate firms having most signals of non-compliance. If the breach of non-compliance is found, firms will be fined from 1 to 3 times the level of underreported tax payment (The report of Grant Thornton, 2014). For example, Formosa paid back of US$10.05 million; and Uber paid administrative penalty and underreported tax amount of total US$2.93 million. Emission tax is also monitored and enforced through similarly administrative procedure and its enforcement may also affected by bribery and political connection. The weak point of the tax system and environmental protection is the capacity of enforcement. Hence, the influence of political connection can make it more difficult to manage the efficiency of environmental regulations.

Like many developing countries, despite achieving high economic growth, Vietnam is facing difficulties in corruption and environmental degradation. Corruption issues, generated from political connection, have caused serious environmental degradation because government officials may ignore firm's illegal activities in environmental compliance. For instance, in 2016, Formosa–steel company in Ha Tinh–caused an environmental tragedy massive deaths of fish along the central coast beach. The tragedy has resulted in several negative impacts on the environment, agricultural sector, fishery and tourism industries, and health of residents living around regions. Formosa had to pay US$500 million for fishermen in 4 most severely affected provinces from this tragedy. The scandal also shows the crucial influence of political connection on environmental degradation. In fact, the Central Inspection Committee conducted the examination and concluded that Ha Tinh People's Committee and Ministry of Natural Resources Environment has serious violations in appraising and providing permission for Formosa's operation in Vietnam. There were 11 members convicted to be accountable for the Formosa scandal. Hence, political connection may have adverse influence on environmental degradation, which can affect Vietnamese sustainable development.

These examples practically show the potential impact of political connection on the efficiency of environmental policies as well as firm's environmental compliance. Theoretically, Sandmo (2002) examined the efficiency of tax corresponding to firm's self-reporting and penalty mechanism but did not mention the role of authority. This role was included in the model of Wilson and Damania (2005) which highlighted the link between tax and emissions and a negative impact of tax on actual and reported emissions. These authors assumed that the probability of being audited depends only on reported emissions; it ignored the potential influence of firm's political connection. However, in reality, firms can use political connection to mitigate the probability of being audited. Nevertheless, the impact of such political connection on firm's environmental compliance has still been underexplored, particularly in developing countries whereby legal capacity, law monitoring and enforcement as well as government's accountability are still weak.

This chapter aims to examine the impacts of tax (in the presence of audit and penalty mechanisms) on current and reported emissions and political connection. Three questions are concerned: (i) Does emission tax reduce firm's emissions with respect to the influence of political connection? (ii) Does bribery increase with tax? (iii) Does tax stringency motivate firms to maintain political connection?

We find that stringent emission tax may be efficient in terms of reducing emissions without the influence of political connection. However, this connection can affect the effectiveness of this policy. In fact, an increase in tax to a level that is higher than the threshold may encourage firms to maintain political connection and commit bribery to avoid tax. The impacts of emission tax on bribery depends on tax magnitude and the correlation between the parameters of audit, penalty, and political connected costs. This research sheds light on the nature of the relationship between tax, environmental compliance, and firm's willingness to commit bribery and develop political capital.

The remaining parts of this chapter are organized as follows. Section 5.2 reviews the literature on environmental regulations, bribery, and political connection. The models and findings are derived and discussed in Section 5.3 and 5.4. Finally, Section 5.5 provides concluding remarks regarding the extended model of tax and firm's emission with a new indicator of political connection.

5.2 Review on environmental regulation, bribery, and political connection

5.2.1 Environmental regulations and enforcement

In order to manage environmental quality, regulators can choose a level of emission fee and/or tax imposed on the amount of emissions. As usual, firms want to discharge a certain level of emission at minimum compliance cost. This can cause pollution and increase marginal environmental damage. The literature shows that firms and inspectors can interact to violate environmental regulations. In addition, environmental agencies (the agencies) are incapable of knowing whether firms are telling the truth about their environmental performance or not (Kolstad, 2000). Hence, governments should adopt audit mechanism to increase the efficiency of environmental policies (Bontems and Bourgeon, 2005; Macho-Stadler and Perez-Castrillo, 2006). A stringent tax and enforcement can encourage firms to reduce emissions. However, complete enforcement may cause more severe environmental damage due to bribery and corruption (Gerigk, 2016).

5.2.2 Environmental compliance and bribery

Firms implement environmental compliance due to their own economic benefits. A stringent environmental regulation may encourage firms to bribe inspectors, following the property that the violation will happen if "the expected utility" exceeds the opportunity cost (Kolstad, 2000). Hence, an increase in the probability of being audited may reduce the expected utility obtained from such violation (Becker, 1968). Practically, in order to manage environmental quality, governments can adopt "the price-based system". However, a too high marginal emission cost will motivate firms to violate regulations by committing bribery and corruption. In such a situation, if the government's legislative capacity is weak, expected environmental standards would be ignored by economic efficient perspectives.[1] Corruption can help firms reduce non-compliance costs, causing the deficiency of management system (Aidt, 2003; Dinda, 2004). Whereas if corruption is low, monitoring and enforcement of environmental policies would be more effective (Pellegrini and Gerlagh, 2004; Rehman et al., 2012). If expected penalty increases, firms can reduce bribery and raise the level of regulation compliance (Becker, 1968). In order to improve the efficiency of environmental policies, the agencies and the auditors can adopt audit and penalty mechanism to prevent firms and inspectors from breaching regulations (Bontems and Bourgeon, 2005).

Empirically, a "naive regulatory policy" that is based only on penalty and environmental standards might be unsuccessful (Cheng and Lai, 2012). For example, Blackman and Harrington (2000) found that the impact of emission fee on environ-

[1] See Heyes (2000), Heyes et al. (2016), Cohen and Shimshack (2016) for a review.

mental performance is significant in Sweden, but insignificant in China and Poland. The present paper proposes the second best measurement in which emission tax could be combined with institutional factors. As usual, firms have "near-sighted outlook" with respect to market outcome and cost saving from their legal violation (Häckner and Herzing, 2017). Firms can bribe inspectors to underreport emissions to avoid tax payment (e.g. Damania et al., 2004). Therefore, it is possible to be biased if tax payment is only based on the reports from inspectors (Cohen and Shimshack, 2016). An appropriate policy should combine tax with audit and penalty mechanism (Kolstad, 2000), in which, the audit probability is affected not only by bribery but also by firm's political capital.

5.2.3 Environmental compliance and political connection

Firm's environmental compliance depends on the effectiveness of regulations, government's law enforcement capacity and accountability. It is also based on firm's capacity in dealing with non-compliance (Heyes, 2000). As usual, firms do not voluntarily provide private information to environmental agencies. Hence, authorities can adopt audit mechanism to achieve the socially efficient emissions (Oestreich, 2017). The audit process often consist of two stages of (i) detecting firms which are most likely to be non-compliant and (ii) imposing penalty on non-compliant polluters. The agencies and auditors use reported emissions as reference information to sort out these firms (Oestreich, 2015). The role of the agencies is to implement the audit mechanism to minimize emissions under a budget constraint. Such an efficient enforcement can motivate firms to discharge properly emissions such that enforcement costs still keep low (Kolstad, 2000). Since the agencies cannot audit all reports, firms can use their political connection to mitigate the audit probability (Oestreich, 2015). Developing this connection increases corruptive activities, causing environmental degradation (Heyes, 2000; Wilson and Damania, 2005).

Political connection shows a close relationship between firms and governmental officials (Nee and Opper, 2010). On the one hand, it brings benefits to firms through charters or preferential treatments in subsidy, tax, and accessing financial resources (Malesky and Taussig, 2008). Politically connected firms are more competitive than their non-connected counterparts (Fisman, 2001; Faccio, 2006). On the other hand, political connection is the root causing of corruption which is higher in poor countries (Bai et al., 2015). This connection could also distort policy objectives and cause adverse effects to social benefits, particularly environmental degradation. For example, firms could use its political capital to reduce the cost of non-compliance. They become less likely to consider environmental protection. Theoretically, political instability generates corruption which may reduce the possibility of compliance (Kolstad, 2000). Indeed, firms can develop political connections with the agencies and high-ranked governmental officials to minimize the audit probability. As a result, the efficiency of legal proposals and the implementation of environmental regulations would become deficient. Furthermore, this efficiency depends not only on the legal stringency but also on the enforcement capacity of governments. Therefore, a more stringent environmental policy through merely increasing penalty might be unsuccessful (Cheng and Lai, 2012; Gerigk, 2016). This situation is likely to be the case in developing countries whereby legal capacity and government's accountability are still weak and the influence of political connection is strong.

For example, in Malaysia, firms having political connection with Prime minister Mahathir gained benefits during the Asia crisis in 1990s. In Indonesian, firms maintaining political connection with President Surhato during his terms received many favorable charters in several sectors of manufacturing industries and natural resources (Bai et al., 2015; Lin et al., 2014). In China, private companies' senior managers frequently have close relationships with high-ranked officials who support them to protect and access resources (Xin and Pearce, 1996). Political connection also have significant negative impacts on their green products and process innovation performance (Lin et al., 2014). Similarly, in Vietnam, corporate executives use their political capital to take advantages in business. This issue seems to be increasingly common. In fact, the Vietnamese government has recently detected and sentenced several high-ranked officials in serious corruption scandals relating to the financial sector and deforestation. These officials are persons who approved the proposals submitted by environmentally polluted companies without appropriate monitoring mechanisms. Take one recent case for example. There were eleven high-ranked governmental officials punished in the Formosa's scandal in 2016.

The review shows the potential role of political connection in environmental degradation, particularly in developing countries. Firms can use their political capital to influence the process of legislative proposals on environmental management. Then they could mitigate the probability of being audited and avoid tax payment. As a result, emissions increase, particularly for the case of heavily polluted enterprises (Cheng and Lai, 2012). Political connection therefore should be considered as a key factor in business planning and also in environmental policy designing.

5.3 Model of tax on emissions and bribery

Based on Damania et al. (2004) and Wilson and Damania (2005), we propose a model to analyze the impacts of tax on emissions and bribery by assuming that there is no political connection. The latter will be introduced in the next section to extend the model. Suppose the production of firm F discharges an emission quantity e following the technology that one unit of output generates one unit of emissions. The inspector I, working at local environmental agency, receives a fixed wage (w). He is in charge of inspecting the firm's emissions and reports the latter to the agency. In order to manage environmental damage, the government imposes a tax (τ) on each unit of reported emissions.

For avoiding tax payment, the firm may commit a bribe to the inspector to underreport the emission level $\hat{e}$ $(\hat{e} < e)$, denote $v \equiv e - \hat{e}$ as the level of under reported emissions. To prevent this bribery, regulators can issue an audit and penalty mechanism to deter non-compliance of the firm and the inspector. Let us assume that the probability of the firm being audited is $\lambda(\hat{e}), \lambda \in (0, 1)$, with $\lambda_{\hat{e}} < 0$ and $\lambda_{\hat{e}\hat{e}} > 0$. If a breach of compliance is detected, both the firm and the inspector will be fined. The expected fine imposed on firm F is $\lambda(\hat{e})f^F(\sigma^F, v)$, and that on inspector I is $\lambda(\hat{e})f^I(\sigma^I, v)$, where σ^F and σ^I are marginal fine. $f_v^F > 0, f_{vv}^F > 0, f_v^I > 0, f_{vv}^I > 0$.

The firm compares the benefits from the two strategies of compliance and non-compliance with bribery and decides which one is the better to follow. Let B be the bribe given to the inspector to get an under-reported emission $\hat{e}$. If the firm complies and produces the output corresponding to the level of emissions e^c, it reports e^c and has the profit $\pi^c - \tau e^c$. If it adopts the strategy of corruption, it gains expected profit $\pi(e) - (B + \tau\hat{e} + \lambda(\hat{e})f^F(\sigma^F, v))$, $\pi_e > 0, \pi_{ee} < 0$. Then the firm's expected gain is derived as

$$g^F = [\pi(e) - \big(B + \tau\hat{e} + \lambda(\hat{e})f^F(\sigma^F, v)\big)] - [\pi(e^c) - \tau e^c]. \tag{5.1}$$

Similarly, if the inspector receives no bribe and accurately reports the firm's current emissions, he will receive a fixed wage. If he takes a bribe and underreports the level of emission, he will face the risk of being detected and punished. His expected gain function is

$$g^I = [w + B - \lambda(\hat{e})f^I(\sigma^I, v)] - w = B - \lambda(\hat{e})f^I(\sigma^I, v) \tag{5.2}$$

5.3.1 Equilibrium

Tax τ and penalty σ^F, σ^I are assumed to be given. We apply the two stage backward induction to find the equilibrium of current emissions (e) and reported emissions ($\hat{e}$). At the first stage, the firm and the inspector collude to respond to emission tax to maximize their total benefits $J = g^F + g^I$; J depends on B. After that, they negotiate together to determine a certain amount of bribe B. Each B corresponds to g^F, g^I and their total utility function $f(J, d)$. If an agreement is not established, they will lose damage $d(d^F, d^I)$. At the first stage, the firm and the inspector's optimization program is the maximization of the joint expected gain J as follows:

$$\begin{aligned}\max_{e,\hat{e}} J \equiv g^F + g^I &= \pi(e) - \tau\hat{e} - \lambda(\hat{e})[f^F(\sigma^F, v) + f^I(\sigma^I, v)] - [\pi(e^c) - \tau e^c] \\ &= \pi(e) - \tau\hat{e} - \lambda(\hat{e})f(\sigma^F, \sigma^I, v) - [\pi(e^c) - \tau e^c],\end{aligned} \tag{5.3}$$

where $f(\sigma^F, \sigma^I, v) \equiv f^F(\sigma^F, v) + f^I(\sigma^I, v)$.

The first order conditions (FOCs) are:

$$\begin{cases} \frac{\partial J}{\partial e} = \pi_e - \lambda(\hat{e})[f_v^F + f_v^I] = 0 \\ \frac{\partial J}{\partial \hat{e}} = -\tau - \lambda_{\hat{e}}[f^F + f^I] + \lambda(\hat{e})[f_v^F + f_v^F] = 0 \end{cases} \tag{5.4}$$

This equation system is solved to find the equilibrium of current emissions e^* and reported emissions $\hat{e}^*$. We then check the second order conditions to ensure this equilibrium to be a maximum. The Hessian matrix is

$$H = \begin{bmatrix} J_{ee} & J_{e\hat{e}} \\ J_{e\hat{e}} & J_{\hat{e}\hat{e}} \end{bmatrix} \tag{5.5}$$

H is negative semi-definite if $H_1 < 0$ and $H_2 > 0$. We observe that

$$H_1 = J_{ee} = \pi_{ee} - \lambda(\hat{e}) f_{vv} < 0.$$

$$H_2 = J_{ee} J_{\hat{e}\hat{e}} - J_{e\hat{e}}^2 > 0 \Leftrightarrow \pi_{ee} < \bar{\pi}_{ee}$$

Lemma 1. *If $\pi_{ee} < \bar{\pi}_{ee}$, the solution in Eq.(5.4) corresponds to a maximum.*
See the proof in Appendix 5.A.□

The Lemma 1 shows that the possibility for the firm and the inspector breaching of environmental regulations depends upon a component constructed by the audit and the penalty mechanisms. The breach is possible if the firm's profit sensitivity π_{ee} is smaller than a threshold $\bar{\pi}_{ee}$ which consists of the parameters of audit and penalty mechanism. Then we can find the critical values of current emissions e^* and reported emissions $\hat{e}^*$.

At the second stage, in order to find the equilibrium of bribery, we assume that the firm and the inspector have equal bargaining power. To determine B, the firm bases on Nash bargaining to propose a bribe B which may be accepted or rejected by the inspector. If this suggestion is rejected, the firm will propose another bribe B_1, and so on until it can determine an optimal bribe B^*. B is defined based on a given total utility frontier $f(J, d)$, where J and d stand for the total utility and the cost of failure in negotiation, respectively. The negotiation will go on until the total surplus for the firm and the inspector are maximized. Following Rubinstein (1982) and Binmore et al. (1986), the maximizing program of the firm and the inspector is derived as follows:

$$\max_{B} \Psi \equiv (g^F \times g^I) = \left\{\pi(e) - [B + \tau\hat{e} + \lambda(\hat{e}) f^F(\sigma^F, v)] - \pi(e^c) + \tau e^c\right\} \times \left\{B - \lambda(\hat{e}) f^I(\sigma^I, v)\right\}. \tag{5.6}$$

The FOC is

$$\frac{\partial \Psi}{\partial B} = \left\{\pi(e) - \left(B + \tau\hat{e} + \lambda(\hat{e}) f^F(\sigma^F, v)\right) - \pi(e^c) + \tau e^c\right\} - \left\{B - \lambda(\hat{e}) f^I(\sigma^I, v)\right\} = 0.$$

$$\Rightarrow B^* = \frac{1}{2}\big\{\pi(e^*) - \pi(e^c) + \tau(e^c - \hat{e}^*) - \lambda(\hat{e}^*)[f^F(\sigma^F, v) - f^I(\sigma^I, v)]\big\}.$$

Then the equilibrium is found $(e^*, \hat{e}^*, B^*)$.

5.3.2 Tax efficiency

Following the theorem of implicit function, we have

$$\begin{bmatrix} \pi_{ee} - \lambda f_{vv} & \lambda f_{vv} - \lambda_{\hat{e}} f_v \\ \lambda f_{vv} - \lambda_{\hat{e}} f_v & -\lambda_{\hat{e}\hat{e}} f + 2\lambda_{\hat{e}} f_v - \lambda f_{vv} \end{bmatrix} \begin{bmatrix} \frac{\partial e}{\partial \tau} \\ \frac{\partial \hat{e}}{\partial \tau} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

where $\pi_{ee} < 0, \lambda_{\hat{e}} < 0, \lambda_{\hat{e}\hat{e}} > 0, f_v > 0, f_{vv} > 0$ and $\lambda \in (0, 1)$. The corresponding matrix equation is

$$\begin{bmatrix} J_{ee} & J_{e\hat{e}} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} \end{bmatrix} \times \begin{bmatrix} \frac{\partial e}{\partial \tau} \\ \frac{\partial \hat{e}}{\partial \tau} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}.$$

The results point out that

$$\frac{\partial e^*}{\partial \tau} = \frac{-J_{\hat{e}e}}{\Delta} < 0 \quad \text{and} \quad \frac{\partial \hat{e}^*}{\partial \tau} = \frac{J_{ee}}{\Delta} < 0.\square$$

where $J_{e\hat{e}} = \lambda f_{vv} - \lambda_{\hat{e}} f_v > 0$; $J_{ee} = \pi_{ee} - \lambda f_{vv} < 0.\square$ and $\Delta = J_{ee}J_{\hat{e}\hat{e}} - J^2_{e\hat{e}} > 0$ (Lemma 1). Then, we have

$$\frac{\partial B^*}{\partial \tau} = \frac{1}{2}\Big\{\frac{\partial \pi}{\partial e^*}\frac{\partial e^*}{\partial \tau} + e^c - \hat{e}^* - \tau\frac{\partial \hat{e}^*}{\partial \tau} - \frac{\partial \lambda}{\partial \hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau}\big(f^F - f^I\big) - \lambda\big(\frac{\partial f^F}{\partial v}\frac{\partial e^*}{\partial \tau} + \frac{\partial f^I}{\partial v}\frac{\partial \hat{e}^*}{\partial \tau}\big)\Big\} \gtreqless 0.$$

Proposition 1. *If the firm's profit sensitivity is smaller than a threshold,*

(i) If the government increases emission tax, the firm will reduce current emissions and reported emissions.

(ii) The impact of emission tax on the firm's probability to bribe is ambiguous. It depends on the parameters of firm's profit, penalty and audit mechanism.

The finding in (i) is similar to Wilson and Damania (2005) who found that an increase in emission tax may pressurize the firm to reduce emissions. It also simultaneously motivates the firm to underreport emissions to avoid tax. For rechecking finding (i) and clarifying these relationships in finding (ii), an analytical illustration is proposed in the next subsection.

5.3.3 Analytical application

Consider parametric functions, we suppose $\pi = (a - be)e, a, b > 0; f^F = \sigma^F v$ and $f^I = \sigma^I v, v = e - \hat{e}; \lambda(\hat{e}) = \frac{exp(-\hat{e})}{1+exp(-\hat{e})}$, $\lambda \in [0,1]$, $\lambda_{\hat{e}} = -\lambda(1-\lambda) < 0$ and $\lambda_{\hat{e}\hat{e}} = \lambda_{\hat{e}}(2\lambda - 1) > 0$.[2] Then, the joint objective function is derived as:

$$J \equiv g^F + g^I = \Big\{(a - be)e - \tau\hat{e} - \lambda(\hat{e})(\sigma^F + \sigma^I)v\Big\} - \big\{\pi(e^c) - \tau e^c\big\} \qquad (5.7)$$

For sake simplicity, let us denote $\sigma \equiv \sigma^F + \sigma^I$. We calculate: $J_e = a - 2be - \lambda\sigma$, $J_{\hat{e}} = -\tau + \lambda\sigma - \lambda_{\hat{e}}\sigma v$, $J_{ee} = -2b < 0$, $J_{\hat{e}e} = -\lambda_{\hat{e}}\sigma > 0$, $J_{\hat{e}\hat{e}} = 2\lambda_{\hat{e}}\sigma - \lambda_{\hat{e}\hat{e}}\sigma v < 0$.
Aforementioned in subsection 3.1, we have:

$$\frac{\partial e^*}{\partial \tau} = \frac{-J_{\hat{e}e}}{\Delta} = \frac{\lambda_{\hat{e}}\sigma}{\Delta} < 0$$

and

$$\frac{\partial \hat{e}^*}{\partial \tau} = \frac{J_{ee}}{\Delta} = \frac{-2b}{\Delta} < 0.\Box$$

where $\Delta = -2b(2\lambda_{\hat{e}}\sigma - \lambda_{\hat{e}\hat{e}}\sigma v) - \lambda_{\hat{e}}^2\sigma^2 > 0.\Box$; and the relationship between bribery and tax is

$$\frac{\partial B^*}{\partial \tau} = \frac{1}{2}\Big\{(a - 2be^*)\frac{\partial e^*}{\partial \tau} + e^c - \hat{e}^* - \tau\frac{\partial \hat{e}^*}{\partial \tau} - \lambda_{\hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau}(\sigma^F - \sigma^I)v - \lambda(\hat{e})(\sigma^F\frac{\partial e^*}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau})\Big\}.$$

Let $\varepsilon = \big\{(a - 2be^*)\frac{\partial e^*}{\partial \tau} - \tau\frac{\partial \hat{e}^*}{\partial \tau} - \lambda_{\hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau}(\sigma^F - \sigma^I)v - \lambda(\hat{e}^*)(\sigma^F\frac{\partial e^*}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau})\big\}$, $\varepsilon \gtrless 0$,

$$\frac{\partial B^*}{\partial \tau} > 0 \quad \text{if} \quad \hat{e}^* - \varepsilon < e^c \Leftrightarrow \begin{cases} \varepsilon < 0 \\ \hat{e}^* < e^c - |\varepsilon| \end{cases} \quad \text{or} \quad \begin{cases} \varepsilon > 0 \\ \hat{e}^* < e^c + |\varepsilon| \end{cases}.$$

$$\frac{\partial B^*}{\partial \tau} < 0 \quad \text{if} \quad \hat{e}^* - \varepsilon > e^c \Leftrightarrow \begin{cases} \varepsilon < 0 \\ \hat{e}^* > e^c - |\varepsilon| \end{cases} \quad \text{or} \quad \begin{cases} \varepsilon > 0 \\ \hat{e}^* > e^c + |\varepsilon| \end{cases}.$$

In other words,

$$\text{If} \quad \varepsilon < 0 \Rightarrow \frac{\partial B^*}{\partial \tau} > 0 \quad \text{if} \quad 0 < \hat{e}^* < e^c - |\varepsilon| \quad \text{and} \quad \frac{\partial B^*}{\partial \tau} < 0 \quad \text{if} \quad \hat{e}^* > e^c - |\varepsilon|.$$
$$\text{If} \quad \varepsilon > 0 \Rightarrow \frac{\partial B^*}{\partial \tau} > 0 \quad \text{if} \quad 0 < \hat{e}^* < e^c + |\varepsilon| \quad \text{and} \quad \frac{\partial B^*}{\partial \tau} < 0 \quad \text{if} \quad \hat{e}^* > e^c + |\varepsilon|.$$

Further, an increase in σ^F will increase $\big\{\lambda_{\hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau}(\sigma^F - \sigma^I)v\big\}$, leading to a decrease in $|\varepsilon|$. It also simultaneously will reduce $\big\{\lambda(\sigma^F\frac{\partial e}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau})\big\}$, leading to an increase

[2] $\lambda_{\hat{e}\hat{e}} > 0 \Leftrightarrow \lambda < 1/2 \Leftrightarrow \hat{e} > 0$. We cannot have $\lambda_{\hat{e}\hat{e}} < 0$ as it implies $\lambda > \frac{1}{2} \Leftrightarrow \hat{e} < 0$ which is a contradiction.

in $|\varepsilon|$. As a result, the probability of the positive impact of emission tax on bribery is ambiguous, $p(\frac{\partial B^*}{\partial \tau}) > 0 \uparrow\downarrow$.

Result 1. *This analytical application confirms Proposition 1 and clarifies the impact of emission tax on bribery.*

(i) Emission tax has a positive impact on bribery if reported emissions is around compliance emission e^c.

(ii) The impact of the penalty mechanism on the relationship between tax and bribery is ambiguous, depending upon tax magnitude and the correlation between compliance emissions, reported emissions, and penalty mechanism.

The findings in (i) are similar to those in Wilson and Damania (2005). However, the findings in (ii) are different from the latter's findings which pointed out that the relationship between penalty and bribery depend on the correlation between σ^F and σ^I.

5.4 Extended model with political connection

In this model, the firm uses its political connection to mitigate the probability of being audited. Let us assume that the cost function of maintaining political connection r_p is $C(r_p), C_{r_p} > 0, C_{r_p r_p} < 0$. The function of audit is $\lambda(\hat{e}_p, r_p), \lambda_{\hat{e}_p} < 0, \lambda_{r_p} < 0, \lambda_{\hat{e}_p\hat{e}_p} > 0, \lambda_{r_p r_p} > 0, \lambda_{\hat{e}_p r_p} > 0$. If the firm follows the strategy of compliance e^c_p, reports e^c_p, and pay tax τe^c_p, its profit is $[\pi(e^c_p) - \tau e^c_p]$. If it adopts the bribery strategy, its profit becomes $[\pi(e_p) - \big(C(r_p) + B_p + \tau\hat{e}_p + \lambda(\hat{e}_p, r_p) f^F_p(\sigma^F, \upsilon_p)\big)]$. Then, the function of the firm's expected gain is

$$g^F_p = \pi(e_p) - \big[C(r_p) + B_p + \tau\hat{e}_p + \lambda(\hat{e_p}, r_p) f^F_p(\sigma^F, \upsilon_p)\big] - \big[\pi(e^c_p) - \tau e^c_p\big].$$

Likewise, the function of the inspector's expected gain is

$$g^I_p = \big[w + B_p - \lambda(\hat{e}_p, r_p) f^I_p(\sigma^I, \upsilon_p)\big] - w = B - \lambda(\hat{e}, r) f^I_p(\sigma^I, \upsilon_p).$$

For sake simplicity, from now on, denotion p is skipped from calculations in certain cases.

5.4.1 Equilibrium

We adopt the two-stage backward induction to find the equilibrium and the impact of tax τ on emissions, political connection, and bribery. At the first stage, the firm and the inspector's optimization program is the maximization of the joint expected gain J_p as follows:

$$\max_{e_p,\hat{e}_p,r_p,} J_p \equiv g_p^F + g_p^I = \pi(e_p) - C(r_p) - \tau\hat{e}_p - \lambda(\hat{e}_p, r_p) f(\sigma^F, \sigma^I, v_p) - \left[\pi(e^c) - \tau e^c\right], \quad (5.8)$$

where γ and f are previously defined such that $\gamma > 0, \lambda_r < 0, \lambda_{rr} > 0; f_{v_p} > 0, f_{v_p v_p} > 0, C_{r_p} < 0, C_{r_p r_p} > 0$

The first order conditions are

$$\begin{cases} \frac{\partial J_p}{\partial e_p} & = \pi_e - \lambda(\hat{e}_p, r_p) f_{v_p} = 0 \\ \frac{\partial J_p}{\partial \hat{e}_p} & = -\tau - \lambda_{\hat{e}_p} f + \lambda(\hat{e}_p, r_p) f_{v_p} = 0 \\ \frac{\partial J_p}{\partial r_p} & = -C_{r_p} - \lambda_{r_p} f = 0 \end{cases} \quad (5.9)$$

Solve Eq.(5.9), we have an equilibrium. In order to ensure this equilibrium is a maximum, the second order conditions is checked. The Hessian matrix is

$$H = \begin{bmatrix} J_{ee} & J_{e\hat{e}} & J_{er} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} & J_{\hat{e}r} \\ J_{re} & J_{r\hat{e}} & J_{rr} \end{bmatrix}$$

H is negative semi-definite if $H_1 < 0, H_2 > 0, H_3 < 0$. We observe that

$$H_1 = J_{ee} = \pi_{ee} - \lambda f_{vv} < 0. \square$$

$$H_2 = \begin{bmatrix} J_{ee} & J_{e\hat{e}} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} \end{bmatrix} > 0 \Leftrightarrow \pi_{ee}^p < \tilde{\pi}_{ee}^p \equiv h(e_p, \hat{e}_p, r_p)$$

$$H_3 \equiv \Delta_p = det(H) = \begin{bmatrix} J_{ee} & J_{e\hat{e}} & J_{er} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} & J_{\hat{e}r} \\ J_{re} & J_{r\hat{e}} & J_{rr} \end{bmatrix} < 0 \Leftrightarrow \pi_{ee}^p < \bar{\pi}_{ee}^p \equiv l(e_p, \hat{e}_p, r_p)$$

Lemma 2. *If $\pi_{ee} < \pi_{ee}^p < \tilde{\pi}_{ee}^p \equiv h(e_p, \hat{e}_p, r_p)$ and*

(i) $C_{rr} < \bar{C}_{rr} \equiv k(e, \hat{e}, r)$ and $\pi_{ee}^p < \bar{\pi}_{ee}^p \equiv l(e_p, \hat{e}_p, r_p)$ or

(ii) $C_{rr} > \bar{C}_{rr} \equiv k(e, \hat{e}, r)$ *and* $\pi_{ee} > \bar{\pi}^{p}_{ee} \equiv l(e_p, \hat{e}_p, r_p)$*, the equilibrium is a maximum.*

See the proof in Appendix 5.B.□

Lemma 2 shows that the cooperation between the firm and the inspector in breach of environmental regulations only exists if (i) the firm's profit sensitivity is smaller than the threshold determined by the value of function $h(e, \hat{e}, \tau)$, and (ii) the political connected cost sensitivity and the profit sensitivity are simultaneously smaller or larger than the thresholds defined by the functions $k(e, \hat{e}, r)$ and $l(e, \hat{e}, r)$ respectively.

At the second stage, the firm and the inspector negotiate to determine the bribery based on Nash bargaining:

$$\max_{B_p} \Psi_p \equiv g^F_p \times g^I_p = \Big\{\pi(e_p) - [B_p + C(r_p) + \lambda(\hat{e}_p, r_p) f^F(\sigma^F, v_p)] - \pi(e^c_p) + \tau e^c_p\Big\} \times \Big\{B_p - \lambda(\hat{e}_p, r_p) f^I(\sigma^I, v_p)\Big\}.$$

The FOC is

$$\frac{\partial \Psi_p}{\partial B^*_p} = \pi(e^*_p) - \pi(e^c_p) - C(r_p) + \tau(e^c_p - \hat{e}^*_p) - \lambda\big(\hat{e}^*_P, r^*_p\big)\big[f^F(\sigma^F, v_p) - f^I(\sigma^I, v_p)\big] - 2B_p = 0.$$

The bribe equilibrium is:

$$B^*_p = \frac{1}{2}\Big\{\pi(e^*_p) - \pi(e^{c_p}) - C(r_p) + \tau(e^{c_p} - \hat{e}^*_p) - \lambda(\hat{e}^*_P, r^*_p)\big[f^F(\sigma^F, v_p) - f^I(\sigma^I, v_p)\big]\Big\}. \tag{5.10}$$

5.4.2 Political connection and tax efficiency

Following the implicit function theorem, we have

$$\begin{bmatrix} \pi_{ee} - \lambda f_{vv} & \lambda f_{vv} - \lambda_{\hat{e}} f_v & -\lambda_r f_v \\ \lambda f_{vv} - \lambda_{\hat{e}} f_v & -\lambda_{\hat{e}r} f + 2\lambda_{\hat{e}} f_v - \lambda f_{vv} & -\lambda_{\hat{e}r} f + \lambda_r f_v \\ -\lambda_r f_v & -\lambda_{\hat{e}r} f + \lambda_r f_v & -C_{rr} - \lambda_{rr} f \end{bmatrix} \begin{bmatrix} \frac{\partial e}{\partial \tau} \\ \frac{\partial \hat{e}}{\partial \tau} \\ \frac{\partial r}{\partial \tau} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}. \tag{5.11}$$

The corresponding matrix equation is

$$\begin{bmatrix} J_{ee} & J_{e\hat{e}} & J_{er} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} & J_{\hat{e}r} \\ J_{re} & J_{r\hat{e}} & J_{rr} \end{bmatrix} \times \begin{bmatrix} \frac{\partial e^*_p}{\partial \tau} \\ \frac{\partial \hat{e}^*_p}{\partial \tau} \\ \frac{\partial r^*_p}{\partial \tau} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \tag{5.12}$$

where $J_{ee} < 0, J_{e\hat{e}} = J_{\hat{e}e} > 0, J_{er} = J_{re} > 0, J_{\hat{e}\hat{e}} < 0, J_{\hat{e}r} = J_{r\hat{e}} < 0\, J_{rr} < 0$, and $J_{e\hat{e}} = J_{\hat{e}e} > 0$.

From Eq.(5.12), we have:

$$\frac{\partial e_p^*}{\partial \tau} = \frac{J_{er}J_{\hat{e}r} - J_{\hat{e}e}J_{rr}}{\Delta_p} = \frac{1}{\Delta_p}\Big\{\lambda_r\lambda_{\hat{e}r}ff_v - \lambda^2 f_v^2 + C_{rr}\lambda f_{vv} - C_{rr}\lambda_{\hat{e}}f_v + \lambda\lambda_{rr}ff_{vv} - \lambda_{\hat{e}}\lambda_{rr}ff_v\Big\} \gtreqless 0$$

$$\frac{\partial \hat{e}_p^*}{\partial \tau} = \frac{J_{ee}J_{rr} - J_{er}^2}{\Delta_p} = \frac{1}{\Delta_p}\Big\{C_{rr}\lambda f_{vv} + \lambda\lambda_{rr}ff_{vv} - C_{rr}\pi_{ee} - \pi_{ee}\lambda_{rr}f - \lambda_r^2 f_v^2\Big\} \gtreqless 0$$

$$\frac{\partial r_p^*}{\partial \tau} = \frac{J_{\hat{e}e}J_{re} - J_{ee}J_{\hat{e}r}}{\Delta_p} = \frac{1}{\Delta_p}\Big\{\lambda_r\lambda_{\hat{e}}f_v^2 + \pi_{ee}\lambda_{\hat{e}r}f - \pi_{ee}\lambda_r f_v - \lambda\lambda_{\hat{e}r}ff_{vv}\Big\} \gtreqless 0$$

$$\frac{\partial B_p^*}{\partial \tau} = \frac{1}{2}\Big\{\frac{\partial \pi}{\partial e}\frac{\partial e}{\partial \tau} + e^c - \hat{e} - \tau\frac{\partial \hat{e}}{\partial \tau} - (\frac{\partial \lambda}{\partial \hat{e}}\frac{\partial \hat{e}}{\partial \tau} + \frac{\partial \lambda}{\partial r}\frac{\partial r}{\partial \tau})(f^F - f^I) - \lambda(\frac{\partial f^F}{\partial v}\frac{\partial e}{\partial \tau} + \frac{\partial f^I}{\partial v}\frac{\partial \hat{e}}{\partial \tau})\Big\} \gtreqless 0$$

Proposition 2. *Firm's political connection may have significant impacts on the cooperation between the firm and the inspector in terms of the breach of regulations. Indeed, if political connection is taken into account, the impacts of tax on current emissions, reported emissions, political connection, and bribery become ambiguous.*

5.4.3 Analytical application

In order to clarify the relationships in Proposition 2, we develop an analytical application, using the similar parametric functions in Subsection 4.3 as $\pi = (a - be)e, f^F = \sigma^F v_p, f^I = \sigma^I v_p$. We include the function of political connection costs $C(r) = \frac{1}{2}\gamma r_p^2$ and the probability of being audited. $\lambda(\hat{e}_p, r_p)$, r_p is the level of political connection, γ is the sensitivity of political connection costs. $\lambda(\hat{e}_p, r_p) = \frac{exp(-\hat{e}_p - \rho r_p)}{1+exp(-\hat{e}_p - \rho r_p)}$, $\lambda \in [0,1]$; $\lambda_{\hat{e}} = -\lambda(1-\lambda) < 0, \lambda_{\hat{e}_p\hat{e}_p} = \lambda_{\hat{e}_p}(2\lambda - 1) > 0, \lambda_r = -\rho\lambda(1-\lambda) < 0, \lambda_{rr} = \rho\lambda_r(2\lambda - 1) > 0, \lambda_{\hat{e}r} = \lambda_r(2\lambda - 1) > 0$. Then, the joint objective function is

$$J \equiv g^F + g^I = \Big\{(a - be)e_p - \frac{1}{2}\gamma r^2 - \tau\hat{e}_p - \lambda(\hat{e}_p, r_p)(\sigma^F + \sigma^I)v_p\Big\} - \big\{\pi(e_p^c) - \tau e_p^c\big\}. \quad (5.13)$$

The first and second derivatives of J are calculated as: $J_e = a - 2be - \lambda\sigma, J_{\hat{e}} = -\tau + \lambda\sigma - \lambda_{\hat{e}}\sigma v, J_{ee} = -2b < 0, J_{\hat{e}e} = -\lambda_{\hat{e}}\sigma > 0, J_{\hat{e}\hat{e}} = 2\lambda_{\hat{e}}\sigma - \lambda_{\hat{e}\hat{e}}\sigma v < 0, J_r = -\gamma r - \lambda_r\sigma v < 0, J_{re} = -\lambda_r\sigma > 0, J_{r\hat{e}} = \lambda_r\sigma - \lambda_{r\hat{e}}\sigma v < 0, J_{rr} = -\gamma - \lambda_{rr}\sigma v < 0$.

Impact of emission tax on the firm's current emissions and reported emissions are as follows:

$$\frac{\partial e_p^*}{\partial \tau} = \frac{1}{\Delta_p}\Big\{ -\lambda_r^2\sigma^2 + \lambda_r\lambda_{r\hat{e}}\sigma^2 v + 2\lambda_{\hat{e}}\sigma\gamma v + 2\lambda_{\hat{e}}\lambda_{rr}\sigma^2 v - \lambda_{\hat{e}\hat{e}}\sigma v\gamma - \lambda_{\hat{e}\hat{e}}\lambda_{rr}\sigma^2 v^2\Big\} > 0.\square$$
$$\frac{\partial \hat{e}_p^*}{\partial \tau} = \frac{1}{\Delta_p}\Big\{ -2b(-\gamma - \lambda_{rr}\sigma - \lambda_r^2\sigma^2)\Big\} < 0.\square$$

The relationship between emission tax and political connection is

$$\begin{aligned}\frac{\partial r^*}{\partial \tau} &= \frac{1}{\Delta_p}\Big\{\lambda_{\hat{e}}\lambda_r\sigma^2 + 2b(\lambda\sigma - \lambda_{\hat{e}r}\sigma v)\Big\}\\ &= \frac{\sigma}{\Delta_p}\Big\{\sigma\lambda^3 - 2(1-2b\rho v)\lambda^2 + (1+6b\rho v)\lambda + 2b - 2b\rho v\Big\}\\ &= \frac{\sigma}{\Delta_p}k(\lambda), \quad k(\lambda) \equiv \sigma\lambda^3 - 2(1-2b\rho v)\lambda^2 + (1+6b\rho v)\lambda + 2b - 2b\rho v.\end{aligned}$$

The sign of $\frac{\partial r}{\partial \tau}$ depends on the value of $k(\lambda)$. We calculate

$$\lim_{\lambda\to 0} k(\lambda) = 2b(1-\rho v) \gtrless 0 \quad \text{and} \quad \lim_{\lambda\to 1/2} k(\lambda) = \frac{1}{8}\sigma + 2b(1+\rho v) > 0.$$

For sake of simplicity, we denote $t \equiv b\rho v$. Since $\sigma > 0$,

$$k(\lambda) \Leftrightarrow \lambda^3 + \frac{2(1-2t)}{\sigma}\lambda^2 + \frac{1+6t}{\sigma}\lambda + \frac{2b(1-\rho v)}{\sigma} = 0. \tag{5.14}$$

Denoting $\lambda = y - \frac{2(1-2t)}{3\sigma}$, since $\lambda \in [0, \frac{1}{2}] \Rightarrow y \in [\psi; \frac{1}{2} + \psi]$, $\quad \psi \equiv \frac{2(1-2t)}{3\sigma}$, Eq.(5.14) then becomes

$$f(y) : y^3 - py + q = 0. \tag{5.15}$$

We define $p \equiv \frac{[\frac{2}{\sigma}(1-t)]^2}{3} - \frac{1+6t}{\sigma} = \frac{4(1-t)^2 - 3\sigma(1+6t)}{3\sigma^2}$ and $q \equiv \frac{2[\frac{2(1-2t)}{\sigma}]^3 - 9[\frac{2(1-2t)}{\sigma}][\frac{1+6t}{\sigma}] + 27\frac{2b(1-\rho v)}{\sigma}}{27} = \frac{16(1-2t)^3 - 18\sigma(1-2t)(1+6t) + 54\sigma^2(b-t)}{27\sigma^3}$, and set $\Phi = 27q^2 - 4p^3$. There are several situations where solutions of Eq.(5.15) depends on the values of p, Φ, q.[3] The result is presented as follows:

We observe that, in Table 5.1, if $q \geqslant 0$, $\psi < 0$, and $\psi < -\frac{1}{2}$, then political connection increase with tax if value of audit λ is smaller than a certain threshold $\bar{\lambda}_0$ ($\equiv y_0 - \psi$). If this value is higher than the threshold, this relationship will become negative. This result is similar to that of the case with $q < 0$ and $\psi > -\frac{1}{2}$. Meanwhile, $\forall\, \lambda \in [0, \frac{1}{2}]$, if $q \geqslant 0$ and $\psi > 0$, this impact will be negative.

[3]See detail calculations in Appendix 5.C.

Table 5.1: Impact of tax on political connection, the case with $p \leqslant 0$

	$q \geqslant 0$	$q < 0$
ψ	$\psi < y_0 < \frac{1}{2} + \psi$	$\psi < y_0 < \frac{1}{2} + \psi$
$(-\infty, -\frac{1}{2})$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_0$ $\frac{\partial r}{\partial \tau} < 0$ if $y_0 < y < \psi + \frac{1}{2}$	
$(-\frac{1}{2}, 0)$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_0$ $\frac{\partial r}{\partial \tau} < 0$ if $y_0 < y < \frac{1}{2} + \psi$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_0$ $\frac{\partial r}{\partial \tau} < 0$ if $y_0 < y < \frac{1}{2} + \psi$
$(0, +\infty)$	$\frac{\partial r}{\partial \tau} < 0$ if $\psi < y < \frac{1}{2} + \psi$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_0$ $\frac{\partial r}{\partial \tau} < 0$ if $y_0 < y < \psi + \frac{1}{2}$

Note: y_0 is root of Eq.(5.15); $y_0 = \sqrt[3]{\frac{-q+\frac{\Phi}{27}}{2}} + \sqrt[3]{\frac{-q-\frac{\Phi}{27}}{2}}$.

Table 5.2: Impact of tax on political connection, the case with $p > 0$ and $\Phi > 0$

	$q \geqslant 0$	$q < 0$
ψ	$\psi < y_1 < \frac{1}{2} + \psi$	$\psi < y_1 < \frac{1}{2} + \psi$
$(-\infty, -\frac{1}{2})$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_1$ $\frac{\partial r}{\partial \tau} < 0$ if $y_1 < y < \psi + \frac{1}{2}$	
$(-\frac{1}{2}, 0)$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_1$ $\frac{\partial r}{\partial \tau} < 0$ if $y_1 < y < \psi + \frac{1}{2}$	$\frac{\partial r}{\partial \tau}$ if $\psi < y < y_1$ $\frac{\partial r}{\partial \tau} < 0$ if $y_1 < y < \psi + \frac{1}{2}$
$(0, +\infty)$	$\frac{\partial r}{\partial \tau} < 0$ if $\psi < y < \frac{1}{2} + \psi$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_1$ $\frac{\partial r}{\partial \tau} < 0$ if $y_1 < y < \psi + \frac{1}{2}$

Note: y_1 is root of eq.(5.15). $y_1 = \sqrt[3]{\frac{-q+\frac{\Phi}{27}}{2}} + \sqrt[3]{\frac{-q-\frac{\Phi}{27}}{2}}$.

Table 5.2 shows that in the case with $p > 0$ and $\Phi > 0$, the relationship between emission tax and political connection is similar to that of the previous case.

Table 5.3: Impact of tax on political connection, the case with $p > 0$ and $\Phi = 0$

	$q \geqslant 0$	$q < 0$	
ψ	$\psi < y_2 < \frac{1}{2} + \psi$	$\psi < y_2 < \frac{1}{2} + \psi$	$\psi < y_3 < y_2 < \frac{1}{2} + \psi$
$(-\infty, -\frac{1}{2})$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_2$ $\frac{\partial r}{\partial \tau} < 0$ if $y_2 < y < \psi + \frac{1}{2}$		
$(-\frac{1}{2}, 0)$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_2$ $\frac{\partial r}{\partial \tau} < 0$ if $y_2 < y < \psi + \frac{1}{2}$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_2$ $\frac{\partial r}{\partial \tau} < 0$ if $y_2 < y < \frac{1}{2} + \psi$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_2$ $\frac{\partial r}{\partial \tau} < 0$ if $y_2 < y < \psi + \frac{1}{2})$
$(0, +\infty)$	$\frac{\partial r}{\partial \tau} < 0$ if $\psi < y < \psi + \frac{1}{2}$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_2$ $\frac{\partial r}{\partial \tau} < 0$ if $y_2 < y < \frac{1}{2} + \psi$	

Note: y_2, y_3 are roots of Eq.(5.15). $y_2 = \pm\sqrt[3]{4q}$ and $y_3 = \mp\sqrt[3]{\frac{q}{2}}$.

For the case with $p \geqslant 0$ and $\Phi = 0$, we observe that if $\psi \in (-\frac{1}{2}, 0)$, political connection will increase with tax if λ is smaller than a certain threshold $\bar{\lambda}_1 (\equiv y_2 - \psi)$ (see Table 5.3). This relationship will be negative if λ becomes larger than $\bar{\lambda}_1$. This result is similar for the case with $(q \geqslant 0, \psi < -\frac{1}{2})$ and $(q < 0, \psi > 0)$. However, given $q \geqslant 0$, the relationship, in this case, will become negative $\forall \lambda \in [0, \frac{1}{2}]$ if $\psi > 0$, which is similar to that of the case with $(p \leqslant 0, q \geqslant 0$, and $\psi > 0)$ and $(p > 0, \Phi > 0$, and $\psi > 0)$. All these results have the same implication to the previous cases.

The results presented in Table 5.4 reveals that if $\psi < -\frac{1}{2}$ or $\psi > 0$, and only one root $y \in (\frac{1}{2}, \psi + \frac{1}{2})$, then the impact of tax on political connection is positive if λ is smaller a threshold $\bar{\lambda}$. Otherwise, this impact will change to be negative if λ is larger a threshold.

Meanwhile, if $y_5, y_6 \in (\frac{1}{2}, \psi + \frac{1}{2})$, this relationship will be reversed. Indeed, political connection will increase with tax if $\lambda \in (0, y_5)$ or $\lambda \in (y_6, \frac{1}{2})$. In the case $y_5 - \psi < \lambda < y_6 - \psi$, this relationship will be negative.

We observe that if there is only one root $y \in (\psi, \psi + \frac{1}{2})$ and if $\psi > -\frac{1}{2}$,

Table 5.4: Impact of tax on political connection, the case with $p > 0, \Phi < 0$ and $q \geqslant 0$

ψ	$\frac{1}{2} < y_4 < \psi + \frac{1}{2}$	$\frac{1}{2} < y_5, y_6 < \psi + \frac{1}{2}$	$\frac{1}{2} < y_6 < \psi, \infty$
$-\infty$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_4$ $\frac{\partial r}{\partial \tau} < 0$ if $y_4 < y < \psi + \frac{1}{2}$		
$-\frac{1}{2}, 0$		$\frac{\partial r}{\partial \tau} < 0$ if $y \in (\psi, y_5)$ or $(y_6, \psi + \frac{1}{2})$ $\frac{\partial r}{\partial \tau} > 0$ if $y \in (y_5, y_6)$	
$+\infty$			$\frac{\partial r}{\partial \tau} > 0$ if $y \in (\psi, y_6)$ $\frac{\partial r}{\partial \tau} < 0$ if $y \in (y_6, \psi + \frac{1}{2})$

Note: y_4, y_5, y_6 are roots of eq.(5.15); $y_4 = 2\sqrt{\frac{p}{3}} \cos x$, $y_5 = 2\sqrt{\frac{p}{3}} \cos(x + \frac{2\pi}{3})$, $y_6 = 2\sqrt{\frac{p}{3}} \cos(x + \frac{4\pi}{3})$.

Table 5.5: Impact of tax on political connection if $p > 0, \Phi < 0$ and $q < 0$

ψ	$\psi < y_5 < \psi + \frac{1}{2}$	$\psi < y_4, y_5 < \psi + \frac{1}{2}$
$-\infty, -\frac{1}{2}$	$\frac{\partial r}{\partial \tau} < 0$ if $y \in (\psi, y_5)$. $\frac{\partial r}{\partial \tau} > 0$ if $y \in (y_5, \psi + \frac{1}{2})$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_4$ or $y_5 < y < \psi + \frac{1}{2}$. $\frac{\partial r}{\partial \tau} < 0$ if $y_4 < y < y_5$
$-\frac{1}{2}, +\infty$		
ψ	$\psi < y_6 < \psi + \frac{1}{2}$	$\psi < y_5, y_6 < \psi + \frac{1}{2}$
$-\infty, -\frac{1}{2}$		
$-\frac{1}{2}, 0$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_6$. $\frac{\partial r}{\partial \tau} < 0$ if $y_6 < y < \psi + \frac{1}{2}$	$\frac{\partial r}{\partial \tau} < 0$ if $\psi < y < y_5$ or $y_6 < y < \psi + \frac{1}{2}$. $\frac{\partial r}{\partial \tau} > 0$ if $y_5 < y < y_6$
$0, +\infty$	$\frac{\partial r}{\partial \tau} > 0$ if $\psi < y < y_6$. $\frac{\partial r}{\partial \tau} < 0$ if $y_6 < y < \psi + \frac{1}{2}$	

Note: y_4, y_5, y_6 are roots of eq.(5.15); $y_4 = 2\sqrt{\frac{p}{3}} \cos x$, $y_5 = 2\sqrt{\frac{p}{3}} \cos(x + \frac{2\pi}{3})$, $y_6 = 2\sqrt{\frac{p}{3}} \cos(x + \frac{4\pi}{3})$.

the impact of tax on political connection change from negative to positive when the value of audit probability is over a threshold $\bar{\lambda}_2$ ($\equiv y_6$) (See Table 5.5). This impact will be opposite if $\psi < -\frac{1}{2}$. However, it is similar to that of the case with $p > 0, \Phi < 0, q \geqslant 0$ and $\psi < -\frac{1}{2}$.

Meanwhile, the result for the case that two roots $y \in (\psi, \psi + \frac{1}{2})$, if $-\frac{1}{2} < \psi < 0$, political connection increase with tax if λ is bounded by these two roots. This result is opposite to that of the case if $\psi < -\frac{1}{2}$. However, it is similar to that of the case with $p > 0, \Phi < 0, q \geqslant 0$ and $\psi \in (-\frac{1}{2}, 0)$.
Finally, the impact of tax on bribery is

$$\frac{\partial B_p^*}{\partial \tau} = \frac{1}{2}\Big\{(a - 2be^*)\frac{\partial e^*}{\partial \tau} + e^c - \hat{e}^* - \tau\frac{\partial \hat{e}^*}{\partial \tau} - (\frac{\partial \lambda}{\partial \hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau} + \frac{\partial \lambda}{\partial r^*}\frac{\partial r^*}{\partial \tau})(\sigma^F - \sigma^I)v - \lambda(\sigma^F\frac{\partial e^*}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau})\Big\} \gtreqless 0.$$

Therefore, the relationship between emission tax and bribery in this case is ambiguous. In order clarify this relationship, the above equation is rewritten as follows:

$$\frac{\partial B_p^*}{\partial \tau} = e^c - \hat{e}^* + \mu.$$

where $\mu = (a - 2be^*)\frac{\partial e^*}{\partial \tau} - \tau\frac{\partial \hat{e}^*}{\partial \tau} - (\frac{\partial \lambda}{\partial \hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau} + \frac{\partial \lambda}{\partial r^*}\frac{\partial r^*}{\partial \tau})(\sigma^F - \sigma^I)v - \lambda(\sigma^F\frac{\partial e^*}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau}), \mu \gtreqless 0$.
We observe that

$$\frac{\partial B_p^*}{\partial \tau} > 0 \quad \text{if} \quad \hat{e}^* - \mu < e^c \Leftrightarrow \begin{cases} \mu < 0 \\ \hat{e}^* < e^c - |\mu| \end{cases} \quad \text{or} \quad \begin{cases} \varepsilon > 0 \\ \hat{e}^* < e^c + |\mu| \end{cases}.$$

$$\frac{\partial B_p^*}{\partial \tau} < 0 \quad \text{if} \quad \hat{e}^* - \mu > e^c \Leftrightarrow \begin{cases} \mu < 0 \\ \hat{e}^* > e^c - |\mu| \end{cases} \quad \text{or} \quad \begin{cases} \mu > 0 \\ \hat{e}^* > e^c + |\mu| \end{cases}.$$

In other words,

$$\text{If} \quad \mu < 0 \Rightarrow \frac{\partial B_p^*}{\partial \tau} > 0 \quad \text{if} \quad 0 < \hat{e}^* < e^c - |\mu| \quad \text{and} \quad \frac{\partial B_p^*}{\partial \tau} < 0 \quad \text{if} \quad \hat{e}^* > e^c - |\mu|.$$
$$\text{If} \quad \mu > 0 \Rightarrow \frac{\partial B_p^*}{\partial \tau} > 0 \quad \text{if} \quad 0 < \hat{e}^* < e^c + |\mu| \quad \text{and} \quad \frac{\partial B_p^*}{\partial \tau} < 0 \quad \text{if} \quad \hat{e}^* > e^c + |\mu|.$$

For analyzing the role of penalty mechanism in the relationship between emission tax and bribery, we consider the first case $\sigma^F > \sigma^I$ and $\frac{\partial r}{\partial \tau} < 0$, an increase in penalty σ^F will increase $\big\{\frac{\partial \lambda}{\partial \hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau} + \frac{\partial \lambda}{\partial r^*}\frac{\partial r^*}{\partial \tau}(\sigma^F - \sigma^I)v\big\}$, leading to a decrease in $|\mu|$. It also simultaneously increases $\lambda(\sigma^F\frac{\partial e^*}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau})$, leading to a decrease in $|\mu|$. Therefore, the probability of the positive impact of emission tax on bribe $p(\hat{e}^* - |\mu| < e^c)$ or $p(\frac{\partial B_p^*}{\partial \tau})$ will be decreased.

For the second case, $\sigma^F > \sigma^I$ and $\frac{\partial r^*}{\partial \tau} > 0$, an increase in σ^F may increase or reduce $\{\frac{\partial \lambda}{\partial \hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau} + \frac{\partial \lambda}{\partial r^*}\frac{\partial r^*}{\partial \tau}(\sigma^F - \sigma^I)v\}$, depending upon the sign of $\{\frac{\partial \lambda}{\partial \hat{e}^*}\frac{\partial \hat{e}^*}{\partial \tau} + \frac{\partial \lambda}{\partial r^*}\frac{\partial r^*}{\partial \tau}\}$, then μ may be decreased or increased. Simultaneously, the term $\lambda(\sigma^F\frac{\partial e^*}{\partial \tau} + \sigma^I\frac{\partial \hat{e}^*}{\partial \tau})$ still increase, leading to an increase in $|\mu|$. Hence, the probability of $p(\frac{\partial B_p^*}{\partial \tau} > 0)$ may be increased or decreased.

Result 2. *This analytical illustration shows that political connection may affect the relationship between emission tax and the firm's emissions. It also provides further explanation for the impacts of emission tax on bribe and political connection.*

(i) Political connection changes the impact of emission tax on current emissions from negative ($\frac{\partial e_p^*}{\partial \tau} < 0$) *to positive affect* ($\frac{\partial e_p^*}{\partial \tau} > 0$)*. Meanwhile, the link between tax and reported emissions maintain unchanged* $\frac{\partial \hat{e}_p^*}{\partial \tau} < 0$.

(ii) The impact of tax on political connection is ambiguous, depending upon the relationship between audit and component consisted of penalty σ, firm's profit sensitivity b, the sensitivity of political connected cost ρ, and the level of underreported emissions v.

(iii) The impact of emission tax on bribery is contingent upon the correlation between compliance emissions e^c and reported emissions $\hat{e}$, which is also associated with the penalty mechanism.

The finding in (i) on the relationship between emission tax and reported emission is aligned with Wilson and Damania (2005). Meanwhile, the finding on the link between emission tax and current emissions, $\frac{\partial e_p^*}{\partial \tau} > 0$ is constradict to Wilson and Damania (2005).

Furthermore, the impact of tax on reported emissions is similar to that in the previous model. With political connection, the firm continues to reduce the level of underreported emissions. This proposition is likely to be consistent with Sandmo (2002) who found that firm's reported emissions are associated with firm's characteristics and its capacity in responding to the probability of being audited.

The finding (ii) reveals that an increase in emission tax may encourage firms in using political connection if audit mechanism is still lower than a certain threshold $\lambda < \bar{\lambda}$. However, this property may not be hold if audit increases to the level which is higher than the threshold $\lambda > \bar{\lambda}$. This finding is in line with Gerigk (2016)'s finding that interest group's response to environmental regulations is contingent on the stringency of regulations and government's enforceability.

The finding (iii) points out that the impacts of tax on bribery is ambiguous, depending on several indicators such as the firm's and the inspector's behaviors about penalty and audit mechanism. Therefore, more stringent environmental regulations might not always to be successful. Such regulations should be accompanied by a framework of policy mix of other complementary measurements such as the firm's production characteristics, audit and penalty mechanism, and institutional capacity. This finding shows that the result of Cheng and Lai (2012) may not be hold because the political connection costs were not analyzed in their model.

5.5 Conclusion

This chapter explores the efficiency of emission tax (in the presence of audit and penalty mechanism) and the impacts of tax on committing bribery and maintaining political connection. We find that an increase in emission tax can decrease both current emissions and reported emissions. However, the first impact on current emissions could be changed from negative to positive if taking into consideration firm's political connection. Further, these impacts depend upon the relationship between the firm's profit sensitivity and parameters of audit, penalty mechanism, and political connection costs. However, if tax is increased quickly, firms would be encouraged in maintaining political connection to avoid tax. Further, the impact of emission tax on bribery is non-monotonous, which is contingent upon tax magnitude and correlation between the parameters of the functions of audit, penalty, and political connection costs.

This chapter clarifies the impacts of tax on firm's emission, bribery, and political connection. This research find the novelty that the effectiveness of tax on emission compliance may be affected by firm's political capital.

These results inspire us to propose further research that could extend a model for the case of asymmetric information between the firm and the inspector in breach of regulations. It would be promising to include the influence of risk preferences. In addition, the relationship between producers and consumers with respect to environmental issues could be also interesting to analyze. In this approach, it is possible to extend a model including governments, firms, and consumers with respect to economic benefits and environmental issues from a dynamic perspective.

5.6 Appendix

Appendix 5.A: Model of tax on emissions and bribery

$$\max_{e,\hat{e}} J \equiv g^F + g^I = \pi(e) - \tau\hat{e} - \lambda(\hat{e})[f^F(\sigma^F, v) + f^I(\sigma^I, v)] - [\pi(e^c) - \tau e^c]$$
$$= \pi(e) - \tau\hat{e} - \lambda(\hat{e})f(\sigma^F, \sigma^I, v) - [\pi(e^c) - \tau e^c], \qquad (5.16)$$

where $f(\sigma^F, \sigma^I, v) \equiv f^F(\sigma^F, v) + f^I(\sigma^I, v)$ is sum of two penalty functions. The first order conditions (FOCs) are:

$$\begin{cases} \frac{\partial J}{\partial e} = \pi_e - \lambda(\hat{e})[f_v^F + f_v^I] = 0 \\ \frac{\partial J}{\partial \hat{e}} = -\tau - \lambda_{\hat{e}}[f^F + f^I] + \lambda(\hat{e})[f_v^F + f_v^F] = 0 \end{cases} \qquad (5.17)$$

In order to ensure the existence of a maximum, we check the second order conditions. We have the Hessian matrix:

$$H = \begin{bmatrix} J_{ee} & J_{e\hat{e}} \\ J_{e\hat{e}} & J_{\hat{e}\hat{e}} \end{bmatrix} \qquad (5.18)$$

H semi negatively definite if $H_1 < 0$ and $H_2 > 0$. We observe that

$$H_1 = J_{ee} = \pi_{ee} - \lambda(\hat{e})f_{vv} < 0.$$

$$H_2 = J_{ee}J_{\hat{e}\hat{e}} - J_{e\hat{e}}^2 > 0 \Leftrightarrow \pi_{ee} < \frac{\lambda_{\hat{e}}^2 f_v^2 - \lambda\lambda_{\hat{e}\hat{e}} f f_{vv}}{2\lambda_{\hat{e}} f_v - \lambda_{\hat{e}\hat{e}} f - \lambda f_{vv}}.$$

Appendix 5.B: Extended model with political connection

At the first stage, the firm and the inspector's optimization program is the maximization of the joint expected gain J_p as follows:

$$\max_{e_p,\hat{e}_p,r_p,} J_p \equiv g_p^F + g_p^I = \pi(e_p) - C(r_p) - \tau\hat{e}_p - \lambda(\hat{e}_p, r_p)f(\sigma^F, \sigma^I, v_p) - \left[\pi(e^c) - \tau e^c\right], \qquad (5.19)$$

where γ and f are previously defined such that $\gamma > 0, \lambda_r < 0, \lambda_{rr} > 0; f_{v_p} > 0, f_{v_p v_p} > 0, C_{r_p} < 0, C_{r_p r_p} > 0$

The first order conditions are:

$$\begin{cases} \frac{\partial J_p}{\partial e} &= \pi_e - \lambda(\hat{e}, r) f_v^T = 0 \\ \frac{\partial J_p}{\partial \hat{e}} &= -\tau - \lambda_{\hat{e}} f^T + \lambda(\hat{e}, r) f_v^T = 0 \\ \frac{\partial J_p}{\partial r} &= -\gamma r - \lambda_r f^T = 0 \end{cases} \tag{5.20}$$

In order to ensure the existence of a maximum, the second order conditions are checked. Hessian matrix is derived as follows:

$$H = \begin{bmatrix} J_{ee} & J_{e\hat{e}} & J_{er} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} & J_{\hat{e}r} \\ J_{re} & J_{r\hat{e}} & J_{rr} \end{bmatrix}$$

H is negatively semi-definite if $H_1 < 0, H_2 > 0, H_3 < 0$. We observe that

$$H_1 = J_{ee} = \pi_{ee} - \lambda f_{vv} < 0.\square$$

$$H_2 = \begin{bmatrix} J_{ee} & J_{e\hat{e}} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} \end{bmatrix} > 0 \Leftrightarrow \pi_{ee} < \frac{\lambda\lambda_{\hat{e}r} f f_{vv} + \lambda_{\hat{e}}^2 f_{vv}^2}{\lambda_{\hat{e}r} f - \lambda f_{vv} - 2\lambda_{\hat{e}} f_v} \tag{5.21}$$

$$H_3 \equiv \Delta_p = det(H) = \begin{bmatrix} J_{ee} & J_{e\hat{e}} & J_{er} \\ J_{\hat{e}e} & J_{\hat{e}\hat{e}} & J_{\hat{e}r} \\ J_{re} & J_{r\hat{e}} & J_{rr} \end{bmatrix} < 0 \Leftrightarrow \pi_{ee} < \lambda f_{vv} + \frac{a}{b} \equiv \underline{\pi}_{ee}, \quad \text{where}$$

$a = 2\lambda\lambda_r\lambda_{\hat{e}r} f f_v f_{vv} - 2\lambda\lambda_r^2 f_v^2 f_{vv} - 2\lambda_r\lambda_{\hat{e}}\lambda_{\hat{e}r} f f_{vv}^2 + 2\lambda_{\hat{e}}\lambda_r^2 f^3 + 2\lambda_r\lambda_{\hat{e}} f_v^2 - \lambda\lambda_r f_v f_{vv} - \lambda_r\lambda_{\hat{e}r} f f_v +$
$\lambda^2\lambda_{rr} f f_{vv}^2 - 2\lambda\lambda_{\hat{e}}\lambda_{rr} f f_v f_{vv} + \lambda_{\hat{e}}\lambda_{rr} f f_v^2 + \gamma(\lambda^2 f_{vv}^2 - 2\lambda\lambda_{\hat{e}} f_v f_{vv} + \lambda_{\hat{e}}^2 f_v^2)$

$b = \lambda_{\hat{e}r}^2 f - 2\lambda_r\lambda_{\hat{e}r} f f_v + \lambda_r^2 f_v^2 + 2\lambda_{rr}\lambda_{\hat{e}} f f_v - \lambda\lambda_{rr} f f_{vv} - \lambda_{\hat{e}r}\lambda_{rr} f^2 + \gamma(2\lambda_{\hat{e}} f_v - \lambda f_{vv} - \lambda_{\hat{e}r} f)$

Lemma 2. *If* $\pi_{ee} < \frac{\lambda\lambda_{\hat{e}r} f f_{vv} + \lambda_{\hat{e}}^2 f_{vv}^2}{\lambda_{\hat{e}r} f - \lambda f_{vv} - 2\lambda_{\hat{e}} f_v} \equiv \bar{\pi}_{ee}^p$ *and*

(i) $\gamma < -\lambda_{rr} f + \frac{\lambda_r^2 f_v^2}{\lambda f_{vv} + \lambda_{\hat{e}r} f - 2\lambda_{\hat{e}} f_v} \equiv \bar{\gamma}$ *and* $\pi_{ee}^p < \lambda f_{vv} + \frac{a}{b} \equiv \tilde{\pi}_{ee}^p$ *or*

(ii) $\gamma > -\lambda_{rr} f + \frac{\lambda_r^2 f_v^2}{\lambda f_{vv} + \lambda_{\hat{e}r} f - 2\lambda_{\hat{e}} f_v} \equiv \bar{\gamma}$ *and* $\pi_{ee} > \lambda f_{vv} + \frac{a}{b} \equiv \tilde{\pi}_{ee}^p$*, the solution of the problem is max.*$\square$

Appendix 5.C: Analytical application for the extended model

Denoting $\lambda = y - \frac{2(1-2t)}{3\sigma}$, since $\lambda \in [0, \frac{1}{2}] \Rightarrow y \in [\psi; \frac{1}{2} + \psi]$, $\quad \psi \equiv \frac{2(1-2t)}{3\sigma}$. We have the following equation:

$$f(y) : y^3 - py + q = 0. \tag{5.22}$$

We use procedure guided in Wolfram MathWorld to find roots of eq.(5.22).[4] We define

$$p \equiv \frac{[\frac{2}{\sigma}(1-t)]^2}{3} - \frac{1+6t}{\sigma} = \frac{4(1-t)^2 - 3\sigma(1+6t)}{3\sigma^2}$$
$$q \equiv \frac{2[\frac{2(1-2t)}{\sigma}]^3 - 9[\frac{2(1-2t)}{\sigma}][\frac{1+6t}{\sigma}] + 27\frac{2b(1-\rho v)}{\sigma}}{27} = \frac{16(1-2t)^3 - 18\sigma(1-2t)(1+6t) + 54\sigma^2(b-t)}{27\sigma^3}$$

and set $\Phi = 27q^2 - 4p^3$. We have $f' = 3y^2 - p$. Therefore,

(i) If $p \leqslant 0 \Rightarrow f'(y) \geqslant 0 \Rightarrow f(y)$ is increasing $\Rightarrow f(y) = 0$ has a unique root y_0.

(ii) If $p > 0 \Rightarrow f'(y) = 0 \Leftrightarrow y = \pm\sqrt{\frac{p}{3}}$ and $f_{max}f_{min} = f(\sqrt{\frac{p}{3}}) \times f(-\sqrt{\frac{p}{3}}) = \frac{\Phi}{27}$.

(ii.1) If $p > 0$ and $\Phi > 0$, Eq.(5.22) has a unique root y_1. To find this root, we set $y \equiv u + v$ then Eq.(5.22) becomes

$$u^3 + v^3 + (3uv - p)(u+v) + q = 0 \tag{5.23}$$

We choose u, v such that $3uv - p = 0 \Leftrightarrow uv = \frac{p}{3}$. Then, $u^3 + v^3 = -q$, the following equation system is derived as:

$$\begin{cases} u^3v^3 = \frac{p^3}{27} \\ u^3 + v^3 = -q \end{cases} \Rightarrow u^3, v^3 \text{ are roots of equation : } Z^2 + qZ + \frac{p^3}{27} = 0 \tag{5.24}$$

Eq.(5.24) has two roots: $Z_{1,2} = \frac{-q \pm \sqrt{\frac{\Phi}{27}}}{2}$. Then, $y_1 = u + v = \sqrt[3]{\frac{-q+\sqrt{\frac{\Phi}{27}}}{2}} + \sqrt[3]{\frac{-q-\sqrt{\frac{\Phi}{27}}}{2}}$.

(ii.2) If $p > 0$ and $\Phi = 0$, Eq.(5.22) has a double root $y_2 = \pm\sqrt[3]{\frac{q}{2}}$ and a single root $y_3 = \mp\sqrt[3]{4q}$, respectively.

(ii.3) If $p > 0$ and $\Phi < 0$, Eq.(5.22) has three separated roots, $y_4 < y_5 < y_6 \in (-2\sqrt{\frac{p}{2}}, 2\sqrt{\frac{p}{2}})$. In order to find these roots, we define $y \equiv 2\sqrt{\frac{p}{3}}\cos x$ and $x \equiv \frac{1}{3}\cos^{-1}(-\frac{3\sqrt{3}q}{2p\sqrt{p}})$, then Eq.(5.22) is written in form as:

$$\cos 3x = -\frac{3\sqrt{3}q}{2p\sqrt{p}} \tag{5.25}$$

We solve Eq.(5.25) and find three solutions $x_1 = x, x_2 = x + \frac{2\pi}{3}, x_3 = x + \frac{4\pi}{3}$. Then three roots of Eq.(5.22) are $y_4 = 2\sqrt{\frac{p}{3}}\cos x, y_5 = 2\sqrt{\frac{p}{3}}\cos(x + \frac{2\pi}{3})$, and $y_6 = 2\sqrt{\frac{p}{3}}\cos(x + \frac{4\pi}{3})$.

[4] http://mathworld.wolfram.com/CubicFormula.html

Chapter 6

General conclusion

6.1 Findings

The first three empirical essays in this thesis examine the impact of environmental compliance, innovation on productivity, survivability, and productivity convergence of firms. The main findings are as follows:

First, the synergy between environmental compliance and product innovation is complementary whereas that between environment and process innovation is substitute. Export activities combined with process innovation might not help firms increase productivity. Meanwhile, the synergy between export and product innovation is ambiguous. The findings in Chapter 2 shows potential combination between export activities and environmental compliance in explaining firm's productivity. However, this link should be cautiously analyzed with respect to innovation capacity.

Second, environmental compliance can be combined with process innovation to improve the firm survival. Similarly, firms follow simultaneously environmental compliance and export activities can improve their survivability. The findings in Chapter 3 imply that the Porter hypothesis may be extended with respect to new indicators of export activities and firm survival.

Third, there is a β-convergence for SMEs' productivity over the period 2007 - 2015. Firm's environmental compliance does not directly impact its TFP convergence. This impact is only significant once environmental compliance is accompanied by innovation. The results in Chapter 4 point out that firms can achieve higher convergence speed if they have higher innovation capacity and/or capital intensity.

Finally, the theoretical models in Chapter 5 explore the impacts of emission tax (in the presence of audit and penalty mechanism) on firm's emission and efforts to commit bribery and maintain political connection. This work shows following new properties. (i) An increase in emission tax may pressurize firms to reduce emissions; such a policy also motivates firms to reduce the level of underreported emissions. However, with political connection, the relationship between tax and current emission is changed from negative to positive. These impacts are contingent upon the relationship between the firm's profit sensitivity, audit, penalty mechanism, and political connection costs. (ii) The impact of emission tax on bribery is non-monotonous and contingent on the relationship between the compliance emission and a component associated with penalty mechanism. (iii) The impact of tax on the firm's efforts to maintain political connection is also non-monotonous. It depends on the relationship between audit and a component consisting of penalty, profit sensitivity, political connection cost, and the level of underreported emissions.

6.2 Contributions

This thesis contributes to existing literature in a number of ways. First, this research proposes a new perspective on the Porter hypothesis by including a new variable, 'export activity', in the analysis of firm productivity and firm survival. In addition, we combined the estimation of firm stochastic TFP and the administration of complementarity/substitutability test to analyze the influence of synergy. It enriches knowledge of a modified Porter hypothesis, especially in a developing country.

Second, it uses a structural modeling framework to examine both strong and weak versions of PH, based on firm-level data to assess the influence of environmental regulation to SMEs' TFP convergence in a developing country.

Finally, it is the first to clarify the impact of tax on firm's environmental performance in the presence of audit and penalty mechanism, and its impact on firm's efforts in committing bribery and maintaining political connection, especially in developing countries. The properties in Chapter 5 can adopt for other circumstances such as law monitoring or anti-corruption measures.

6.3 Policy implications

Some policy recommendations can be drawn from these results. First, in order to improve both environmental performance and firm's productivity, environmental policies should be combined with support programs encouraging firms to strengthen product innovation and improve the efficiency of process innovation. Such improvement in innovation performance would a have positive impact on the synergy between export and environmental compliance in explaining firm's TFP.

Second, for increasing firm's survivability, environmental policies should be combined with export promotion programs because the synergy between environmental compliance and export activities is complementary. The government could provide supports to encourage firms to obtain international environmental certificates. In the same way as the case of productivity, improving the efficiency of innovation is necessary to increase firm's survivability.

In addition, information about environmental awareness should be disseminated on a large scale because it has positive influence on firm's environmental compliance. In this sample, the number of owners/senior managers have good knowledge of environmental law is very small, most of which have no knowledge or show little concern about the law.

To sum up, the three empirical essays suggest that in order to enhance firm's economic performance, governments can focus on supporting policies on R&D, technology, innovation, and export promotion programs. These policies can be implemented through subsidy programs such as providing loans with low interest, tax concessions, direct subsidy for producing of innovative and environmentally friendly products. In this way, firms could be motivated to integrate their new technologies, improving production as well as organizational process. In addition, innovation performance can be stimulated through national innovative programs. The latter may help SMEs be more innovative and convenient in adopting new innovation, exchange ideas, transfer technologies. Additionally, these activities may help firms enhance their perception of the relationship between economic performance and environmental protection.

The theoretical essay suggests that environmental regulations should be issued in combination with efficient monitoring and enforcement. Firm's decision on environmental compliance depends on compliance cost and expected investment return. Furthermore, giving bribery and maintaining political connection in breach of regulations are based on firm's expected risk and expected return of these actions. Governments therefore can increase the frequency of the shift of inspectors to increase the expected risk and reduce expected return. Environmental policies should be designed in such a way that firm's economic benefits in environmental compliance could be achieved.

6.4 Perspectives

Despite tackling most important research questions on environmental compliance and firm's economic performance, this thesis did not address some aspects. For instance, firms having good business networks and clusters can improve their economic performance. Indeed, such networks and clusters can help them to enrich knowledge, update information, share and learn experiences in innovation and environmental compliance. In this way, firms can cooperate to transfer or exchange technology, equipment, and patent. As a result, firms can reduce compliance cost and increase their innovation, competitiveness, and economic performance.

In addition, firm's environmental compliance can be affected by competitors, industry characteristics as well as special policies adopted for each industry. For instance, a firm which is in an industry whereby most of its competitors implement environmental compliance would have higher probability of compliance. Therefore, networks, clustering, political connection, and competition may effect firm's environmental compliance and environmental performance is also a potential area for research.

The theoretical model in Chapter 5 can be extended for the case of asymmetric information between the firm and the inspector in breach of regulations. It would be promising to include the influence of risk preferences. Moreover, it is interesting to develop a model including governments, firms, and consumers with respect to economic benefits and environmental issues from a dynamic perspective.

Finally, existing data lacks information of political connection and bribery. Therefore, it is a challenge for future research which relies on new data sets on firm's environmental compliance and perceptions of law enforcement and corruption.

Conclusion générale

Principaux résultats

Les trois premiers essais de cette thèse analysent l'impact de la conformité environnementale et de l'innovation sur la productivité, la survivabilité, et la convergence de la PTF entre les firmes. Cette partie expose les principaux résultats découlant de ces trois essais.

Premièrement, il existe une complémentarité entre la conformité environnementale et l'innovation de produit, alors que la conformité environnementale et l'innovation de processus semblent être des substituts au niveau de la firme. De plus, il apparaît que les activités exportatrices couplées à l'innovation de processus n'augmentent pas nécessairement la productivité des firmes. La relation entre les activités d'exportation et l'innovation de produit est ambigue. Les résultats du chapitre 2 montrent qu'il peut exister une combinaison entre les activités d'exportation et la conformité environnementale qui permettrait d'augmenter la productivité des firmes. Cependant, ce lien doit être analysé simultanément avec la capacité d'innovation des firmes.

Deuxièmement, la conformité environnementale peut être combinée avec des innovations de processus afin d'améliorer le probabilité de survie. De façon similaire, les firmes qui, simultanément, adhèrent aux régulations environnementales et développent leurs activités d'exportation, peuvent améliorer leur survivabilité. Les résultats du chapitre 3 impliquent que l'hypothèse de Porter pourrait être étendue, en prenant par exemple en compte de nouveaux indicateurs tels que les activités d'exportation des firmes, ou encore leur survivabilité.

Troisièmement, il existe une "beta-convergence" de la PTF des PME Vietnamiennes sur la période 2007-2015. La conformité environnementale des firmes n'affecte pas directement cette convergence; l'impact est significatif seulement si l'on prend simultanément en compte la capacité d'innovation. Les résultats du chapitre 4 suggèrent que les firmes convergent plus rapidement si elles sont davantage capables d'innover, et/ou si elles détiennent une forte densité de capital.

Dernièrement, le modèle théorique contenu dans le chapitre 5 a exploré l'impact d'une taxe sur les émissions, en présence d'une possibilité d'audit et d'un mécanisme de pénalité, sur les émissions des firmes et leurs incitations à payer des pots-de-vins aux inspecteurs, ou encore à developper et maintenir des connexions politiques. Ce travail a mené à différents résultats. Premièrement, une augmentation de la taxe sur les émissions peut effectivement réduire le niveau d'émissions des firmes; une telle politique peut aussi motiver les firmes à réduire le niveau de sous-déclaration des véritables émissions. Cependant, lorsque des connexions politiques sont possibles, la relation entre la taxe sur les émissions et le niveau actuel d'émissions devient positive: une taxe plus élevée va tendre à engendrer un niveau d'émissions plus élevé. Cet effet dépend la relation entre la sensibilité du profit de la firme, la probabilité d'audit, le mécanisme de pénalité, et le coût des connexions politiques. Deuxièmement, l'impact d'une taxe sur les incitations à payer des pots-de-vins est non-monotone et dépend de la relation entre la conformité environnementale et le mécanisme de pénalité. Enfin, l'effet de la taxe sur l'incitation des firmes à maintenir des connexions politiques est aussi non-monotone. L'effet dépend de la relation entre la probabilité d'audit, le mécanisme de pénalité, la sensibilité du profit, le coût des connexions politiques, et le niveau de sous-déclarations des véritables émissions.

Contributions

Cette thèse contribue à la littérature existante de différentes façons. Premièrement, cette thèse propose une nouvelle perspective sur l'hypothèse de Porter, en incluant une nouvelle variable, "les activités d'exportation", dans l'analyse de la productivité et la survivabilité de la firme. De plus, nous avons combiné l'estimation de la PTF stochastique de la firme avec l'administration d'un test de complémentarité/substituabilité afin d'analyser la synergie entre la conformité environnementale, l'innovation, et les activités exportatrices. Ceci contribue au développement d'une hypothèse de Porter "modifiée", notamment dans le cadre d'un pays en développement.

Deuxièmement, cette thèse est la première à clarifier l'impact d'une taxe sur la performance environnementale des firmes en présence d'audit et d'un mécanisme de pénalité. Aussi, nous analysons l'effet de la taxe sur les incitations qu'ont les firmes à verser des pots-de-vins et à maintenir des connexions politiques.

Troisièmement, en utilisant une base de données en panel au niveau de la firme, nous examinons simultanément les versions "faible" et "forte" de l'hypothèse de Porter, en analysant l'influence des régulations environnementales sur la convergence de la PTF entre les PME Vietnamiennes.

Dernièrement, notre modèle théorique enrichit la littérature existante en investiguant l'influence du "capital politique" de la firme sur son adhérence aux régulations environnementales, en présence d'audit et d'un mécanisme de pénalité. Les résultats découlant de notre modèle peuvent être appliqués à d'autres problématiques, telles que les mesures anti-corruption ou encore l'application de la loi.

Implications en termes de politiques publiques

Des recommendations en termes de politiques publiques émanent de nos résultats. Premièrement, dans l'optique d'améliorer simultanément la performance environnementale et économique des firmes, les politiques environnementales devraient être combinées avec des programmes visant à encourager et à inciter les firmes à développer leur capacité à innover. Ces améliorations en termes de capacité à innover peuvent avoir des conséquences directes sur la synergie entre la conformité environnementale et les activités d'exportation, et ainsi la PTF des firmes.

Afin d'améliorer la survivabilité des firmes, les politiques environnementales devraient être combinées avec des programmes visant à promouvoir les exportations. En effet, la conformité environnementale des firmes et leurs activités d'exportation sont complémentaires. Les autorités publiques pourraient soutenir les firmes et les encourager à obtenir des certificats environnementaux internationaux. Dans la même optique que pour la productivité, améliorer les capacités d'innovation des firmes est nécessaire afin d'améliorer leur survivabilité.

Des politiques de sensibilisation à la qualité de l'environnement devraient être mises en place à une grande échelle, dans le mesure où la prise de conscience environnementale semblerait améliorer l'adhérence des firmes aux régulations environnementales. Dans notre échantillon, la proportion de dirigeants/managers ayant une bonne connaissance de la loi liée aux pratiques environnementales est très faible, alors que la plupart d'entre eux/elles n'ont aucune connaissance ou ne ne montrent que peu d'intérêt envers la loi.

Pour résumer, les trois essais empiriques suggèrent qu'afin d'améliorer la performance économique des firmes, les autorités publiques devraient développer des programmes visant à encourager et à inciter les firmes à investir en R&D, à améliorer la technologie utilisée, à développer les capacités d'innovations et les activités d'exportation. Ces politiques peuvent être implémentées à travers des programmes de subventions tels que des prêts à taux très faible, des concessions fiscales, ou encore des subventions directes aux firmes les plus respecteuses de l'environnement. De cette façon, les firmes peuvent être motivées à utiliser de nouvelles technologies, ainsi qu'à améliorer leur processus de production. Des programmes dédiés à améliorer la capacité innovative des firmes peuvent notamment être très utiles aux PME, et peuvent inciter à l'échange d'idées et au transfert de technologies. De plus, ces programmes pourraient améliorer la perception des firmes quant à la relation entre leur performance économique et la protection de l'environnement.

L'essai théorique du chapitre 5 suggère que les régulations environnementales devraient être implémentées simultanément avec des mécanismes de surveillance et de mise en application des régulations très efficaces. La décision des firmes d'adhérer ou non aux régulations environnementales dépend du coût associé à la conformité et du taux espéré de retour sur investissement. De plus, le versement de pots-de-vins ou le développement/maintenance de connexions politiques dépendent du coût/risque éspéré de ces actions. Les autorités publiques peuvent ainsi augmenter la fréquence de rotation des inspecteurs, pour éviter toute éventuelle collusion de longue durée, et ainsi réduire le risque de contournement des régulations de la part des firmes.

Les politiques environnementales devraient être conçues de telle sorte à ce qu'elles soient compatibles avec les objectifs économiques des firmes.

Perspectives

Malgré le fait que cette thèse ait abordé les questions de recherche les plus importantes en rapport avec la conformité environnementale des firmes et leur performance économique, un énorme travail reste encore à être mené. Par exemple, les firmes ayant un bon réseau commercial tendent à avoir de meilleures performances économiques. En effet, ces réseaux et clusters permettent aux firmes de développer leur savoir, d'avoir une meilleure information, ainsi que d'observer des expériences d'innovation et de conformité environnementale venant d'autres firmes. De cette façon, les firmes peuvent coopérer afin de transférer ou d'échanger des technologies, de l'équipement, ou des brevets. Une conséquence directe est que les firmes peuvent réduire leur coût d'adhérence aux régulations environnementales, améliorer leur capacité d'innovation, leur compétitivité et leur performance économique.

Ensuite, la conformité environnementale des firmes peut être affectée par les compétiteurs, les caractéristiques de l'industrie dans laquelle les firmes se trouvent, ou encore par le type de politiques menées dans différentes industries. Par exemple, une firme qui se trouve dans une industrie dans laquelle la plupart de ses compétiteurs adhèrent aux régulations environnementales aura une probabilité plus élevée d'y adhérer aussi. Ainsi, l'impact des réseaux, des clusters, des connexions politiques et de la compétition sur la conformité environnementale et la performance économique des firmes est une piste de recherche très intéressante.

De plus, le modèle théorique présenté dans le chapitre 5 peut être étendu afin de prendre en compte le cas d'une asymmétrie d'information entre la firme et l'inspecteur. Il pourrait être intéressant d'intégrer et d'étudier le rôle des préférences pour le risque. Aussi, il pourrait être intéressant de développer un modèle incluant les autorités publiques, les firmes et les consommateurs dans une perspective dynamique.

Enfin, les bases de données existantes manquent d'information sur les connexions politiques et le versement de pots-de-vins. Ainsi, de futures recherches, utilisant des bases de données plus complètes et détaillées, pourront davantage répondre à ces questions primordiales du point de vue du respect des régulations environnementales.

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Nam-Quoc TRAN

Essais sur la performance environnementale et la productivité des entreprises : Applications aux PME Vietnamiennes

Résumé

Cette thèse vise à examiner les impacts de la performance environnementale sur la performance économique des PME Vietnamiennes. En outre, cette thèse développe également un modèle théorique de taxation sur les émissions de la firme, la corruption et les connexions politiques. Le chapitre 2 examine les effets de la synergie entre la conformité environnementale, l'innovation, et les activités d'exportation sur la Productivité Totale des Facteurs (PTF) des firmes. Cette étude montre que la relation entre la conformité environnementale et l'innovation de produit est complémentaire dans l'explication de la PTF de la firme. Elle montre également que l'impact de la synergie des activités d'exportation et de la conformité environnementale peut être influencé par l'innovation. Le chapitre 3 présente l'impact de ces synergies sur la capacité de survie de la firme. Ce travail montre que la relation entre la conformité environnementale et les activités d'exportation est complémentaire pour améliorer la survie des firmes. La survivabilité des enterprises peut également être affectée par la conformité environnementale de façon séparée. Le chapitre 4 étudie l'impact de la conformité environnementale sur la convergence de la productivité des firmes. Les conclusions indiquent que la conformité environnementale pourrait ne pas affecter directement cette convergence; cet impact peut devenir significatif seulement si cette conformité s'accompagne d'innovation. Enfin, dans le chapitre 5, nous développons un modèle théorique sur la relation entre la taxation sur les émissions, le niveau d'émissions et les incitations à verser des pots-de-vins ou à dèvelopper des connexions politiques. Les résultats montrent que le lien entre la firme et la sphère politique peut avoir une incidence sur l'efficacité des taxes sur les émissions. Nous constatons également que les effets de la taxation sur la corruption et les connexions politiques sont non-monotones, et dèpendent du mécanisme d'audit et de pénalité, de la sensibilité du profit de la firme et des coûts de la connexion politique.

Essays on environmental performance and productivity of firms: Applications to Vietnamese SMEs

Abstract

This thesis aims to examine the impacts of environmental performance on economic performance of firms which apply to Vietnamese SMEs. In addition, this thesis also develops a theoretical model of tax on firm's emissions, bribery, and political connection. Chapter 2 examines the synergy effects of environmental compliance, innovation, and export activities on firm TFP. This study finds that the synergy of environmental compliance and product innovation is complementary in explaining firm's TFP. In addition, the impact of the synergy of export activities and environmental compliance may be influenced by innovation. Chapter 3 presents the impact of these synergies on firm's survivability. This work reveals that the synergy between environmental compliance and export activities is complementary in enhancing firm survival. The latter may be also affected by separated environmental compliance. Chapter 4 investigates the impact of environmental compliance on firm's productivity convergence. Its findings indicate that environmental compliance may not directly affect this convergence. This impact may become to be significant if this compliance is accompanied by innovation. Finally, in Chapter 5, we develop a theoretical model of the relationship between emission tax, emissions and willingness to commit bribery and to maintain political connection of firms. The result points out that firm's political connection can affect emission tax efficiency. Furthermore, the impacts of tax on bribery and political connection are non-monotonous, depending upon the nature of audit and penalty mechanism, sensitivity of firm's profit and political connection costs.