THE RELATIONSHIP BETWEEN ENVIRONMENTAL REGULATIONS AND KOREAN ECONOMY

(TFP, OUTWARD FDI, TRADE)

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2018

Declaration

I hereby declare that this thesis is my own work that it has not been submitted for any other degree.

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Signature:

Abstract

This thesis tries to analyse the relationship between stringency of environmental regulations and Korean economic performance. This research deals with three themes as the following: First examination lies on the effects of Korean domestic environmental restrictions on Total Factor Productivity in terms of industry and firm; second is the influences of relative difference of environmental stringency between Korea and counterpart (importer or host countries) on Korean outward FDI and Korean exports to the nations, and finally, the effects of Korean domestic environmental stringency on Korean trade performance are researched on.

Acknowledgements

I'd like to express my sincere appreciation to my PhD supervisors, Dr Robert Read and Dr Kwok Tong Soo for their exceptional guidance and support. Their kind and generous advice and encouragement were the most important impetus to continue my research even though I was occupied with much work, as a director in The Korean Prime minister's office. Moreover, their creative ideas were a source of inspiration during the last years.

I also owe a debt of gratitude to all my family for their abiding support. My wife (Yeosom), son (Taeu) and daughter (Sinwon) have tolerated all difficulties during my MRes and PhD studies. My parents and parents-in-law deserve special thanks for their sacrifices and infinite encouragement.

I thank the faculties in the Department of Economics for supplying excellent research conditions. Finally, I am also grateful to the Korean Government for its financial support and dataset.

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CHAPTER I

Introduction

1. Objectives of the Thesis

Most of countries experienced high performing economic growth (especially, manufacturing sectors) have faced serious pollution problems and increasing demand from public people pursuing better environmental condition. Such situation has led governments to introduce or/and enhance environmental regulations. However, along with concern on environmental issue, another crucial apprehension has emerged. That is an influence of environmental restrictions[1] on business and economy. Traditionally, economists believe that the regulations may have a negative impact on business activities through imposing additional cost on production, encouraging them to move to countries with lax regulations, known as the ‘Pollution Heaven Hypothesis’. On the

[1] Measurement issue of stringency of environmental regulations will be discussed in chapter II and III.

contrary, a few researchers argue that environmental measures could help to strengthen competitiveness of firms and industries, called 'the Porter hypothesis[2]'.

This study aims to check which influence exists in case of Korea. In terms of empirical analysis testing the impacts, many papers have chosen productivity, FDI, trade performance and employment as a proxy for competitiveness[3] of firm, industry and country. In this paper, our research will select industry and firm level productivity, Korean outward investment & export in terms of country level and Korean trade performance in terms of manufacturing industry. That is because checking productivity is a general method to test the strong version of the Porter hypothesis (Jaffe & Palmer, 1997). In addition, outward FDI, export, and trade performance are the most important issues to keep economic development and job opportunities in Korean society (MTIE[4]'s annual report, 2015)

1.1. Productivity, Outward Investment, Trade performance in Korea.

As mentioned above, the major interest of the study lies on productivity, Korean outward investment, export and trade performance. This part explains why four objectives are selected for the study. Total factor productivity (TFP) growth has been considered as an important element to boost Korean economy. Even TFP decrease is regarded as one of causes of Korean economic growth down after 2010 and it is emphasized that government regulations should not interrupt TFP growth (Kim and

[2] More discussion and papers about the Porter hypothesis will be dealt with in chapter II.
[3]Competitiveness is "ability of a firm or a nation to offer products and services that meet the quality standards of the local and world market at prices that are competitive and provide adequate returns on the resources employed or consumed in producing them" (businessdictionary.com). The proxy is usually business performance such as productivity, innovation, employment, profitability, output and trade (Dechezlepretre & Sato, 2014)
[4] Korean Ministry of Trade, Industry and Energy

Choi, 2017[5]). Kim (2017) also suggests that government policies should focus on TFP increase in order to recover Korean economic growth rate.

Therefore, it can be said that analysing relationship between TFP and environmental regulations is crucial. However, unlike many mentions about importance of TFP, it is not easy to collect productivity data because no Korean institutes publish direct information about the productivity officially. Instead, the second way is recommended; estimating residue through using capital stock and labour data. In practice, getting capital stock data play a crucial role in calculating the TFP. In fact, the industrial data has been only recently announced. Previous Korea papers (Lee *et al*., 2015; Oh *et al*., 2014) therefore have no choice but to use labour productivity (industrial output per worker) or fixed assets instead of industrial capital stock. This study however, is able to use industrial capital stock data from The Bank of Korea. Given that TFP is an additional contribution to output over and above inputs of capital and labour, its growth could be derived by technology innovation (Hall, 2011). Therefore, if empirical study shows environmental regulations lead to the TFP increase, we could think that environmental restrictions led innovations surpass additional cost increase and then result in profit increase. Jaffe and Palmer (1997) call such good result as evidence of strong Porter Hypothesis.

Korea has enjoyed both job opportunities and technology spillovers through inward foreign direct investment (FDI) and many papers show that FDI has made an important contribution to Korean economic development. However, recently, there is an emerging concern about Korean economy relating to a rapid increase of Korean outward direct investment abroad. It has grown sharply by a factor of seven – from $5.4 billion in 2000 to $35.3 billion 2016 – during a period when Korean GDP growth

[5] They employed overall Korean TFP, not TFP in manufacturing.

rate has been below 3%. MTIE (2015) attributes the major reasons of outward investment to the followings: for developing countries like Asian region, market access and cheap input factor costs are regarded as the most important cause – that is, the firms want to utilize relatively low labour wage and material price as well as huge market of Asian countries experiencing industrializing. For developed countries, market access and expansion lead outward investment increase. This steep upward trend of outward investment and the mixed reasons have attracted many Korean researchers to dealing with the influence of outward FDI on Korean economy (mainly, economic growth, employment and export) (Lee *et al*., 2012; Jae *et al*., 2012; Jun & Wang, 2015; Hwang, 2016). Hwang (2016) argues that moving to developing countries affect negatively Korean employment while investment in developed countries has insignificant influence. This thesis attempts to establish whether or not environmental restrictions are significant reason on change of outward investment. Because up and down of the investment is one of major interests for policy makers in Korea (MTIE Annual Report, 2016), we are sure that this study will cast important insight.

Until 1998, exports alone were considered as the main driver of the Korean economy (MTIE Annual Report, 2015). After the end of the Korean War in 1954, the most important agenda for the Korean Government was to develop the economy and provide more job opportunities. With this aim, it changed the existing Korean economic structure from an agrarian-based society to an export-oriented economy. To do this, the Korean Government decided to try and attract foreign investment through establishing Free Export Zones (FEZs), where firms could import intermediate goods without tariffs and carry out manufacturing activities with special tax reduction measures. The need for FDI was because Korea did not initially have the necessary technology and skills to make products for export. This very efficient strategy brought economic success to the Korean economy. Korean companies could export labour-intensive goods to the rest of the world on the basis of a competitive advantage through low wages. The Korean Government and private firms utilised this method at every stage to upgrade the Korean economy. In the past, the export strategy of the Korean Government was no more complex than it is now.

However, over time the situation has totally changed. Most developing countries have followed the example of the Korean economic growth model and have taken advantage of price competition. Moreover, the Asian financial crisis in 1997-98 cast new light on trade performance. That is, the shortage of foreign exchange holdings, considered as one of the main reasons of the crisis, threw emphasis on the level of trade surplus. It was believed that even though exports were growing annually, the faster import growth might have a negative effect on the sustainable growth of the Korean economy. In addition, since 2000, the increased Korean export does not always confirm improved trade performance, job increase and economic growth[6].

1.2. Global Environmental Regulation relating to Greenhouse Gas Emissions

The relative discrepancy of stringency of environmental regulations among countries has encouraged many researchers to analyse its effect on country-level economy (trade flow and investment). The differences are dependent on diverse factors countries face, such as: response to global environmental regulation trend; level of economic development; environment quality; citizen consciousness; Law &

[6] Even though Export volume (million US dollar) has expanded from 162,470 (2002) to 555,214 (2011), rather, Economic growth rate (%) has been decreased: 7.4 (2002), 3.7 (2011) and Unemployment rate (%) has not been improved : 3.3 (2002), 3.4 (2011).

enforcement system; and so on. Recently, it is likely that one of the most popular motives leading to such gaps among countries is related to reduction of greenhouse gas emission ley by UNFCCC. Each country has its own stringency through selecting diverse environmental regulation combination under the global pressure against Greenhouse Gas (GHG). To represent its level, diverse proxies have been used in many papers, such as pollution abatement costs (PAC), pollution emission volume and energy consumption. Each factor has its advantage and disadvantage to use, which will be discussed in chapter II. From the following, we will say briefly history of UNFCCC dealing with GHG mitigation.

Since 1992 when The United Nations Framework Convention on Climate Change (UNFCCC) started, mitigation against greenhouse gas (GHG) emissions has been a key global issue. Specifically, the Kyoto Protocol[7], signed in 1997, levied compulsory obligations on Annex B (comprising thirty-nine countries) to cut their greenhouse gas emissions on average 5.2 per cent against 1990 levels in the first commitment period of 2008-2012. Even though the Protocol only dealt with obligations of developed countries, it made a great contribution to encouraging many other countries to consider reducing their GHG emissions. The Bali Roadmap (2007)[8] discussed activity post-2012 and, through the Bali Action Plan, showed the long-term vision, while also discussing technology and financing, besides just mitigation. The Copenhagen Accord (2009)[9], in spite of not being part of the official document, confirmed that 'climate change is one of the greatest challenges of our time', and set up the final goal of tackling global warming, with an aim that it should be kept under 2.0^{o}C compared to preindustrial temperatures. Furthermore, the Cancun Agreements

[7] http://unfccc.int/kyoto_protocol/items/2830.php
[8] http://unfccc.int/key_steps/bali_road_map/items/6072.php
[9] http://unfccc.int/meetings/copenhagen_dec_2009/items/5262.php

(2010)[10] expanded the responsibility of mitigation against GHG emissions to developing countries, and induced even Non-Annex I[11]countries to submit their GHG emission reduction goals and schedules. The Durban Package (2011)[12] formed consensus among all the countries of the UNFCCC for the second commitment period of the Kyoto Protocol, and launched the Durban Platform to deal with a new GHG mitigation Protocol until 2015, to be applied to all members of UNFCCC beyond 2020. The Doha Climate Gateway (2012)[13] adopted the "Doha Amendment to the Kyoto Protocol" and established the second commitment period of 2013-2020.

The filter-down importance of GHG mitigation is leading all the countries in the world to consider and take steps against climate change, either voluntarily or compulsorily. Such a change has significant influences on the economic policies of both developed and developing countries and trading blocs. For instance, the EU enacts and enforces financial support and regulations concerning e.g. the EU emission trading scheme, support for renewable energy, reducing the energy use of buildings and industries and reducing CO_2emissions from new cars and vans. Developing nations have also taken actions as part of this global world trend. For example, Korea forced Korean manufacturing firms to set GHG reduction targets in September 2011, and then launched the Korean emissions trading market in January 2014. In addition, Korea has pledged that it will make great efforts to reduce GHG emissions by 2020 by 30 % under the "Business as usual" baseline. Paris agreement (2016) renewed all results of UNFCCC meeting and levied responsibilities for climate change on all member countries. It asked them without distinction of Parts to participate in reducing

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[10] http://unfccc.int/key_steps/cancun_agreements/items/6132.php

[11] Non-Annex I countries – most of which are developing countries – are not subject to the Kyoto Protocol.

[12] http://unfccc.int/key_steps/durban_outcomes/items/6825.php

[13] http://unfccc.int/key_steps/doha_climate_gateway/items/7389.php

GHG emission and report each targets and performances. Besides GHG emission mitigation, an enhancing global environmental protection trend has been represented as diverse regulations such as EU (REACH, ELV, WEEE, Ecodesign & Labelling, RoHS), US (CLM) [14] and so on

1.3. Korean Environmental Regulations

After the end of the Korean War, the most important target of the Korean Government was economic growth. On the base of relative cheaper product factors (i.e., labour), the Government strived for industrialization at the expense of environment. The Environmental Protection Act was not enacted until 1978 while the first economic master plan was established in 1962. The worse was that the law was too comprehensive (not stipulating specific regulations) even though it indicated that the Korean Government started to have more interest in environmental regulations than before and the official organisation dealing with environmental problems, the Korean Environmental Administration, was not established until 1980.

As other developed countries experienced, however, income-induced development of public consciousness aggressively asked the Korean Government to enact and enforce more specific and stricter environmental laws and policies in 1990s. Moreover, the Seoul Olympics in 1988 forced the Government to focusing on improving environmental quality. As a result, there was dramatic change 1988-99, with the enactment of several environmental protection laws dealing with various causes of contamination. These include: the Environmental Policy Act; the Clean Air

[14] REACH (the European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals), ELV (End of Life Vehicles), WEEE (Waste Electrical and Electronic Equipment), Ecodesign & Labelling Directive, RoHS (Restriction of Hazardous Substances), CLM (Chemical Life-cycle Management). See Appendix 1.

Conservation Act; the Water Quality & Aquatic Ecosystem Conservation Act; the Waste Control Act; the Noise-Vibration Regulation Act; the Toxic Chemicals Control Act; and the Environmental Dispute Mediation & Arbitration Act.

These important regulatory changes demonstrated that the Korean Government clearly considered environmental protection as its main responsibility for public health, and has aggressive intension to introduce regulations focusing on each cause of contamination, not comprehensive environmental level. Specifically, the Clean Air conservation Act regulated ozone contamination level, pollutant charge, car exhaust gas level. The Water Quality and Aquatic Ecosystem conservation Act levied clean-up costs on firms emitting wastewater. The Waste Control Act introduced the polluter payment principle. The Environmental Dispute Mediation & Arbitration Act enabled people to apply for dispute mediation even about expected damage of environmental pollution and introduced *ex officio* adjustment. According to active efforts of the Korean Government for improving environment, while only three acts existed in 1970s, twenty one acts were enforced in 1996, and 643 environmental regulations were registered officially in 1998[15]. In addition, the small administration was promoted to the Ministry of the Environment in 1995. A command and control system of environmental regulations was also established at the same time. The number of government officials was dramatically increased; from 253 in 1980 to 429 in 1994. The budget of the Ministry also grew from KW77.3 billion ($69 million) in 1988 to KW1,080.2 billion ($972 million) in 1997.

In 2000s, except 1998-1999 during the Asian Financial Crisis, the strength of environmental stringency has been increased. The number of environmental

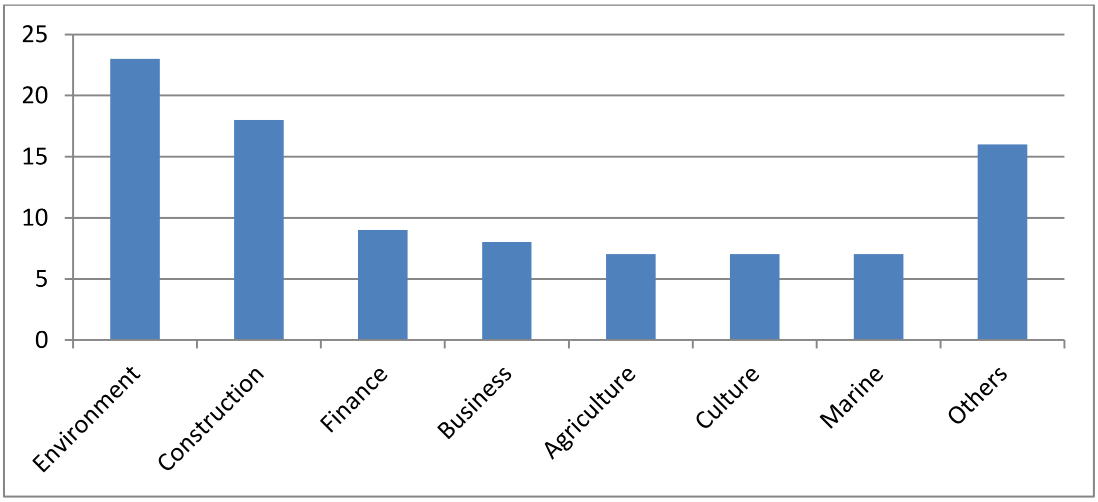
[15] Source: Regulatory Reform Committee which registered the number of regulations from 1998-2014.

regulations expanded from 569 in 2009 to 848 in 2014[16]. The growth rate (19.1%) exceeded the increasing rate (15.9%) of total governmental regulations by 3.2%p (Table 1.1) at the same period. The number of charges in Ministry of Environment also held the top level in comparison to other charges in different Ministries. For example, the environmental charge (23) accounted for 24.2% of total charges (95) in 2014 (Figure 1.1)[17].

Table 1.1: The number of Regulations (unit: one, %)

	2009	2010	2011	2012	2013	2014	Growth rate
Environmental regulations	712	732	775	810	844	848	19.1
Total regulations	12,616	13,104	13,752	14,525	14,888	14,618	15.9

Figure 1.1: The number of Charges (unit: one)



Another important issue in 2000s lied on recycling. In 2003, the Extended Product Responsibility (the EPR) was introduced which gives producers duties for recycling waste (packaging[18], tire, battery, lubricants and so on). The effectiveness of the EPR

[16] Source from Regulatory Reform Committee
[17] Source from Ministry of Strategy and Finance
[18] glass, can, paper and synthetic resins

however, was not good; the recycling rate was only 42 per cent in 2008 and rather, usage of synthetic resins packaging[19] was increased. That was because waste fee was not enough high to force producers to recycle (Ministry of Environment Annual Report, 2009). After 2008, the Korean Government wanted to improve more recycling. Then, it raised fee rate to force producers to participate in the EPR. Such actions lead to increase of both number of waste treatment facilities and volume of recycling from 4,350 and 33 million ton/per in 2008 to 5,432 and 42 million ton/per in 2015[20].

The Operation Mechanism of Korean Environmental Regulations

Air: The Korean Government enact the Clean Air Conservation Act in 1990. Then, it designated 61 pollutants such as carbon monoxide, ammonia, nitrates, and sulfates. According to the Act, it manages them through monitoring and emission controls. Meanwhile, around 48,000 facilities are controlled by the Act. The control process is as the following. First, the facilities must get permission to be installed and be reported to the Government. Second, they receive permissible emission levels which have gradually been tightened. Third, in special regions (such as Ulsan-Onsan & Yeosu industrial complex), the facilities are given stricter permissible emission levels. Fourth, the Government continuously inspects the facilities to confirm that they keep their duties and operate emission prevention equipment. If they do not keep their responsibility, they will be prosecuted. Finally, in terms of nine pollutants (such as sulfur oxides, ammonia, and dusts), if the facilities emit pollutants beyond permission, they will be given excess emission charges. Meanwhile, the SmokeStack Tele-Monitoring system (the TMS) which automatically checks emission volume and

[19]Using rate of synthetic resins packaging increased by 92.8% on average in 2008.(Ministry of Environment, 2008)
[20]https://www.recycling-info.or.kr/rrs/viewPage.do?menuNo=M130201

report is installed into the facilities. The TMS is used for emission charges and observing business behaviour.

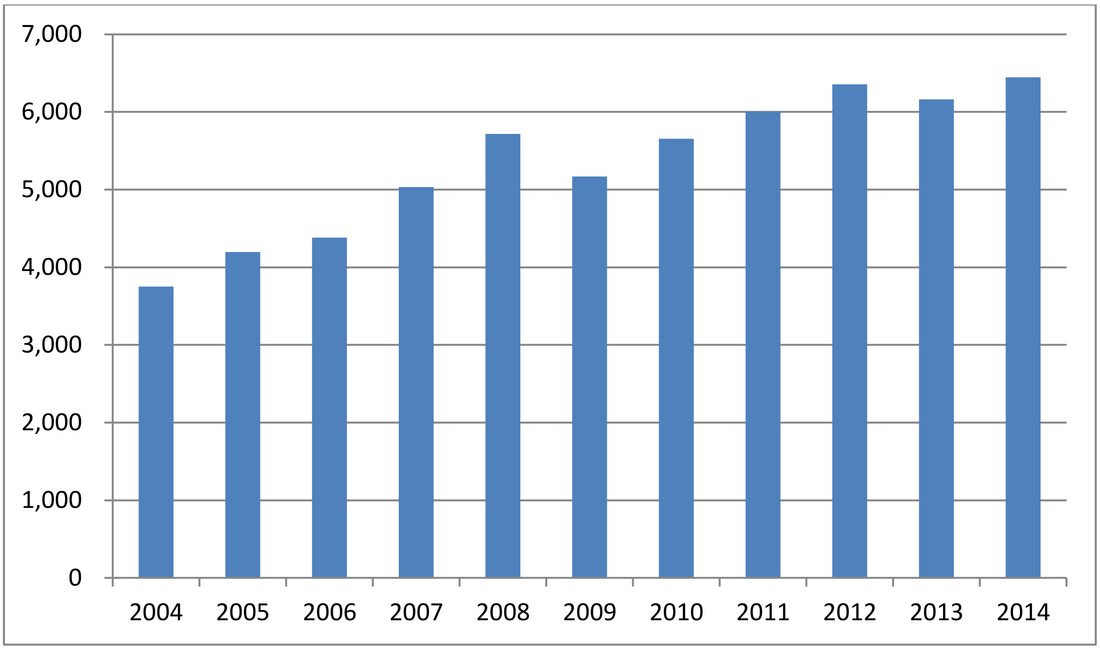
Water: According to Water Quality and Aquatic Ecosystem conservation Act, 48 water pollutants (such as organic substances, copper, lead, nickel, and cyanide) are selected for control. Each pollutant is given permissible emission levels and qualities. The facilities emitting industrial wastewater must keep the standards. Automatic monitoring network system is installed in 2,188 locations which report real-time water quality to the branch of Ministry of Environment. If it gets alarm, it immediately checks and inspects facilities around the locations. The plants violating the rules would be prosecuted.

Through checking monitoring system of Air and Water quality, we can know that the Korean Government prefers direct intervention, regular inspection and strong legal punishment. That is, the mechanism of the Korean environmental regulations is based on compulsory command & control system.

Stringency of Korean Environmental Regulations

The Ministry of Environment supplies two cost data which manufacturing industry faces due to Korean environmental regulations. One is Environmental Protection Expenditure (the EPE). The other is Investment in Environmental Pollution Control (the IEPC). The former consists of operation and facility investment costs to prevent, reduce and eliminate pollutants in all parts (public, business, and consumer sectors) and has been submitted to the OECD while the latter deal with only equipment installation costs in business sector. Considering that the EPE can reflect both operation and capital costs (equipment installation) in business sector, it is likely that the EPE is better than the IEPC. Moreover, because the IEPC is collected indirectly from firms providing environment equipment, not firms paying for the equipment, it has a limitation not to represent obviously the costs to firms face. The EPE[21] for Korea increased from KW5,419 billion in 2004 to KW8,947 billion in 2014 in terms of business sectors. The manufacturing sector accounted for 72 per cent in 2014. Its costs also grew from KW3,752 billion in 2004 to KW6,443 billion in 2014, suggesting that the stringency of environmental restriction might gradually increase at that period.

Figure 1.2: Environmental Protection Expenditure in Manufacturing sector (unit: KW billion)



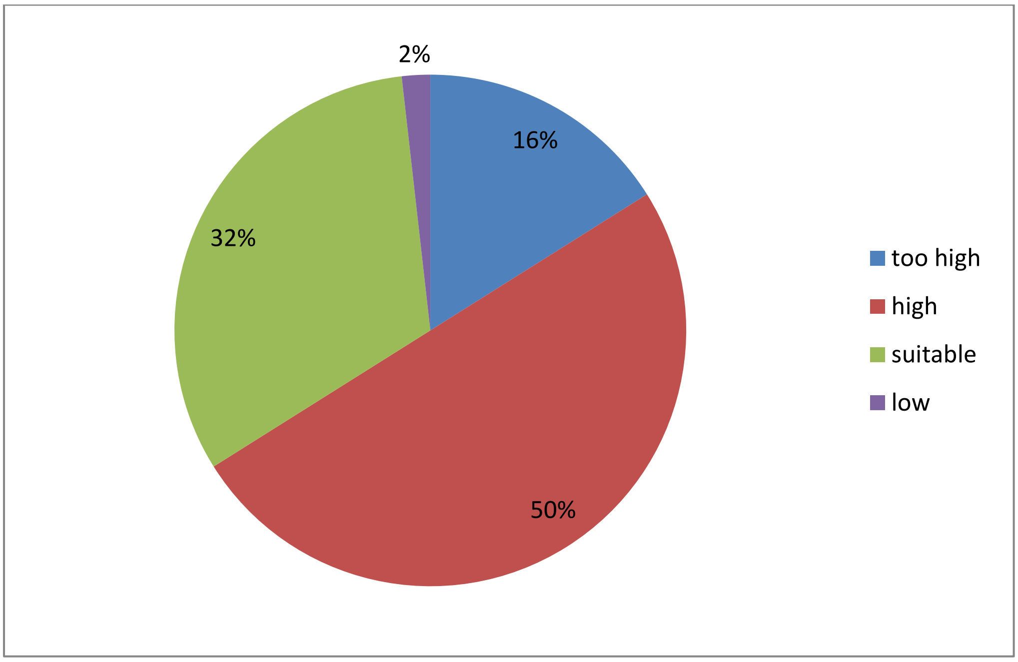
In addition, the stringency of Korean environmental regulations can be measured using surveyed opinions of business sector. Figure 1.3 shows the survey of FKI[22] which explains the opinions of firms about environmental stringency. Over 66%

[21] The EPE is announced only in nation level, not industry level. Therefore, previous papers could not study Korean industry level approach using the industrial EPE. With support of Ministry of Environment, however, we can make access to the industrial EPE on the condition that the data must be used for only this research.

[22] Federation of Korean Industries. The survey is operated by FKI in 2015 on 304 firms which rank in the top 600 firms in terms of sale.

argues that the stringency is high enough to contract business production activities. The survey of KBIZ[23] in 2014 also indicates that 81.3% of small and middle size firms (the SMEs) think that environmental regulations affect production activities. Likewise, 62% of firms hire skilled workers to manage pollutant emitting. According to these figures, we could believe that Korean firms may be sensitive to change of environmental stringency and over majority of the firms feel that the stringency is high. Meanwhile, in terms of redundant regulations, environmental regulations rank the first[24] among regulations of the Korean Government. Because such regulations cause additional burden such as unnecessary administrative costs & workers and regulation interpretation conflicts among Ministries, we could think that firms experienced more pains than expected.

Figure 1.3: The Survey result of FKI on stringent level of environmental regulations (unit: %)



[23] Korea Federation of SMEs (Small and Middle size enterprises). KBIZ did the survey on 300 firms in 2014.
[24] See Appendix 2

Korean Regulation in Comparison with Other Countries

To evaluate the stringency of Korean environmental regulations in international terms, we adopt the Environmental Policy Stringency (the EPS)[25] of the OECD. In 2012, Korea ranked 18th among 32 countries of the OECD & the BRIICS[26] countries. It means that stringency of Korean environmental regulations located around middle position. That is, Korean stringency is lower than some developed countries (e.g., Denmark, UK, Sweden and Canada) while higher than developing countries (e.g., China, India and Brazil). Besides index's perspective, we will check level which Korean firms feel in business field through comparing specific cases.

In terms of emission trading scheme, Korea operates national level trading scheme while the USA, Japan, Canada and most Asian countries do not or introduce only regional scheme. Especially, comparing cases of the USA and Japan, Korean firms feel that the Korean Government made hasty decision on introduction of the scheme (KFI, 2015). Moreover, in the range of regulated sectors and gases, the EU includes three sectors (industry, power and aviation) and three gases (CO_2, N_2O and PFC_5) while Korea regulates six parts (industry, power, aviation, building, transport and waste) and six gases (CO_2, N_2O, PFC_5, CH_4, HFC_5 and SF_6).

In terms of regulations on chemicals, unlike the EU's REACH, the Korean Government forces firms to report and register new material less than one tonne. In addition, the Government also compels plants to submit hazard & toxicity assessment of foreign institutes when Korean ones cannot analyse, which could levy considerable additional regulation compliance costs on the SMEs (KBIZ, 2015). Moreover, the

[25]The index is created by the OECD to represent environmental stringency of the OECD countries and some developing countries. More detail explanation of the EPS will be discussed in data description section in chapter III.

[26] Brazil, Russia, India, Indonesia, China and South Africa

Government pushes firms to report every year regardless of change of chemical storage, which the EU does not. In terms of introducing new regulations against pollution, most developed countries consider their effects on business and society and enact and enforce them by stages for middle or long terms. The Korean environmental regulations however have been introduced in a short term by the Government lead projects. For example, the EU's ETS, REACH and ELD were operated in two or three year gaps while Korean regulations similar to them were enforced at one time, 2015, not considering economic influence carefully. Many companies argued that too short period of canvassing opinion and overlooking economic impact were the first and second problems of Korean environmental regulation enforcement (FKI, 2015 survey).

In car industry, the Korean Ministry of Environment adopts emission standards of either the EU or America. Specifically, California standards in the U.S. are applied for passenger gasoline vehicle while diesel cars are regulated based on European standards. In addition, big truck and bus standards employ the EU contents. Such formation makes Korea one of the strictest countries in terms of car industry. Moreover, GHG emission target will be (97 g/km) stricter in 2020 comparing to America (113 g/km), which is almost the same level as the EU standard (95 g/km) in 2020.

Overall index, the EPS indicates that Korean environmental stringency is in middle level. In terms of some cases, however, the Korean Government adopts stricter regulations than other countries; that is, Korean industries and firms face harsher environmental stringency. Specially, in considering Korean Government's superior status to firm and aggressive administrative behaviour, we could believe that stringency for firms to feel would be more than as the letter of regulations are.

Conclusions

The stringency of Korean environmental regulations has increased since 1990s. The burden for Korean industries and firms to face has also raised along with stringency growth. In comparison to environmental stringency of other countries. The overall index indicates that Korea located in the middle position among the OECD & BRIICS countries. Some certain regulations however, have tougher level than the EU & America. In addition, through some survey result for both large and small & middle size firms, we could conclude that Korean firms and industries would be sensitive to change of the stringency.

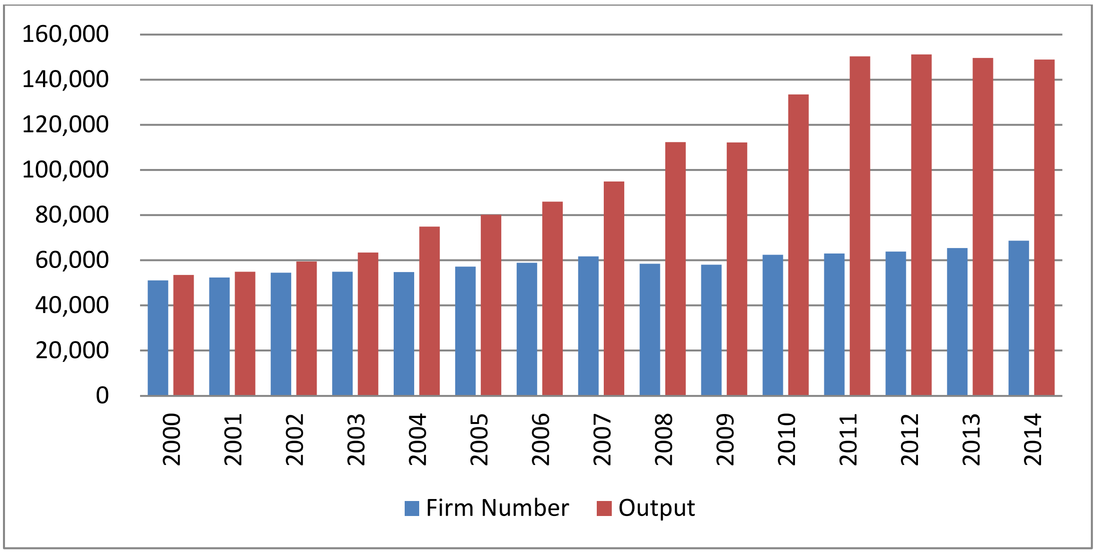
1.4. The Properties on Korean Manufacturing Industry

Korea has a high portion of manufacturing in total industry in terms of gross output in comparison to other countries; in 2014, Korea 50.7%; Japan 31.3%; Germany 33.7%; Hungary 40.4% and America 19.5%[27]. This implies that the Korean economy is relatively dependent on manufacturing industry. That is, if competitiveness of the industry deteriorates due to negative economic environment, overall Korean economy would also experience recession. Figure 1.4 shows that firm number and output in manufacturing sector increased[28]. Specifically, firm number[29] increased from 51,148 in 2000 to 68,640 in 2014 while output increased from KW534,450 billion to 1,489,212 billion KW. At the same period, the share of manufacturing in total output also rose from 42.6% to 50.7%. That is, the importance of manufacturing sector has continued to grow. The interesting lies on difference of upward trend pattern of number & output. Output increased in huge amount while the firm number expended

[27] Source from the OECD.
[28] Source from the KOSIS (Korean Statistical Information Service)
[29] Firms with more than 10 were surveyed

relatively lower. This graph & figures indicates that concentration of economic power of big companies had strengthened at the same period.

Figure 1.4: Firm number & Output in 2000-2014 (unit: one, KW 100 billion)



In terms of each manufacturing industry, Figure 1.5 shows output portion over total output of main industries. Computer & ICT industry accounted for 24%; Car industry (18%); Chemicals industry (15%); Basic metal industry (13%) and Cokes & oil (13%).

Figure 1.5: Output in terms of main industries in 2014 (unit: %)

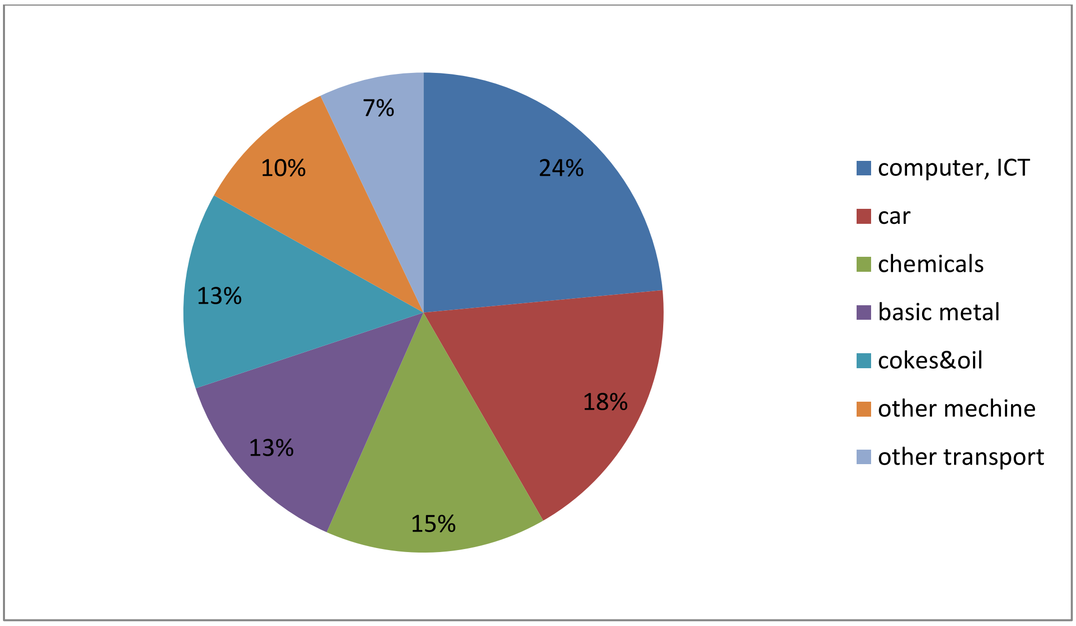


Table 1.2 shows those goods accounting for majority of Korean export data[30] in 2014. 10 goods are displayed with each portion. Electrical machinery & Apparatus & Appliances account for 17.1% of total export volume in 2014. From goods list, we could know that the principal industries in terms of output are also leaders in Korean export. That is, it is likely that output is linked to export in Korean manufacturing sector. Table 1.3 shows main imported goods in 2014. Seven goods among ten goods in export held important position in import. Given that intermediate goods account for 64.1% in export and 50.6% in import in 2014, it indicates possibility that export is related to import. When we analyse influence of environmental stringency, therefore, we should consider not only export but also import. In this thesis, we will test impacts of stringency of environmental regulations on trade performance.

Table 1.2: Main exporting goods in 2014 (unit: %)

Goods	Portion
Electrical machinery, Apparatus, Appliances	17.1
Road vehicles	12.7
Petroleum, Petroleum products and related materials	9.1
Telecommunication, Sound recording apparatus	7.1
Other transport equipment	7.0
Professional, Scientific, Controlling apparatus	5.3
Iron and Steel	5.1
Plastics in primary forms	3.9
General industrial machinery and equipment	3.5
Machinery specialized for particular industires	3.4

[30] Source from KIET (Korea International Trade Association), goods in SITC rev 2

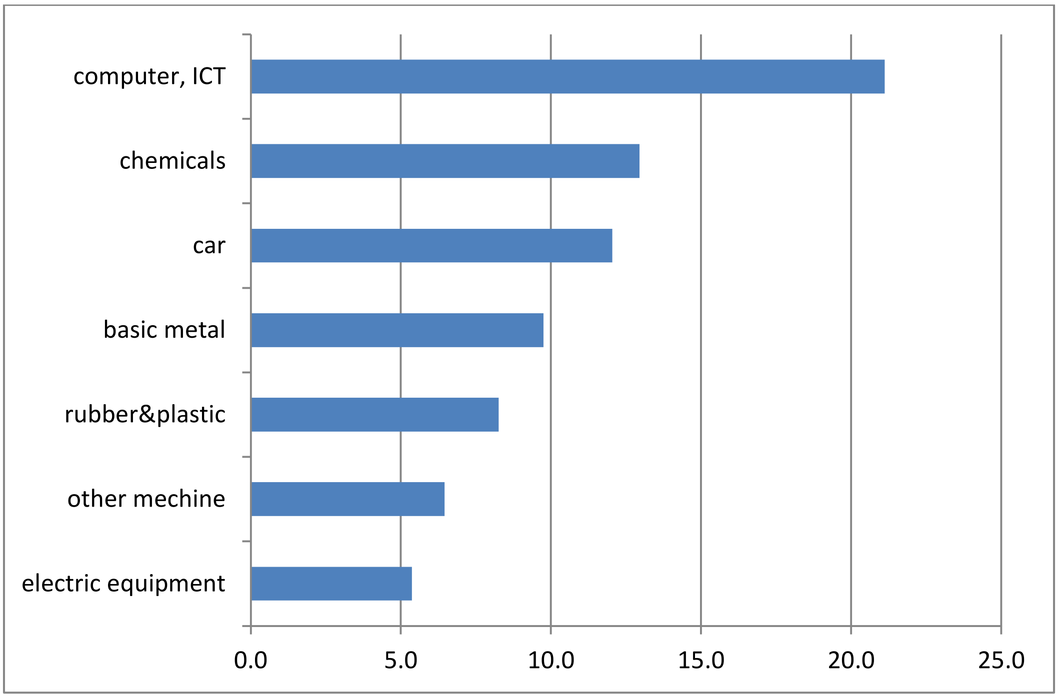
Table 1.3: Main importing goods in 2014 (unit: %)

Goods	Portion
Petroleum, Petroleum products and related materials	24.1
Electrical machinery, Apparatus, Appliances	11.0
Gas, Natural and Manufactured	7.0
Metalliferous ores and Metal scrap	4.6
Iron and Steel	4.0
General industrial machinery and equipment	3.3
Machinery specialized for particular industires	2.9
Organic chemicals	2.8
Telecommunication, Sound recording apparatus	2.7
Road vehicles	2.5

Figure 1.6 explains outward FDI of Korean main industries in 2014. Computer & ICT industry held the highest rank. The interesting is that industries in outward FDI are related with goods in export. This data implies that there might be a connection between export and outward FDI. We will check directly the relationship between export and outward FDI in chapter III.

From analysing properties of Korean manufacturing industrial data, we could confirm that as explained in section 1.1, TFP related with output, outward FDI, export and trade performance should be tested when estimating influence of environmental stringency on Korean economy.

Figure 1.6: Korean outward FDI in terms of main industries in 2014 (unit: %)



1.5. Principal Hypotheses

Research on the impacts of environmental stringency can be classified into two perspectives. The standard view argues that environmental restrictions have negative effects on product activities of regulated industries and firms. That is, the legislations can levy additional production costs on the industries and firms emitting pollutants, leading to decrease of competitiveness and profitability. Further damage can be caused through the way that the harmed industries and firms relocate their plants toward countries with more lax environmental regulations, finally leading to job loss. This is the Pollution Haven Hypothesis.

The alternative opinion is related to the Porter hypothesis[31]. This states that environmental regulations can affect the regulated firms positively. Porter & Linde (1995) argued that environmental stringency may result in technology and production process innovation, which could offset the increased costs caused by the restrictions, and finally lead to increasing their competiveness.

The above discussion of the properties of Korean environmental regulations and manufacturing industry reveals that the Korean manufacturing sector faces tough stringency of environmental regulations. We therefore assume that tough stringency of environmental regulations could have a significant influence on Korean economic competition. Specifically, we will test the following hypotheses.

1. Tougher stringency of Korean domestic environmental regulations would affect negatively total factor productivity in Korean manufacturing industries and firms.

2. A lager gap between Korean environmental stringency and that of other countries would have a positive influence on Korean outward FDI to the foreign countries.

    - Countries with relatively lower stringency than Korea would attract more investment from Korea

3. Given that Korean export might be linked to Korean outward FDI, we will test whether a greater gap between Korean EPS and the EPS of an importing country leads to an increase in Korean exports to that country.

[31] The hypothesis is classified into three versions, which are discussed in chapter II

4. To consider both export and import synthetically, we will test whether tougher stringency of Korean domestic environmental regulations would have a negative impact on trade performance of Korean manufacturing.

2. Outline of the Thesis

This thesis comprises four empirical tests analysing the influence of environmental regulations on the firm, industry and national competitiveness in Korea. The first evaluates whether or not Korean regulations have had significant effects on domestic productivity in terms of both industry-level and firm-level dataset. Next, we expand this research into competitiveness among countries. The second study deals with whether or not Korean outward FDI has been significantly affected by differences in relative environmental stringency between Korea, the OECD & the BRIICS countries. In the third, as additional country competitiveness test, we analyse whether or not Korean export to the OECD & the BRIICS countries is linked to the environmental regulation gap between countries. The final empirical test analyses the impact of domestic environmental restrictions on Korean trade performance at the industry level.

In chapter II, we deal with the first test. That is, we analyse influences of Korean domestic environmental stringency on total factor productivity (TFP). We employ both industry level and firm level dataset. Then, to create TFP on Cobb–Douglas function, we use industrial capital stock from the Bank of Korea. Considering that previous Korea papers (Lee *et al*., 2015; Oh *et al*., 2014), used labour productivity or fixed assets, instead of industrial capital stock, we give meaningful contribution to industrial TFP research in Korean case. By using dynamic panel model and multilevel panel model, we find that Korean domestic environmental protection expenditure has a negative influence on TFP in terms of both industry level and firm level. In other words, tougher Korean environmental stringency affects negatively competitiveness of industry and firm.

Chapter III includes the second and third tests. As a proxy variable for environmental stringency across countries, we adopt the Environmental Policy Stringency (the EPS) of the OECD. For empirical analysis, we use gravity models with Korean outward FDI and Korean export as dependent variables. Considering the zero and heteroscedasticity problems in the logarithm-form of the gravity model, we employ the Poisson Pseudo Maximum Likelihood (PPML) estimator (Silva & Tenreyro, 2005). The finding is that the relatively tougher Korean environmental stringency would lead Korean domestic investors to host countries. In other words, expanded gap between environmental stringencies of Korean and foreign countries affect negatively competitiveness at the country level. This result supports the PHH. Meanwhile, we also find that Korean outward FDI could lead to increase of Korean export to importing countries.

Chapter IV test the influence of Korean domestic environmental stringency on Korean trade performance. Referring to components of Levinson and Taylor (2008) and Song and Sung (2014) and Using a dynamic panel model and the EPE in chapter II, we find that Korean domestic environmental stringency could have a negative influence on Korean performance.

Chapter V summarises the key elements of the study and highlights its conclusions along with policy implications.

CHAPTER II

The Effects of Korean Domestic Environmental Regulations on Total Factor Productivity in Korean Manufacturing Industries

1. Introduction

Until now, many papers have tried to reveal the influence of stringency of environmental regulations on total factor product (TFP) of firms and industries. Although the attempt of these papers was to show general and widespread results, the analyses were inconclusive. That is, several papers argue that environmental stringency has a negative impact while others assert that the influences are positive. Another suggests that there is insignificant relationship between environmental regulations and the economy as costs induced by regulations account for only a small portion of total expenditures by firms and industries. These inconsistent conclusions are attributed to some conditions which researchers adopted. For example, diverse proxy variables representing environmental stringency lead to disparate estimates. Different methods & approaches and period ranges also explain various influences.

These variations shed meaningful insights. In other words, to derive consistent estimates in the Korean case, we will need to check at least proxy variables for environmental stringency and efficient methods. The candidates for the proxy consist of pollution abatement costs, external environmental regulation (eg. US CAAA), pollution emission or energy consumption and composite index. This study will employ industrial pollution abatement cost (referred to as environmental protection expenditure in Korea) because it could be burdensome on an individual firm or an industry (Cole *et al* 2017). Unless mistaken, this thesis is the first attempt[32] to use manufacturing industrial costs to see the impact of environmental stringency at both firm level as well as industry level TFPs. In particular, considering that most papers employing pollution abatement costs dealt with the US or western nations, it is meaningful to expand the analysis frame of environmental regulation-TFP into the Korean manufacturing case.

For an empirical equation, in terms of industrial TFP, this study will adopt dynamic panel model with lagged dependent variables as explanatory variables. Without extreme external shock and large internal innovation, an industry will maintain its existing production methods in production activity. Otherwise, industry would improve its process gradually meaning that past TFP could affect current TFP. Therefore, it is reasonable to employ a dynamic panel model. For estimation purposes,

[32] Because the environmental protection expenditure has been announced in terms of national level, not industry, there has been inherent limitation for previous papers to use industrial expenditure.

the difference GMM will be applied to remove inherent endogenous problems in dynamic panel equation and to obtain efficient estimates. In terms of firm level TFP, we will employ a multilevel model because except for TFP, other variables (R&D and the EPE) are the same as the industrial case due to realistic limitation that we cannot collect panel R&D and the EPE data of each firm[33]. Considering that firms typically exhibit similar management behaviour within the same industry, we believe a multilevel model is an appropriate method. As far as we are aware, both dynamic panel and multilevel models have not previously been employed to analyse the effects of environmental stringency on TFP.

We found that Korean domestic environmental protection expenditure has a negative influence on the TFP in manufacturing industries. In addition, we found that environmental R&D also affects TFP negatively. The firm level TFP analysis also shows the same result that both environmental stringency and environmental R&D have negative impact. This chapter is organized into the following sections. Section 2 discusses relevant previous papers on the impact of stringency of environmental regulations on TFP and proxies for the stringency. Section 3 explains empirical equations and methodology. In section 4, data is described. Section 5 provides results of estimation in terms of industry and then firm-level estimate as a robustness check. Section 6 concludes.

2. Literature Review

The main purpose of environmental regulations is to reduce the pollutants emitted by targeted companies and sectors, clean up contaminated environments and improve social welfare (Kozluk & Zipperer, 2014). The operational process of polices however,

[33] These variables are announced in industrial level after sampling surveyed.

induce complicated effects on firms' economic activities. There are two principal perspectives on these effects.

The traditional view argues that environmental stringency has negative impacts. The logical foundation of this view is that environmental policies levy additional costs on production. Specifically, suppose that a government poses environmental restrictions – such as pollutant treatment charges and environmental taxes on firms emitting pollutants. These policies cause additional production-related operational costs. In addition, firms may also hire special equipment and workers, incurring additional costs or dedicate some share of inputs to the reduction of pollutants. Therefore, governmental interference may be harmful to firm productivity.

The second perspective is based on the Porter Hypothesis. This argues that environmental regulations have a positive influence on productivity by inducing innovation, thus leading to increased profitability. There are three interpretations of the Porter hypothesis: weak, strong and narrow (Jaffe & Palmer, 1997). The weak version argues that environmental regulations trigger innovation while the second argues that these restrictions result in rising firm productivity. For practical estimation purposes, the weak interpretation is generally checked with patents and R&D expenditures while the strong one employs productivity data. The third version, considered to be the important premise of the Porter Hypothesis, is that well-designed market-friendly regulations provide incentives for firms to innovate.

This narrow interpretation often provides useful supporting arguments for advocates of the hypothesis. For example, advocates of environmental regulation often attribute the weakness of many empirical results to government regulation design error. Such arguments however, could be considered irrational. This is because it is almost impossible to engineer perfect restrictions in the real world as any government intervention could distort the behaviour of principal agents unintentionally. A further criticism lies on the Coase Theorem that regardless of how property rights are distributed, firms can decide optimal inputs and outputs in perfectly competitive markets without transaction costs. In this context, considering government regulations against pollutants, not providing property rights in terms of law economy, might not give any help to improve firms' production activity. That is, practically, if we consider that Korean environmental system appears compulsory, it is very difficult that the Porter hypothesis could exist in Korean economic situation.

In even positive signs of empirical estimates, it is unclear whether all the significant empirical signs on firm-level productivity effects of environmental regulation lend support to the Porter Hypothesis. This is primarily because increases in productivity could be unrelated to innovative activity. For example, if some plants use clean water in their production process, government's efforts to improve water quality (such as investment in sewage system) could lead to a reduction of costs for firms refining water, thus promoting their productivity (Jaffe *et al*., 1995). In addition, additional expenditures as a result of environmental regulations could play a role in the exit of inefficient firms from a market. In this case, aggregate productivity could increase without any change in the productivity of incumbent firms (Kozluk & Zipperer, 2014). For these reasons, it is important to be cautious when interpreting the positive estimated outcomes of empirical tests.

There is substantial empirical literature that attempts to evaluate the effects of environmental regulation. Earlier studies focus on confirming its negative impact (Gollop & Roberts, 1983: Smith & Sims, 1985). More recent research attempts to test empirically the various interpretations of the Porter hypothesis (Lanoie *et al*., 2007;

Yang *et al*., 2011; Albrizio *et al*., 2017). In spite of these efforts, the overall results are diverse and inconclusive. This is because many of the empirical estimations are dependent upon the properties of specific firms, industries, countries and proxies for environmental regulations.

This chapter analyses the impacts of environmental regulations on total factor productivity (TFP) derived from a Cobb-Douglas production function. This can be viewed as testing the strong interpretation of the Porter Hypothesis. Testing the weak interpretation on its own is not sufficient to confirm the hypothesis because such innovation research does not consider the practical constraints (Rubashkina *et al*., 2014). That is, although results of research might show that regulation could lead to growth in environmental innovations such as R&D expenditure and patents, more necessary innovation needed for profitability growth may not be implemented in practice due to budget constraints.

This discussion therefore focuses on providing a critical review of the research literature on the productivity effects of environmental regulation in the context of plant-level and industry-level data so as to justify the choice of level with respect to the available information and statistics for Korea. This discussion also includes a review of papers dealing with the selection of environmental regulation proxies.

2.1. Studies of the Impact of Environmental Regulation on Productivity

Early literature on the empirical analysis of environmental regulations on productivity focuses on their negative effects, with the general intention being to confirm these effects. Gollop & Roberts (1983) use data for the US electric power industry 1973-79 to test the impact of the US Clean Air Act Amendments. Controlling for components of productive factors, which harmed productivity growth of electric power generation in 1970s, they argue that the imposition of restrictions on sulphur emissions reduced productivity growth in the sector. Their analysis however, does not consider the properties of each plant.

Smith & Sims (1985) follow Gollop & Roberts in using a cost function to analyse the impact on Canadian brewing, using confidential plant-level data for 1971-80. They find that regulated firms experienced declining productivity growth, calculated by the standard residual method. As in the study by Gollop & Roberts (1983), this ‘difference-in-difference’ analysis does not consider the differing properties of regulated and unregulated firms (Kozluk & Zipperer, 2014). In addition, their cost function has an important limitation because, while production costs are related to environmental regulation, there may not be any correlation between the regulatory costs and the fall in productivity (Domazlicky & Weber, 2004).

In a study of five specific polluting industries in the United States, Barbera & McConnell (1990) use industry-level data to confirm the role of environmental regulations in the decline of productivity over 1970-80. They show that these restrictions lead to various decreases in productivity according to the properties of each industry. It is noteworthy that they attempt to classify the productivity effects into direct (the diversion of inputs to reduce pollutants) and indirect (changes in production process).

Gray & Shadbegian (2003), analyse the impact of environmental regulation using confidential firm-level data for 150 paper mills, oil refineries and steel mills, 1979-1990. Unlike Gollop & Roberts (1983) and Smith & Sims (1985), they employ a Cobb-Douglas production function. The study finds that a “$1 increase in pollution abatement cost leads to an estimated productivity decline of $3.11, $1.80, and $5.98 in the paper, oil and steel industries respectively" (Gray & Shadbegian, 2003). The authors also point out that inputs used to reduce pollutants do not affect output, so that capital and labour should be classified into productive (related to output) or non-productive (only related to pollutant abatement) for estimation purposes if possible.

In contrast to earlier papers, Berman & Bui (2001) test for increases in productivity at the end of the 1980s. They argue that previous papers did not consider selection bias (i.e., those firms intending to reduce pollution in the absence of government regulations), such that the estimations can undervalue the effects as well as measurement error in pollution abatement costs. As a result, they find that it is not possible to derive conclusive results about the impact of environmental regulations on productivity. Instead, the authors adopt an indirect approach by estimating the impact of regulatory change on pollution abatement costs rather than directly on productivity. They focus on oil refineries in Los Angeles and compare the differences between regulated and unregulated plants using plant-level data for 1972 and 1992. They find that the regulated oil refineries experienced increases in productivity 1987-1992, concluding that surveyed pollution abatement costs (PAC) could be overestimated. The indirect research way via change in pollution abatement costs however, do not reflect the influence of environmental regulations on TFP.

Lanoie *et al*. (2001) analyse the impact of environmental regulation on TFP in 17 Quebec manufacturing industries using data for 1985-1994, including one- to three-year lags. The authors attempt to understand the dynamic influence of environmental regulations on productivity and emphasise the importance of competition to induce firms to trigger innovation. They found that current environmental restrictions have had a negative effect on TFP but that previous regulations have had a positive effect over time, so lending support to the Porter Hypothesis.

Hamamoto (2006) extends the analysis of the productivity effects of environmental regulation to Japan. He uses data for five industries from 1966 to 1976 with pollution control expenditure covering only capital costs. He finds a positive relationship between pollution control expenditure and R&D investment and this induced R&D leads to the growth of TFP. It is notable that Hamamoto attempts to introduce R&D in an econometric equation to estimate effects of pollution control expenditure on TFP. In addition, this industry-level approach considering survey level of pollution control expenditure provides useful insights into this study given that pollution abatement costs (officially, called as Environmental protection expenditure) has been surveyed in industry level in Korea.

Becker (2011) investigates the impact of environmental regulation on plant-level labour productivity using a Cobb-Douglas production function as an estimate equation. This data covers all manufacturing sectors unlike previous studies, such that it includes both pollution-emitting and non-polluting industries. Becker finds no significant effect on labour productivity in terms of manufacturing generally but, when the sample is narrowed to include only those firms which underwent 'meaningful change' in their environmental compliance costs, labour productivity experiences a decease. It is notable that Becker (2011) also emphasises the character of industries as dirty or clean.

Greenstone *et al*. (2012) use the most extensive plant-level data and also consider the regional nature of environmental regulations. They find a negative effect of environmental regulation on TFP and also that ozone restrictions have a greater impact. Further, the lagged effects have a greater negative impact than contemporaneous effects. The principal contribution of the paper is that it attempts to control for the regional and industrial characters of the US Clean Air Act Amendments, which allow them to consider various conditions. In addition, like Lanoie *et al*. (2001), they suggest the role of time lags should also be tested.

Yang *et al*. (2011) investigate the Porter Hypothesis in the case of Taiwan using industrial data for 1997-2003 like Hamamoto (2006). They adopt a two-stage estimation approach. That is, they first test for the R&D expenditure effects of environmental regulations. The estimated coefficient for R&D is then inserted into a second empirical model which has TFP as a dependent variable. They find that environmental regulations do not affect R&D expenditure while the estimated R&D coefficient from first model indicates an increase in industrial productivity. In addition to these two results, they find positive effects of environmental regulations on productivity, supporting the Porter Hypothesis. The paper is notable for extending the research target towards Taiwan's case as opposed to western developed countries and using both capita and operating abatement costs, giving insight for this study which will employ expenditure including both capital and operation costs.

Rubashkina *et al*. (2014) also made use of industry-level data from 17 European countries for 1997-2009. They investigate the weak and strong versions of the Porter Hypothesis for the case of Europe, arguing that previous papers only focus on the United States. They attempt to confirm the comments of the European Commission (2010) that 'Environmental policies and increased competitiveness are not mutually exclusive, but can indeed strengthen one another'. No significant relationship was found between environmental regulation and productivity. They test the strong version of the Porter Hypothesis in the EU case but omit major European countries such as Germany, France and Italy owing to data restrictions.

Hancevic (2015) uses plant-level data for 1985-99 and finds a negative effect of the 1990 US Clean Air Act Amendments on the productivity of coal-fired electricity-generating firms. Although burning coal accounts for most emitted SO_2, the analysis is too context specific to provide more generalised findings. Hancevic (2016) however, does suggest the use of a Cobb-Douglas form for estimation in terms of the convenience of the function and ease of interpretation of the coefficients.

Albrizio *et al*. (2017) addresess the lack of complementarity between industry- and firm-level data by employing both for the period of 1990-2012. They use 'a standard Neo-Schumpeterian model of multifactor productivity (MFP) growth'. MFP is based upon Levinsohn & Petrin (2003) using the method of Woodridge (2009), which deals with calculation problem of capital. They found that, at the plant-level, environmental regulations have a negative effect on productivity growth of high pollution-intensity and low-productivity firms. At the industry-level, the impact of environmental regulation is positive, although the impact is smaller for low productivity industries. The principal contribution of the paper is that it attempts to use the OECD's Environmental Policy Stringency (EPS) Index, making panel analysis possible. They also confirm that the EPS Index is representative of the overall level of environmental restrictions and that it is free from endogeneity problems through the use of various robustness checks. In addition, it is notable that they attempt to use both plant- and industry-level data to avoid criticism of the flaws in the two datasets, suggesting that our study should attempt to use two approaches (industry and firm level). Likewise, like previous papers, it considers R&D important in the equation. Their limitation is that they use MFP instead of TFP.

Lee *et al*. (2015) deals with the case of Korea in terms of impact of regulations on Korean industrial labour productivity, using panel data analysis of nine industries 1985-2007. Strictly speaking, their research is not a study dealing with only effects of environmental regulations on TFP because it attempts to analyse relationship between all government regulations and labour productivity[34]. They find that enhancing social regulations, including environmental regulations, does not have a significant effect on labour productivity. It is notable that they first attempt to analyse influence of the Korean Government regulations including environmental regulations on labour productivity. Their limitation is not using TFP and specific proxy for environmental stringency. Such weakness gives me important insights. That is, this study encourages me to create TFP using industrial capital stock and get access permission for industrial environmental protection expenditure in order to exactly estimate influence of environmental regulations on TFP in terms of Korea.

2.2. Measuring Environmental Regulatory Stringency

It is very important to choose an appropriate measure of the stringency of environmental regulations on economic performance, such as productivity, trade, employment and investment (Botta & Kozluk, 2014; Albrizio *et al*., 2017). There are several ways to calculate stringency. The first is pollution abatement costs, which are frequently and widely used in many US analyses because these costs have been surveyed by the US Census Bureau 1973-1994, 1999 and 2005. They have the merit

[34] This study covers all industries, including manufacturing, transportation, agriculture and services. In addition, they also incorporate social regulation, covering environment, health, industrial accident and consumer safety. The authors construct their own regulation index by classifying Korean economic and social regulations. Environmental regulations are classified as social, which are allocated a lower weight than economic regulations. The regulations are then scored according to their properties – inputs, outputs and market-friendly – so as to compare the stringency of regulations, although the weights applied are arbitrary.

of representing the general expectation that pollution-intensive industries could have high pollution abatement costs. Besides US case, the studies of Rubashkina *et al*. (2014) and Yang *et al*. (2011) employ pollution abatement cost-type measures for European countries and Taiwan. Hamamoto (2006) uses pollution control expenditure, including capital cost. The drawback of using pollution abatement costs is that they represent all of the costs – including material delivery fees – of pollution abatement as well as the contribution of stringency. In addition, because of the difficult abstract meaning of pollution abatement costs in the questionnaire, they should be dealt with carefully (Brunel & Levinson, 2016). For example, Gray & Shadbegian (2003) show that actual pollution abatement costs could be more than three times, compared to the amount in the surveys. Moreover, they cannot be used for comparison across countries because of different definition and measurement in each nation.

The second is to use specific and external regulation, such as the National Ambient Air Quality Standards (NAAQSs) of the US Clean Air Act. This measurement is applied for 'difference-in-difference' studies analysing differences between regulated and non-regulated firms emitting air pollution. A similar approach is used by Greenstone (2002, 2004), Chay *et al*. (2003), List *et al*. (2004) and Chay & Greenstone (2005). Another version utilises a certain acceptable standard as the overall degree of environmental regulations. For example, Cole *et al*. (2006) employ lead levels in gasoline as a measure of the stringency of environmental regulations in terms of FDI. The limitation of using this approach is that the estimated results for different cases cannot be generalised.

The third measurement is a composite index, which is comprehensive and agglomerates various government efforts to improve the environment. Several indices have been used as representative of the stringency of environmental regulations.

Kellenberg (2009), Wagner & Timmins (2009) and Kalamova & Johnstone (2011) all employ the World Economic Forum survey index. Smarzynska & Wei (2004) adopt an index using the number of NGOs for environment and the ratification of global treaties protecting environment. Albrizio *et al*. (2017) uses the OECD environmental policy index. Lee *et al*. (2015) created their own Korean regulation index. Cole *et al*. (2010) compile an industrial index using a share of sub-sector value added within an industry. Using indices however, has a limitation in that it is not possible to calculate exact differences in magnitudes; if countries A and B have index scores of 50 and 55 respectively, the difference does not necessarily mean that stringency in country B is 10 per cent greater than in country A.

The fourth method utilises emission, pollution and energy consumption data. This approach is based on the assumption that higher levels of emission, pollution and energy consumption means less stringent environmental regulations. Xing & Kolstad (2002) employ US sulphur dioxide emissions and Smarzynska & Wei (2004) use carbon dioxide, lead and water pollution. Cole & Elliot (2003) and Harris *et al*. (2003) use energy consumption. The drawback with these measures is that the selected emission and pollution can be applied only to the industry concerned. In addition, energy consumption may depend upon non-stringent activity such as price and the cost of delivery.

It is difficult to identify the most appropriate measurement of stringency of environmental regulation. In addition to the drawbacks of each measure discussed above, four major challenges need to be considered (Brunel & Levinson, 2016). The first is Multidimensionality. This issue happens because environmental pollution is a complicated multidimensional problem. Because environmental regulations of various types feed through via complicated processes, it is very difficult to identify which regulations are exactly linked to change of firm actions. For example, research on firm movement to countries with lax environmental regulations; restrictions against lead level in car fuel or household waste recycling policies, do not have a direct influence on company movement. It is also difficult to compare levels of stringency of complex regulations in the situation that each regulation is based on different units, for example evaluating which is stronger between volume and percentage restrictions against pollutant emissions.

Two ways are recommended to avoid multidimensionality (Brunel & Levinson, 2016). The first is to narrow specific environmental issue and use the related regulations. For example, Berman & Bui (2001) focus on air pollution restrictions connected to oil refineries and Levinson (1999) narrows to dangerous waste-removing tax. Secondly, a composite index can be used, such as those mentioned above by Smarzynska & Wei (2004); Cole & Elliott(2003), Kellenberg(2009) and Kalamova & Johnstone (2011) as well as the Environmental Performance Index (EPI) of the Yale Center for Environmental Law and Policy and the OECD's Environmental Policy Stringency Index.

The second challenge is Simultaneity. It is possible that environmental regulations and targeted variables (production, trade, FDI etc.) affect each other simultaneously. The recommended solution is to use environmental policies that are determined by an external authority. McConnell & Schwab (1990), Henderson (1996), Greenstone (2002), and Chay *et al*. (2003) use the US Clean Air Act, decided federally and therefore uniform across all US states since no state has the power to avoid it. An alternative is to employ instrumental variables that are related to the proxy for environmental regulation but uncorrelated with the error term. It is very difficult however, to identify panel instrumental variables that vary across region and time and these instruments could also directly affect the dependent variable (Brunel & Levinson, 2016). Ederington & Minier (2003) political economic instruments, Levinson & Taylor (2008) a regional instrument, Kellenberg (2009) a lagged level of corruption, income, education and Jug & Mirza (2005) lagged wage.

The third challenge is Industrial Composition. Even if two jurisdictions have the same level of stringency of environmental regulations, the one with the more pollution-intensive industrial structure will have greater pollution abatement costs than the other with relatively clean industries. Moreover, if a concentration of dirty industries leads to higher stringency levels, this may lead to the erroneous conclusion that high levels of restrictions help polluting intensive industries. Stringency measured independently from industrial composition can be useful solution. The final challenge relates to practical limitations on enforcing regulations. That is, many laws are stricter for new as opposed to existing firms (Stavins, 2006). In this case, regulations are referred to as being 'grandfathered'. This leads to a problem that less stringent restrictions (non-grandfathered) might have higher pollution abatement costs than stronger grandfathered ones not causing new and higher costs. To control an industrial composition and grandfathered problem, Levinson (1996) employs age of the facility as one of explanatory variables and industrial fixed effect in plant-level data while Keller and Levinson (2002) use their own ratio (actual expenditure over predicted costs) in industry level data. In Korean case, grandfathered issue is not serious because all regulations have been applied for new and old facilities.

Brunel & Levison (2016) argue that because the correlation between various measurements of environmental stringency is not large, and each proxy has advantages and disadvantages, excessive trust should not be placed upon estimates from studies using only one proxy measurement. Considering the drawbacks of each proxy candidate measure and four challenges, three standards are established to choose an appropriate proxy for Korean environmental regulation in this study. The first condition is that in terms of Korea, with reference to the possibility of collecting, it must be feasible to survey the appropriate measurement. Next, the proxy should also be appropriate for the purposes of the study; that is, industry-level data is required to analyse industrial trends and change. Finally, the measure of stringency should be officially approved so as to dispel any concern about the arbitrary creation of a proxy.

With regard to these three criteria, although any measurement has research limitations, industrial environmental protection expenditure from Ministry of Environment is chosen to measure the effect of environmental regulations on TFP in terms of industrial behaviour. After a thorough search of all data from Korean Government and private institutes, we found that only environmental protection expenditure deals with pollution abatement activities and it composes nine manufacturing sectors. In addition, as mentioned above, it has been officially surveyed by the Ministry of Environment. This means that it satisfies all three standards highlighted above. Given that this proxy measure includes both capital costs and operating costs, this study attempts to make better analysis in Korean case than Hamomoto (2006) using only capital cost[35].

Pollution protection expenditure will be also employed in the last empirical chapter which deals with the influence of environmental regulations on Korean trade performance. In the next empirical chapter which compares country-level behaviour however, the OECD's Environmental Policy Stringency (EPS) Index is used in spite

[35] Like Hamomoto, Song and Sung (2014) used capital costs for pollution abatement which they created to analyse the effect of the costs on Korean export performance.

of its shortcomings – it focuses on climate and air regulations affecting the whole manufacturing sector, not dealing with biodiversity etc. and overlooking useful methods to improve air quality such as voluntary approaches and tax benefits for clean investment.

As in the case of environmental protection expenditure, the EPS Index is based upon official data and represents countries' efforts (regulations) to improve the environment. In addition, the country-level measurement is suitable because the second empirical chapter deals with the relationship between discrepancies in the stringency of environmental regulations among the OECD countries and changes in Korean outward FDI. As a composite index, the EPS Index also deals with the challenge of multidimensionality (Botta & Kozluk, 2014) because it includes all components. It is also free from the CEO bias different from index from the WEF survey and can cover a long period (from 1990 to 2015) while the EPI has only biannual data from 2008 to 2016[36]. Some papers utilize this information to analyse the economic influence of environmental regulations across countries (Sauvage, 2014; Kozluk & Timiliotis, 2016).

2.3. Conclusions

Through literature review, we can refer to crucial points for this study. First, to check the Porter Hypothesis in the strong version, relation between productivity and environmental stringency should be dealt with. In addition, because TFP is better than MFP or labour productivity, we are encouraged to search capital stock in Korean case

[36] The EPI is provided by Yale University (Yale Center for Environmental Law and Policy) and Columbia University (Center for International Earth Science Information Network) in collaboration with the World Economic Forum and the Joint Research Center of the European Commission.

and calculate TFP. Finally, we realise that in situation that there are flaws of all measurement of environmental stringency, not enough trust is given to estimated results. Then, we can establish our own criteria to decide appropriate proxy for Korean case.

3. Econometric Specification & Estimation Method

In this section, we will deal with econometric equations for study. Specifically, this study will explain components of the dynamic panel model, condition that must be considered for selecting data level, and econometric issue like endogenous problems.

3.1. Empirical Model

Dynamic Panel Model for Industry level analysis

Assuming that current TFP is affected by past TFP, lagged TFP should be included in econometric equations. Such panel equation is called as the dynamic Panel Model. According to year graph of TFP (shown in data description part) in Korean manufacturing sectors, it seems that TFP in each year is related to lagged TFP. To consider this influence, we add one-year lagged TFP in the model.

Meanwhile, previous papers dealing with effects of environmental stringency on total factor productivity face two challenges. One is to calculate TFP as a dependent variable. The other is to establish a right side of estimation equation. To solve the first challenge, a residue derivation is suggested. In Cobb-Douglas function, coefficients of capital stock and labour are estimated and then predicted output is calculated. Through difference between real output and the predicted output, a residue is measured. Finally, standard residue is considered as TFP. In Korean case, because until recent, industrial capital stock data was not able to be received from Korean official authority, previous Korean papers have tried to do different approaches. For example, Lee *et al*.(2015) use only labour productivity. In this study, however, because we can receive industrial capital stock from the Bank of Korea, it is possible to analyse directly relationship between TFP and stringency of environmental regulations. Unless mistaken, this study is the first thesis using industrial TFP.

A solution for the second challenge goes through intuitive approaches and empirical models used by previous papers. The basic equation starts from TFP as a dependent variable and environmental stringency as an explanatory variable. As known, selecting appropriate proxy for the stringency is a very important issue. We have already discussed this issue in previous section. As mentioned, we will employ industrial environmental protection expenditure (the EPE) dataset as a proxy for Korean environmental stringency.

This study also adds general R&D [37] and environmental R&D under the assumption that general R&D and environmental R&D play different roles in firms' management. That is, we believe that general R&D could lead to improvement of production process and innovation resulting in TFP growth while environmental R&D is similar to expenditure to meet environmental standards because the R&D may be unnecessary investment without pressure of environmental regulations. Albrizio *et al*. (2017), Yang *et al*. (2011) and Hamamoto (2006) also employ econometric equations with R&D. The unique approach lies on controlling environmental R&D separately. Our equation is as follows;

[37] General R&D is generated from 'total R&D – environmental R&D'

$$\text{Industry } TFP_{it} = \beta_0 + \beta_1 \text{ TFP}_{it-1} + \beta_2 ln \text{ general R\&D}_{it-1} + \beta_3 ln \text{ environmental R\&D}_{it-1} + \beta_4 ln \text{ EPE}_{it-1} + \beta_5 ln\, Size_{it} + \theta_i + \theta_t + e_{it} \quad (2.1)$$

where i = industry, θ_i *and* θ_t catch unobserved characters of industry and time.

The right side of equation (2.1) involves lagged TFP as explanatory variables. We could think that without extreme external shock and large internal innovation, an industry would keep existing production pattern or improve its process gradually on the base of past system. It implies that past TFP could affect current TFP. Therefore, dynamic panel model could reflect firms' behaviour better than static panel model. Surely, the expected sign is positive.

In addition, the model includes lagged value of general R&D, environmental R&D and the EPE. It is likely that influence of industrial R&D will take time to emerge in the industrial performance (Albrizio *et al*., 2017). Because it is generally said that industries with high R&D are more likely to pursuit higher TFP, coefficient of general R&D variable will show positive value. Considering that manufacturing output increased sharply by 77% from 2006 (KW976,065 billion) to 2014 (KW1,728,375 billion), we guess that general R&D might play a positive role in output increasing. On the contrary, if it is true that industries consider environmental R&D as reluctant costs, environmental R&D will have negative sign.

Meanwhile, in spite of the fact that different GMM could control much endogenous problems in equations, we employ lagged EPE to avoid the standard concern that industrial TFP is endogenously linked to environmental stringency at the national level (Albrizio *et al*, 2017). This problem might happen if government manipulate environmental stringency considering industrial TFP or business association in an industry experiencing TFP decrease lobbies governments to lessen TFP. Because the EPE is additional costs which might be used for more productive activity without environmental regulations, its sign will be negative.

$Size_{\mathrm{it}}$ represents portion (%) of firms with more than 300 employees in the concerning industry. It is included to catch role of over middle size firms in an industry on the TFP. If big companies have more educated human and good material resources, industry with higher portion would have higher TFP than industry with lower value. Coefficient of Size therefore will have a positive sign.

Multilevel Linear Model for Firm level analysis

For firm level approach, we will employ multilevel linear model. That is because a dependent variable is firm level TFP while explanatory variables are industrial data. We assume that firms in a certain industry show similar action pattern. For example, it is common that firms in Chemical industry emit much air pollutant and need much energy. It implies that firms are nested in terms of industry. In this case, multilevel linear model is recommended (Min & Choi, 2012). The equation is

$$Firm\ TFP_{\mathrm{it}} = \beta_0 + \beta_1 ln\ \text{general R\&D}_{\mathrm{it}} + \beta_2 ln\ \text{environmental R\&D}_{\mathrm{it}} + \beta_3 ln\ \text{EPE}_{\mathrm{it}} + \mathrm{M}_f + SML_f + \mathrm{e}_{\mathrm{it}} \quad (2.2)$$

where Firm TFP represents firm level calculated TFP. General R&D, environmental R&D and the EPE are industrial data like industrial dynamic panel model. We guess that the signs are similar to results of industrial case except general R&D. Sign of the general R&D could be negative or insignificant because manufacturing output in 2010-2014 show seriously static movement. – that is, we could think that the R&D

played as just costs not leading to output increase or did not make significant contribution to the growth.

M_f is added to control influence of Target management system[38] on individual firm action. The system is a special regulation tool because most Korean regulations are indifferent across all firms while the system is activated in targeted firms. Because the targeted firm could respond differently to industrial environmental stringency from non-targeted firms, we insert this dummy variable; 1 if a targeted firm and 0 if non-targeted firm. M_f therefore is firm-level data. We think that M is negative sign because Target management system is also burden on firms.

SML_f represents firm size dummy variable. It has 1 if the number of employees of a firm is less than 10; 2 if from 10 to 299; 3 if 300 or over. Considering that when firms move towards larger size, they will need to spend expenditure to comply with environmental regulations more than before – especially, in economy recession period[39] without meaningful innovation, expansion of firm size only means increasing equipment and operating costs, it is likely that the coefficients have negative signs.

Unlike industrial dynamic panel model, we will use current value of variables because we believe that firm level TFP are not endogenously related to industrial explanatory variables. That is, we think that firms could do environment friendly actions voluntarily. It is also unlikely that the Government does not consider meticulously specific TFP of each firm when it decides environmental regulations.

[38] "The Government designates entities that emit greenhouse gas and consume energy in large volumes as controlled entities, imposes greenhouse gas emission and fossil energy consumption targets, and manages and supports them performance check."(Ministry of Environment)

[39] This study use firm level data in 2010-2014 when Korea experienced economic recession.

The Korean Government determines stringency of environmental regulations according to pollutant volume and air, water and land quality at industry or nation level (Ministry of Environment annual report 2014)

3.2. Date Level for Estimation

Selecting Plant level or Industry level

Choosing the data level for analysis is dependent on the actual availability of data. Each data level has its own advantage and disadvantage. Plant-level data reveals the impact of regulation on each individual firm and also enables researchers to circumvent, to some degree, multidimensionality. Plant-level studies of the impact of environmental regulation however, tend to show relatively larger decreases in productivity than industry-level analyses (Shadbegian & Gray, 2003). These results may indicate that using firm-level data is problematic in that it does not control for the less productive bias faced by polluting plants (Berman & Bui, 2001).

A further criticism of firm-level data is that studies only include surviving companies, so they do not consider the entry and exit of firms (i.e., dynamic change) in one industry even though firm-level data can avoid aggregation bias in industry-level data. Plant-level data also suffers from the representativeness problem; that is, it is common for firm-level data to be collected using surveys. This means that the data may not include information about firms not participating in the survey such that the survey data can be criticised as being unrepresentative of the industry concerned. Moreover, most plant-level data is only available for industrialised economies and is often confidential, meaning that only people with special permission can utilise the data. Lee *et al*. (2013) argue that there is also an ‘atomistic fallacy’; that is, that incorrect general inferences regarding industry-level effects are derived on the basis of individual firm-level data. Empirical studies reliant on firm-level data include the followings: Gollop & Roberts (1983); Smith & Sims (1985); Berman & Bui (2001); Kozluk & Zipperer (2014); Gray & Shadbegian (1993, 2002, 2003); Becker (2011); Greenstone *et al*. (2012); Hancevic (2012); Albrizio *et al*. (2017).

Many other empirical papers use industry-level data, primarily because of a lack of plant-level data rather than because of the methodological issues identified above, notably the atomistic fallacy. If the objective is to analyse industrial trends, then using higher level group data is more suitable than low level individual firm data (Lee *et al*., 2013). The main problem faced by research using industry-level data however, is the 'ecological fallacy' (Robinson, 1950; Winzar, 2015). This problem occurs when individual (plant-level) action is predicted based upon estimations using aggregated (industry-level) data. The choice between plant-level and industry-level data therefore depends upon the research objectives because each has its own advantages and disadvantages. Firm-level data is suitable for individual inference while industry-level data is appropriate for the analysis of industry behaviour (Winzar, 2015). There are several notable studies using industry-level data (e.g., Lanoie *et al*., 2001; Hamamoto, 2006; Yang *et al*., 2011; Rubashkina *et al*., 2014; Lee *et al*., 2015; Albrizio *et al*., 2017) .

In general however, the most critical determinant of this choice depends upon data availability such that data limitations determine the level of analysis. This is the case with the study of Total factor productivity effects of environmental regulations under limitation of the TFP data and proxy data for environmental regulations. TFP in this study is calculated as the estimated residue using a Cobb-Douglas production function with capital stock and labour. In the Korean case, the capital stock is officially calculated in terms of industries by the Bank of Korea. Few previous literatures on Korea however, used the Bank of Korea's capital stock because the data has been only recently provided. Instead of capital stock, Lee *et al*. (2015) employed industrial labour productivity (industrial GDP/labour).

In addition, Korean environmental protection expenditure (the EPE) – representing operation and capital (investment) cost to reduce or eliminate pollutants – has only been surveyed at the nine industries from Ministry of Environment. It however has only been announced at national level. It means that to date, industrial analysis has been difficult to study. It is needless to say firm-level analysis. Some Korean case papers cannot help using the CEO survey (national level) of World Economic Forum (Chung, 2015) or weighted number of regulations (Lee *et al*., 2015) as industrial environmental stringency. We could get the industrial EPE on condition that the data must be used only for this research. Unless mistaken, this study is the first time to make industry-level approach by using the industrial EPE.

As mentioned above, because of data availability, this study has little choice but to adopt the industry-level analysis as a main study. To check firm behaviour, however, the study tries to undertake complementarily plant-level data analysis using firm-level data with tangible assets, not capital. This data has been sourced from NICE (Korean National Information & Credit Evaluation Inc.) which provides firms' financial and business information for its members. As mentioned above, however, because there is no firm-level industrial environmental protection expenditure available for Korea, the study uses industry-level environmental cost data, instead. Utilising these two approaches simultaneously means that it is possible to check for both industry trends and individual plant reactions to the stringency of environmental regulations.

Multilevel Linear Model

Some caution however is required regarding the latter plant-level analysis owing to different data components in econometric model. Estimated TFP data is firm-level but the proxy for environmental regulations is industry-level. That is, plant-level and industry-level data are mixed such that the dataset has multilevel structure[40]. When using this multi-level data, it is important to take into account both individual variation (within-group difference) and group variation (between-group difference) (Winzar, 2015; Lee *et al*., 2013).

Three approaches have been suggested: disaggregation, aggregation and multilevel linear modelling. The disaggregation method distributes industry values into individual firm-level observations. It therefore ignores 'between-group differences' and does not take it into account that observations within the same group may affect each other. This contravenes the OLS condition of independence of observations. The aggregation method does not consider the original properties of the lowest (firm) data level such that it loses observations of within group differences. Using this method therefore results in incorrect estimations.

In such cases, Min & Choi (2012) recommend multilevel linear modelling to cure the problems of both the disaggregation and aggregation methods[41]. The model can consider both within- and between-group variation in a multi-level dataset (Beaubien *et al*., 2001; Osborne, 2000). The estimation is therefore more efficient and appropriate. Multilevel linear modelling is also the suggested methodology to analyse

[40] The Environmental protection expenditure data could nest firm-level dataset. That is, the expenditure is higher level criteria into which firm-level data can be classified. In this case, I could think that firms within the same industry have similar properties (resembling TFP trend of firms in a categorized group with an environmental protection expenditure)

[41] Woltman *et al*. (2012) suggest hierarchical linear model (HLM) which is a different name of multilevel model

nested data because it needs fewer conditions compared to other statistical tools (Rautenbush & Bryk, 2002). It also has some disadvantages, such as requiring a large sample size (the 30/30 rule) and removing group without information in certain parts. In spite of these drawbacks however, multilevel model is still preferred for multi-level data (Beaubien *et al*., 2001; Osborne, 2000). The multilevel linear model is therefore applied in this study for firm-level analysis.

3.3. Endogenous Issue of Dynamic Panel Model

To consider dynamic adjustment of economic activity in panel, lagged dependent variables should be added to estimation model (Bun and Sarafidis, 2013). Such model is called 'Dynamic Panel Model'. This equation has some problems. First, because the equation includes lags of dependent variable as explanatory variables, there should be correlation between the variables and error term violating condition for consistent estimators. Then, if the model has policy variables, it should also face endogenous problems. That is, it is likely that the policy might be decided by dependent variable (Besley and Case, 2000). These plights cause biased and inconsistent estimators, which still exist even in fixed effects and random effects. To deal with the first issue, the first differences method is utilised. When dynamic specification is the following,

$$y_{it} = \alpha y_{i,t-1} + \beta x_{it} + \mu_i + \varepsilon_{it} \,; i = 1, \dots N,\ t = 1, \dots T \quad (2.3)$$

Where μ_i is unobserved time-invariant heterogeneity. The first difference is that

$$\Delta y_{it} = \alpha \Delta y_{i,t-1} + \beta \Delta x_{it} + \Delta \varepsilon_{it} \quad (2.4)$$

Where $\Delta y_{it} = (y_{i,t} - y_{i,t-1})$, $\Delta y_{i,t-1} = (y_{i,t-1} - y_{i,t-2})$, $\Delta x_{it} = (x_{i,t} - x_{i,t-1})$ and $\varepsilon_{it} = (\varepsilon_{i,t} - \varepsilon_{i,t-1})$.

To solve the endogenous problem, 2SLS and The Generalized Method of Moments (GMM) of Arellano & Bond (1991) (called as difference GMM) are recommended. It is said that difference GMM is more efficient than 2SLS method in over-identified model (Baum 2006; Min and Choi 2009). The difference GMM method use past data of lagged dependent variable as instrumental variables[42]. Meanwhile, to use difference GMM, both over identified test and autocorrelation test should be checked. The former can be done with Sargan test not rejecting while the latter use Arellano-Bond test for zero autocorrelation in first-differenced errors. If Sargan test does not reject null hypothesis (overidentifying restrictions are valid), we can believe that overidentified difference GMM is appropriate. Moreover, if the Arellano-Bond test show that null hypothesis (no autocorrelation) at first order is rejected while the hypothesis at second order is not rejected, using t-2 and behind dependent variables as instrumental variables is correct. In this chapter, therefore, we will employ difference GMM[43]. In Stata, xtabond is for difference GMM.

The second endogenous issue between a dependent variable and environmental regulations should also be controlled. Albrizio *et al*. (2017) argue that there is a possible endogenous problem because of opposite causality saying "if good performance in given industries (in terms of MFP growth) facilitates adoption of more stringent environmental policies or if firms that are performing poorly are able to successfully lobby against more stringent policies". As known, measurement error and omitted variable could also cause endogenous problems. To avoid the first

---

[42] For Δy_{t-1} , $y_{i,t-2}$, $y_{i,t-3}$ ... ... used as instrument variables

[43] Besides difference GMM, system GMM could be also recommended. System GMM employs both level variables and lagged variables as instrumental variables. It therefore is known that system GMM is more efficient than difference GMM (Arellano and Bover 1995; Blundell and Bond 1998). There however can be cases where system GMM does not meet Sargan or Arellano-Bond test, or standard error becomes larger than difference GMM. In this case, difference GMM should be used (Min and Choi, 2012).

problem, the study adopts lagged environmental protection expenditure[44]. For the latter, industry and time effects are introduced which can catch unobserved effects.

3.4. Conclusions

We will analyse influence of environmental stringency on TFP in terms of both industry and firm level. For industrial analysis, we will employ dynamic panel model which consists of industrial TFP as a dependent variable, and lagged TFP, lagged general R&D, lagged environmental R&D, lagged environmental protection expenditure and Size as explanatory variables. For estimation method, difference GMM is applied. For firm level estimation, we will use a multilevel linear model. A dependent variable is firm TFP while industrial data (R&D, environmental R&D and the EPE) and firm level size dummy are explanatory variables.

4. Data Description

In this section, we will explain properties of Total factor productivity (TFP), R&D and Environmental protection expenditure (the EPE). TFP is derived from Cobb–Douglas function with capital stock and labour (number of employee). Because capital stock has been estimated in terms of twelve manufacturing industries by the Bank of Korea, TFP data also follow the classification. However, because the EPE has been created under nine manufacturing sectors, TFP and R&D data should be arranged subject to the EPE classification criteria for panel data.

[44] It is difficult to find out external measurements and as pointed out by Brunnermeier & Levinson (2004), even instrumental variable are not free from endogeneity. As mentioned in section 2. Brunnermeier & Levinson (2004) argue that 'as is always true of instrumental variable analyses, the instruments are open to critique'.

4.1. Total Factor Productivity

Total factor productivity (TFP) accounts for the certain part of output which traditional inputs in product activity, capita and labour, cannot explain. It implies that the level of TFP is decided by efficiency and intensity of factors in production process (Comin, 2010). As such, TFP is a close relationship with output growth, all other inputs being equal. Further, Hall (2011) and Lipsey and Carlaw (2004) argue that productivity reflects innovation and technological development and growth of the TFP leads to increase of profitability. In this context, as mentioned earlier, studying influence of the environmental stringency on TFP is related to checking the strong porter hypothesis (Jaffe & Palmer, 1997). The calculation of TFP is based Cobb–Douglas function. Specifically, first, predicted output is calculated by using estimated coefficients of industrial capital stock and labour (the number of employees). The next stage is to get a residue of difference between real output and predicted output. Finally, the residue is transformed to standard residue. The standard residue is called as TFP. The Cobb–Douglas function is as the following;

$$\text{output} = \mathrm{A} \times K^{\alpha} \times L^{\beta} \quad (2.5)$$

Where K is capital stock and L is labour (number of employee).

From empirical perspective, getting capital stock data play a crucial role in calculating TFP. This study receives the data from The Bank of Korea. In fact, the industrial data has been only recently announced. Previous Korea papers (Lee *et al*., 2015; Oh *et al*., 2014) cannot help using labour productivity (industrial output per worker) or fixed assets, instead of industrial capital stock. Unlike former research, we employ manufacturing capital stock which composes of twelve sectors. It means that we employ direct capital data in terms of individual manufacturing industry, not proxy. As such, we give meaningful contribution to industrial TFP research. In terms of labour, we use the number of employee in each industry from Ministry of Labour. Because Korean economic increased in 2006-2014, most of industries experienced increase of capital stock and employee number at the same period.

In general, Figure 2.1 shows slowly increasing trend of TFP in terms of all manufacturing sectors. In terms of each industrial analysis, Figure 2.2 however indicates that ‘non-metallic mineral’, ‘machinery, computer, electronic equipment’ and ‘other manufacturing’ industries have negative TFP while other sectors do positive value. The interesting point lies on negative value of the TFP of ‘machinery, computer, electronic equipment’ industry which means that it experienced no improvement of efficiency of production process[45] even though R&D expenditure increased from KW12,389 billion to KW31,170 billion. This negative data also means that the growth of ‘machinery, computer, electronic equipment’ industry is led by increase of investment volume of capital and labour, not improved TFP (HRI, 2013). Further, Figure 2.3 argues that the some manufacturing sectors face lack of efficient use of inputs and static innovation. In this condition, if stringency of environmental regulations has significant effects on TFP, determining the level of environmental stringency should be very critical issue for policy makers who want to boost manufacturing industries. In terms of descriptive graph (Figure 2.4), we could not identify relationship between TFP and Environmental protection expenditure used as proxy for environmental stringency. The correlation coefficient is 0.023.

[45] Under the situation that decreasing price of Semiconductor and Other Electronic Component Manufacturing and low efficiency of R&D investment in Korea, it is not easy to achieve upward TFP (HRI, 2013). See Appendix 5 and 6.

Figure 2.1: Industrial TFP in 2006-2014

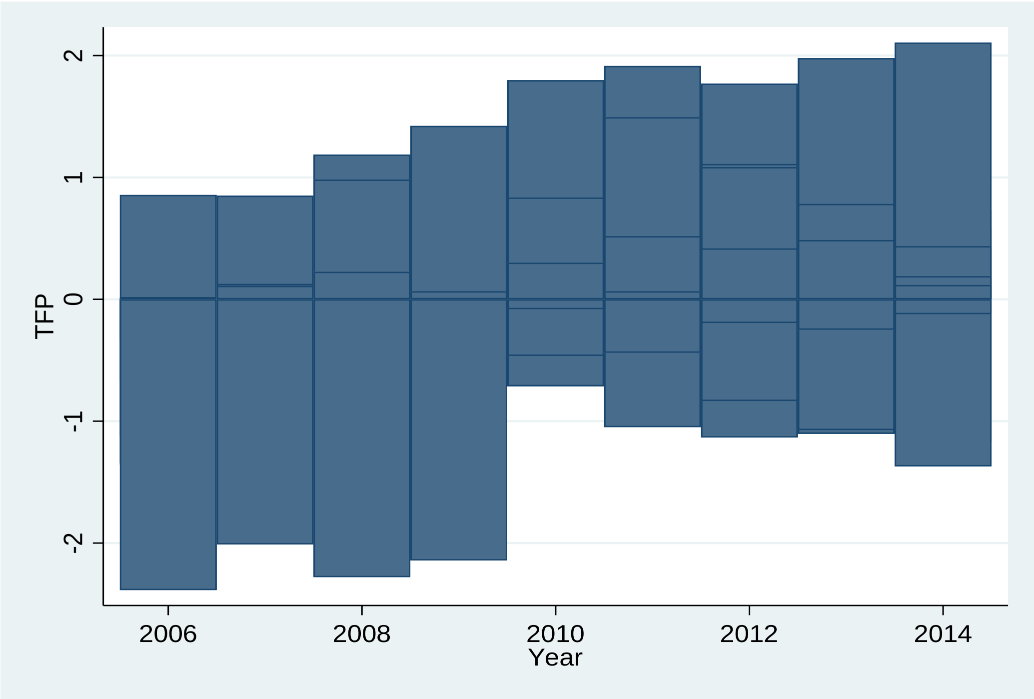


Figure 2.2: TFP of nine manufacturing sectors

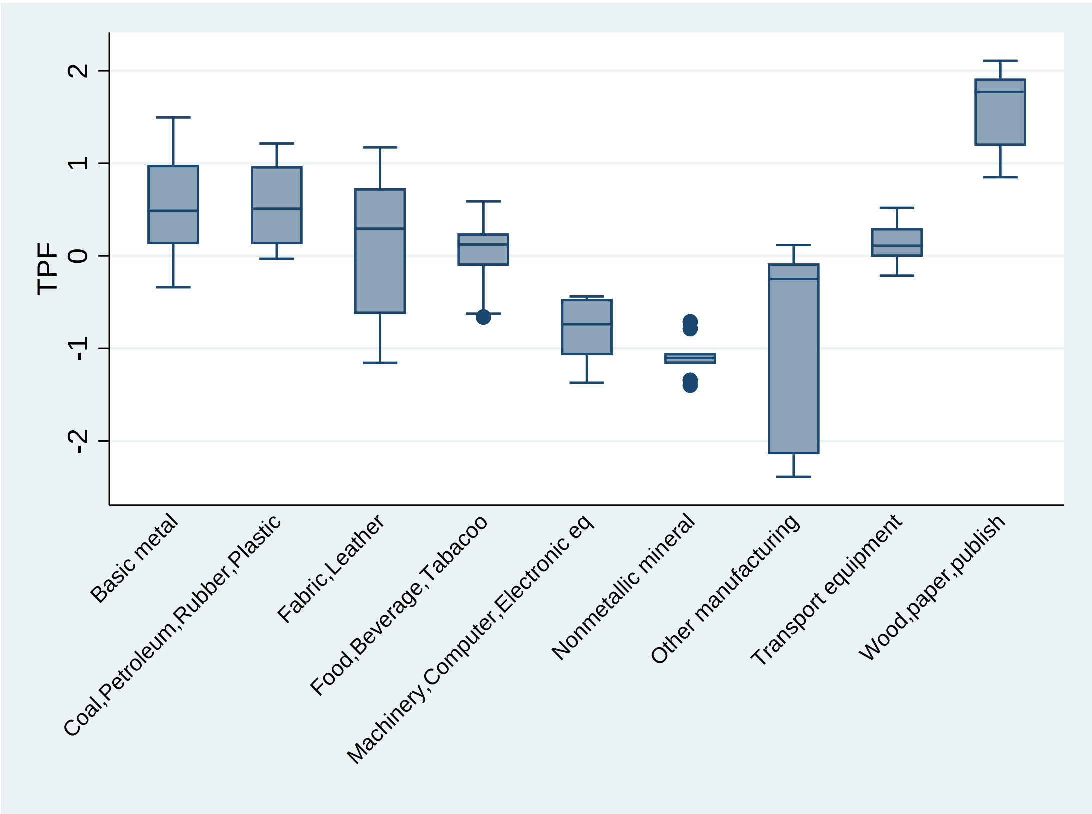


Figure 2.3: TFP change in 2006-2014, in terms of each industry

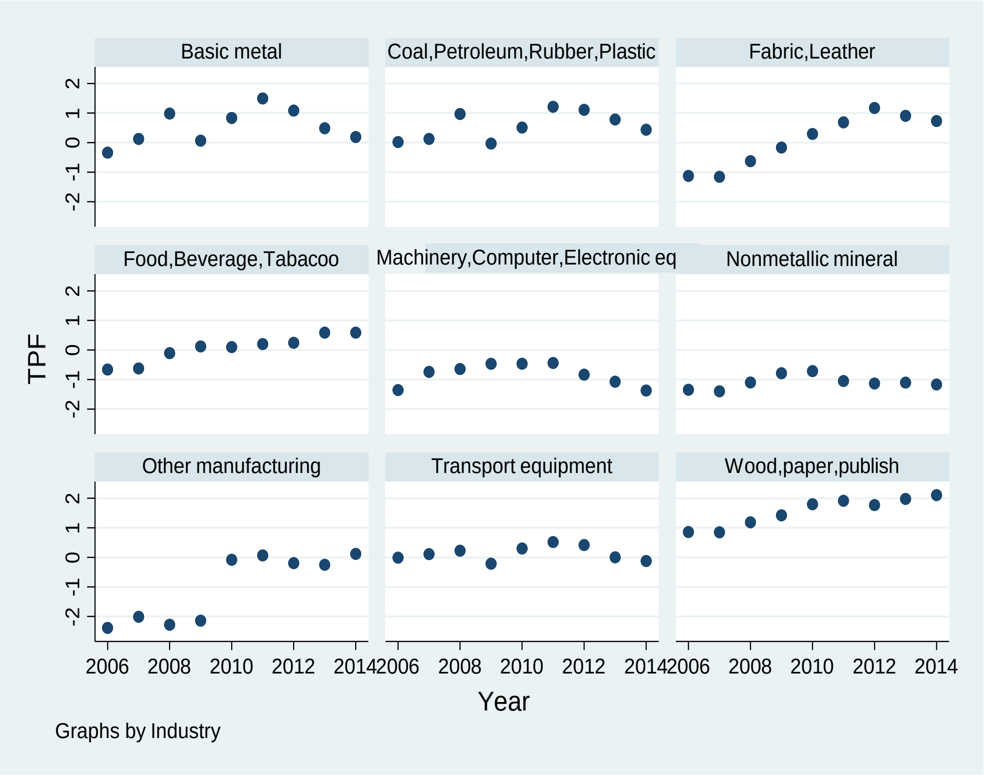
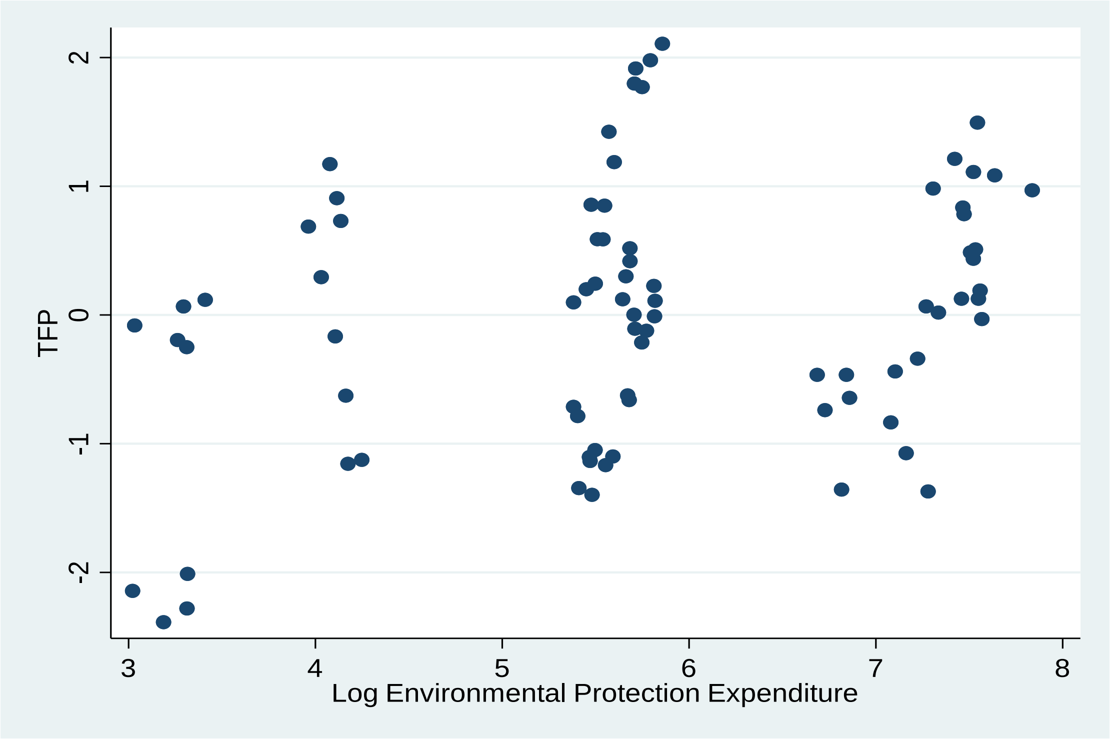


Figure 2.4: Industrial TFP and Environmental Protection Expenditure



4.2. Environmental Protection Expenditure

Environmental protection expenditure (the EPE) is identified by the OECD as follows: "This dataset provides information on purposeful activities directly aimed at the prevention, reduction and elimination of pollution or any other degradation of the environment resulting from production or consumption processes". According to recommendation of the OECD, the Korean Government has surveyed the EPE and submitted to the OECD.

Korean EPE is created by using 1,900 firms' data which are selected among firms with over 100 million dollars of sales, including five big companies (such as Samsung, LG, etc.) with high ranks in each industry. It represents costs to reduce or eliminate air, water and land pollutant, noise, waste and so on (Ministry of Environment). It catches operation and capital costs. Specific equation is as follows:

$$\text{EPE} = \text{capital cost} + \text{operation cost} - \text{by product income} \qquad (2.6)$$

Capital cost: establishing new equipment for environmental protection, repairing existing equipment. Operation cost: labour cost in charge of environment management, consignment management cost[46], maintenance fee (rental, electricity, fuel, etc.). By product income: selling desulfurization fuel, geopolymer from coal combustion, etc.

Korean EPE has been announced in terms of public, business and consumer at national level. It means that because of data limitation, previous papers could not employ industrial EPE to analyse influence of environmental stringency on the TFP.

[46] It represents business activity that a firm consign management (collecting, delivering, solving pollutants) to public or private agency.

According to Figure 2.5, the expenditure increased in 2004-2008 but 2009 shows down related to economic recession by financial crisis in 2008-2009[47]. From 2009, the cost appears slow increasing trend. Manufacturing sector also shows the same pattern as total Environmental protection expenditure. That is because manufacturing sector accounts for majority (72%) of total expenditure. Figure 2.6 shows change of the costs of each industry. Some industries such as 'coal, petroleum, rubber, plastic', 'basic metal' and 'machinery, computer, electronic equipment' experienced relatively high level.

For 'coal, petroleum, rubber, plastic' industry, empirically, relatively high expenditure is reasonable because the sector is major emitter of pollutant. Considering the fact that 'basic metal' and 'machinery, computer, electronic equipment' also employ much chemicals in production process contaminating water and air, and produce more output than other industries (Figure 2.7), it is likely that the industries need much expenditure for equipment investment and operating to reduce or eliminate pollutants.

As mentioned above, because it has not been provided in terms of manufacturing industrial classifications[48], there have not been previous Korean papers using this data to analyse productivity effects of environmental regulations on each manufacturing industrial sector. Lee *et al*. (2015) create their own Korean regulation index using number of regulations. In this context, our contribution to studies dealing

[47] The down in 2009 is likely on aftermath of US financial crisis. That time, output of manufacturing, economic growth rate, export to US decreased compared to that in 2008 (KW1,331,996 billion in 2008 → KW1,313,909 billion in 2009 ; 2.8 in 2008 → 0.7 in 2009; $46.4 billion in 2008 → $37.6 billion in 2009)
[48] Ministry of Environment has industrial Environmental protection expenditures in terms of nine sectors but does not open publicly. We can get the information on condition that the data must be used only for this research.

with relationship between environmental regulations and productivity in terms of manufacturing lies on the first attempt to use Environmental protection expenditure in terms of manufacturing industrial classifications.

Figure 2.5: Environmental Protection Expenditure in Total and Manufacturing (unit: KW million)

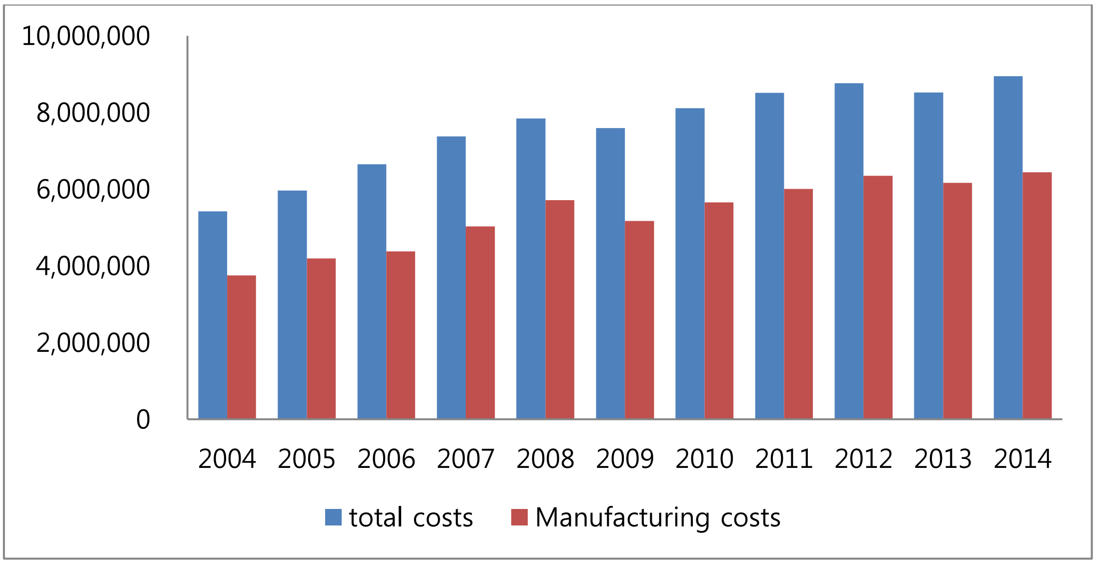


Figure 2.6: Environmental Protection Expenditure in terms of industry (unit: KW billion)

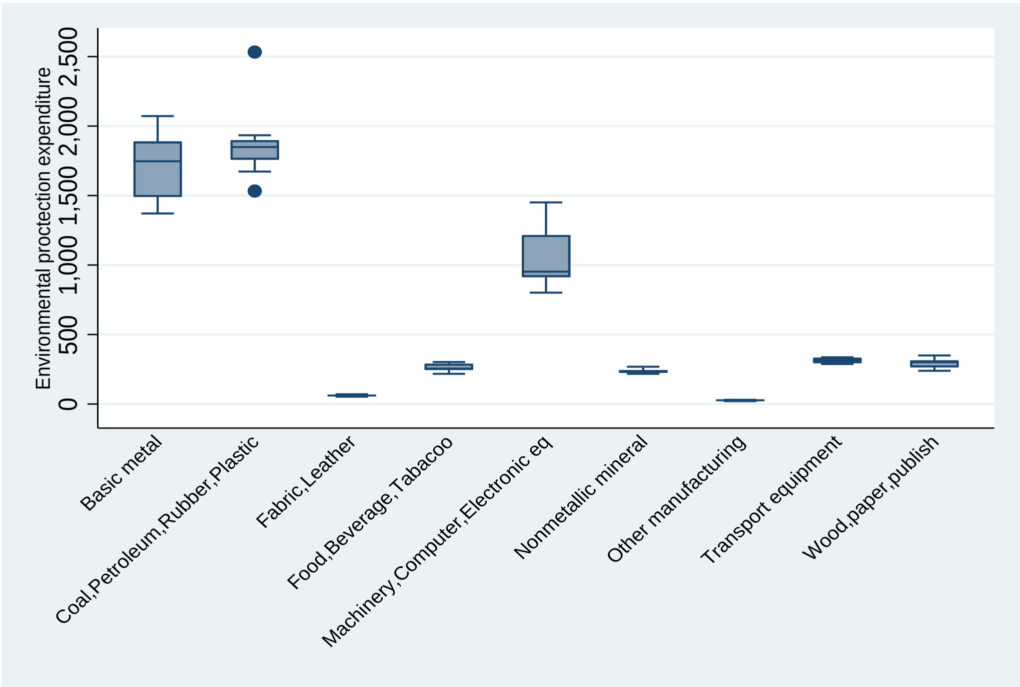
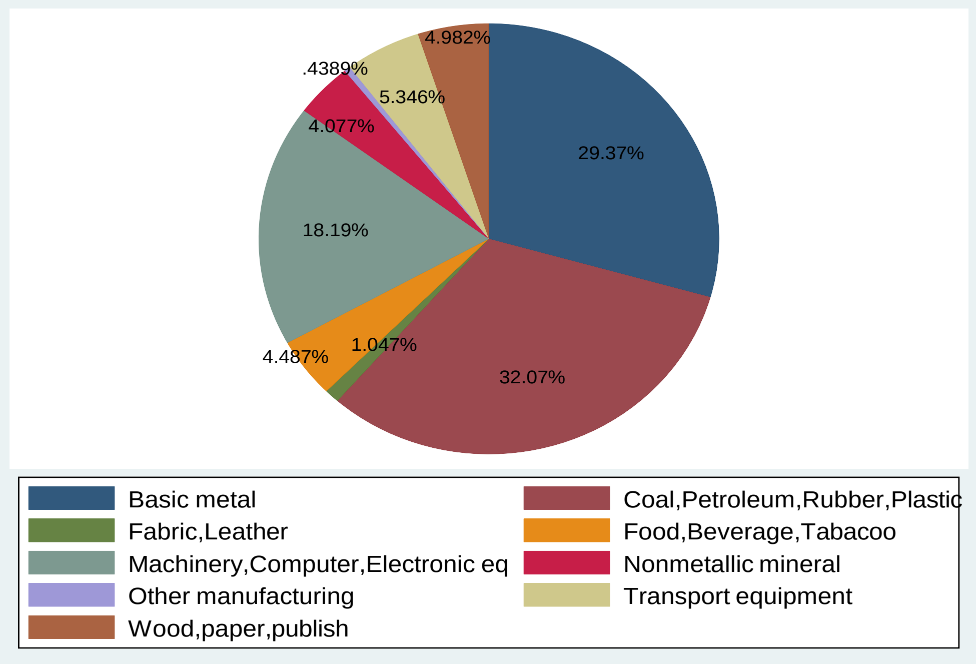


Figure 2.7: Output percentage in terms of industry (unit : %)



4.3. R&D

We introduce two R&D concepts in the model. One is general R&D calculated by total R&D minus environmental R&D while the other is environmental R&D. As Albrizio *et al*. (2017), Hall (2011) and Hamamoto (2006) argue, in general, R&D is crucial driver of productivity growth. It is likely common concept that high R&D could lead to improvement of production process and product quality, resulting in better productivity. Figure 2.8 shows that the total amount of general R&D expenditure in manufacturing industry increased in 2006-2014 [49]. In terms of individual sector, Figure 2.9 indicates that 'machinery, computer, electronic equipment', 'coal, petroleum, rubber, plastic' and 'transport equipment' industries have higher investment in general R&D than other industries. Specially, considering the fact that machinery, computer, electronic equipment' industry deals with state-of-

[49] For reference, Korea ranks the first position among the OECD countries in 2014 in terms of R&D expenditure as a percentage of GDP : Korea (4.29%), Israel (4.27%), Japan (3.4%), US (2.16%).

the art technology and face fierce international competition[50], it is reasonable that the sector shows very high R&D expenditure.

Figure 2.10 explains trend of environmental R&D, which is intended to develop method of evaluating pollution level, production process to deal with pollutants, and equipment to abate pollutants, and establish new R&D division, and so on. The environmental R&D showed decreasing trend until 2011 except 2010. Then, it experienced gradually upward. Unlike total R&D, this appearance implies that total R&D has intension to improve firm efficiency and profit while environmental R&D is expensed as costs to defend pressure of environmental regulations. That is, once a firm invests much in environmental R&D to meet environmental standard, the firm would not need to increase much the R&D next year which means that the firm is unwilling to invest on R&D with purpose of improving environment. 2006 experienced tough air quality regulations like that stronger sulphur standard was introduced in all cities and regions. It led firms to much environment R&D investment. Figure 2.11 shows that like total R&D, 'machinery, computer, electronic equipment', 'coal, petroleum, rubber, plastic' and 'transport equipment' industries invested relatively more than other industries.

To check briefly relationship between R&D and TFP, our study takes two steps. One is to analyse relationship between general R&D and TFP. The other is to check connection between environmental R&D and TFP. Figure 2.12 dealing with the former says that overall shape seems to have downward trend. The correlation coefficient (-0.05) also indicates the direction. We however can classify figures into four groups. After grouping, each shape appears upward. Figure 2.13 also shows most

[50] As mentioned already, this industry has already experienced sharp down of related products price (see Appendix 5).

industries experienced upward TFP along with R&D growth. This different pattern in each industry suggests that we should consider properties of industries in estimation. Meanwhile, in terms of environmental R&D, it seems that relationship between environmental R&D and TFP show appropriately negative trend (Figure 2.14). The correlation coefficient (-0.24) confirms the relationship. This value indicates that as mentioned above, firms are reluctant to environmental R&D.

Figure 2.8: General R&D in Manufacturing sector (unit: KW billion)

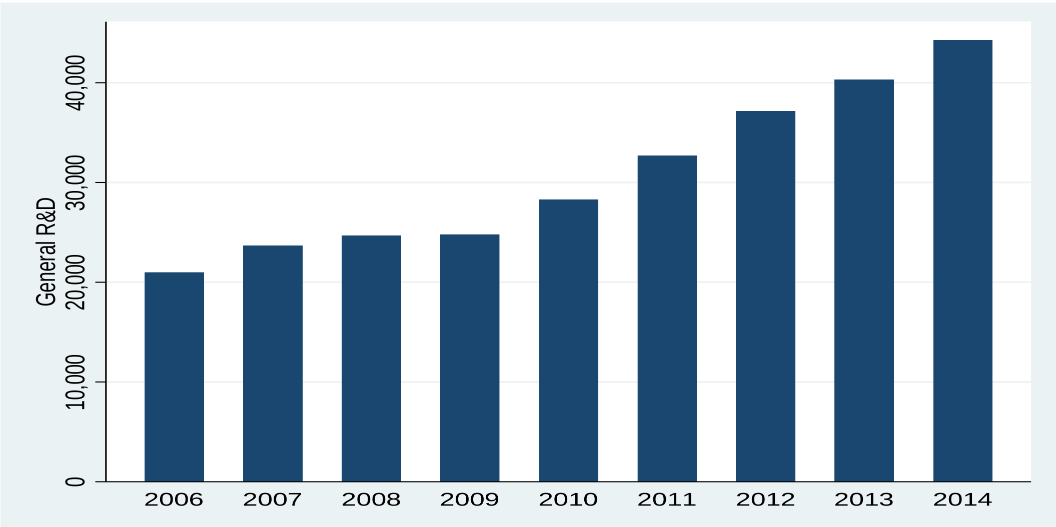


Figure 2.9: General R&D in terms of industry (unit: KW billion)

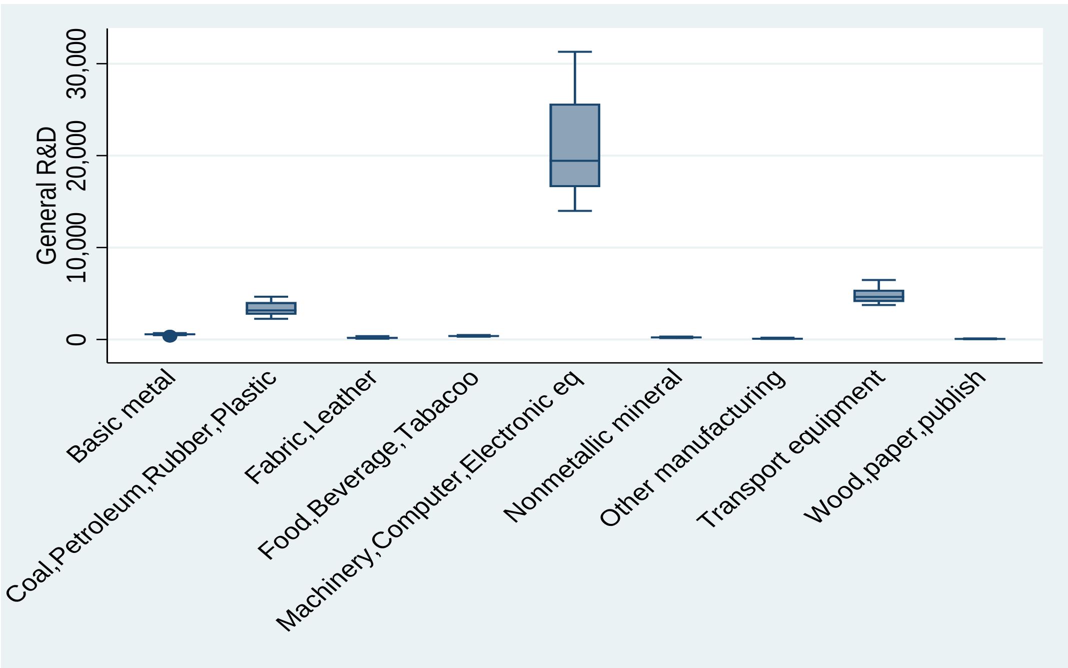


Figure 2.10: Environmental R&D in Manufacturing sector (unit: KW billion)

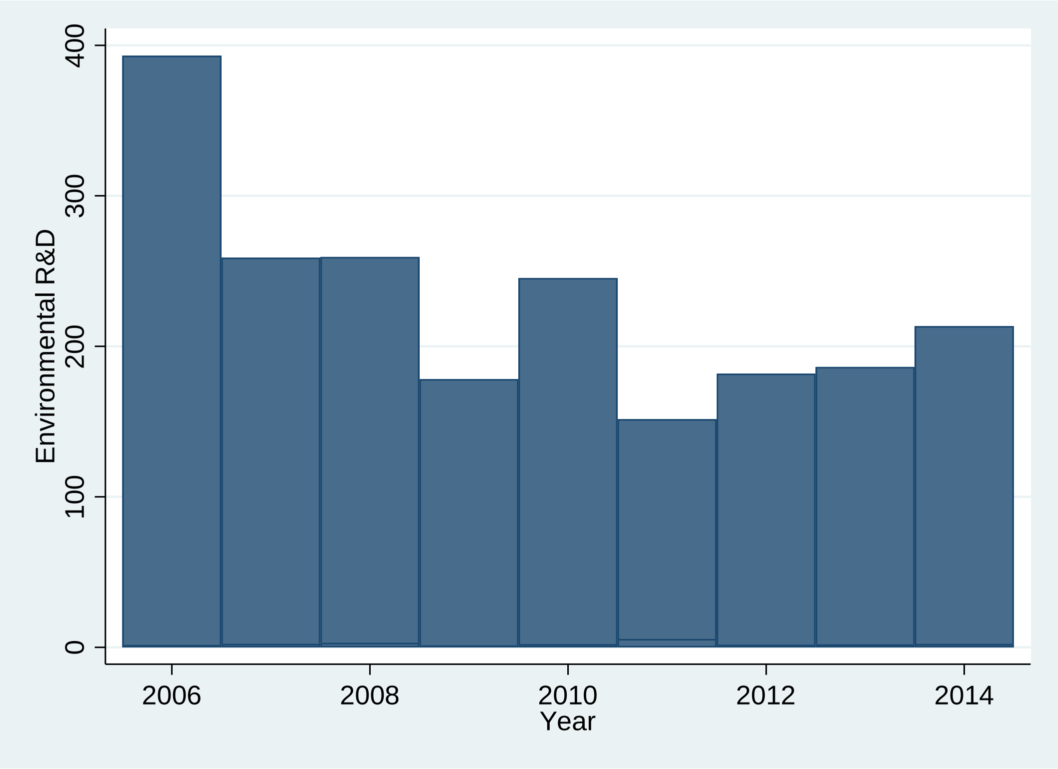


Figure 2.11: Environmental R&D in terms of industry (unit: KW billion)

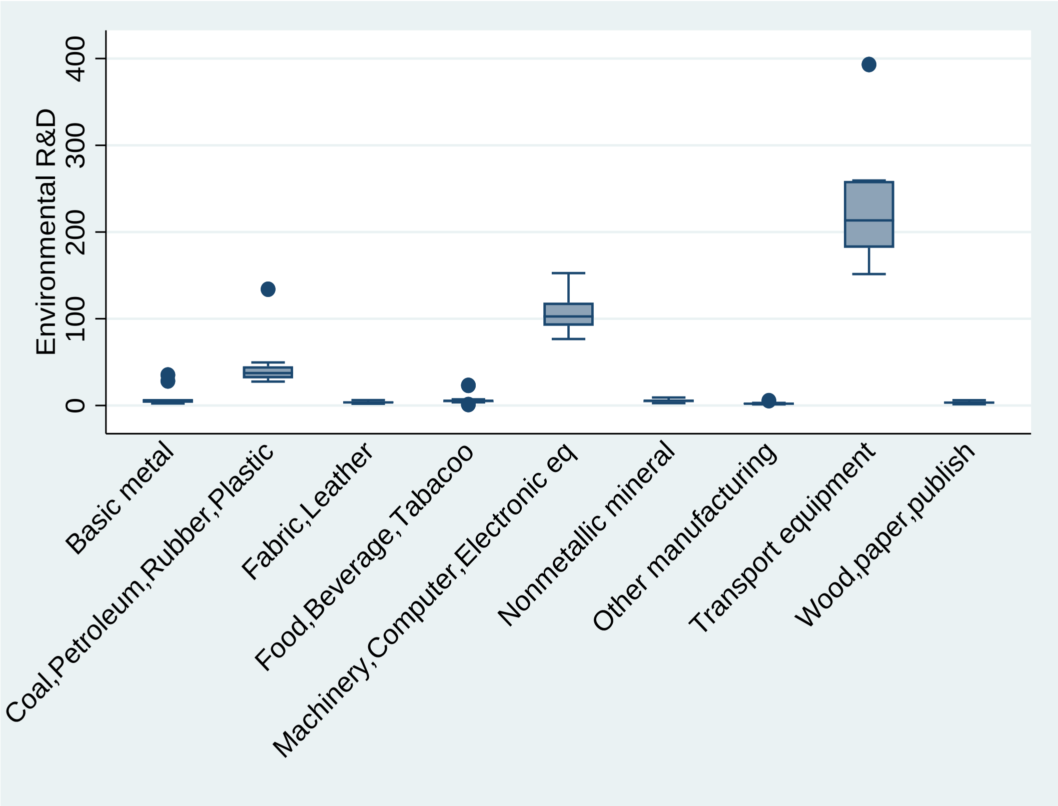


Figure 2.12: TFP and general R&D

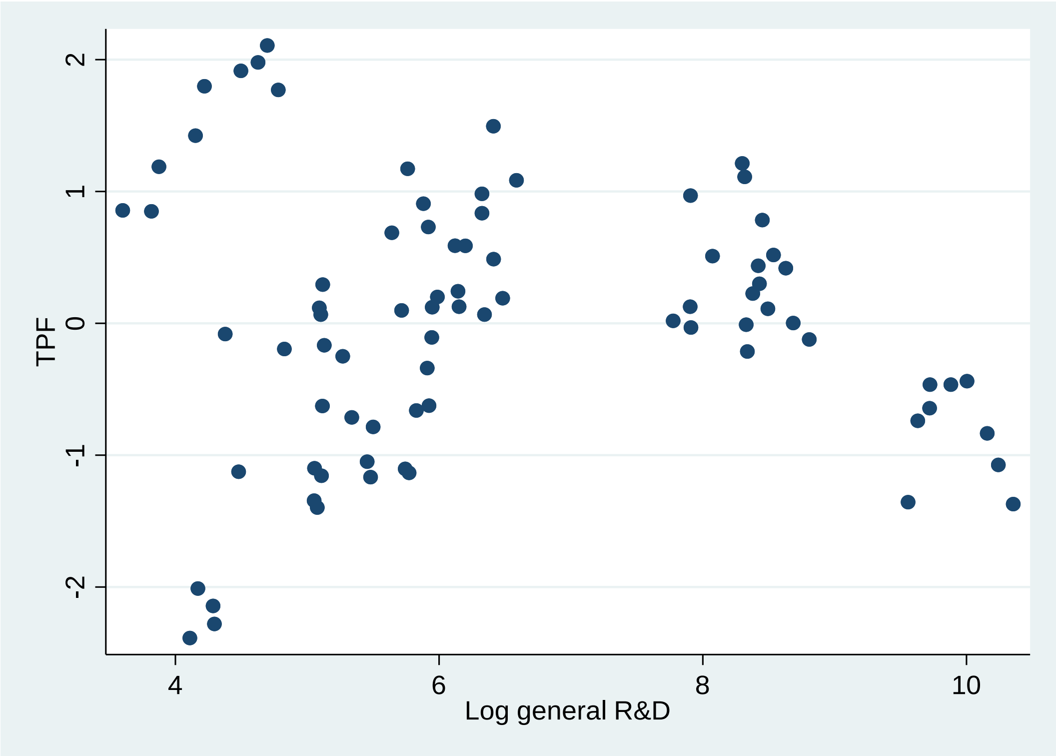


Figure 2.13: TFP and general R&D in terms of industry

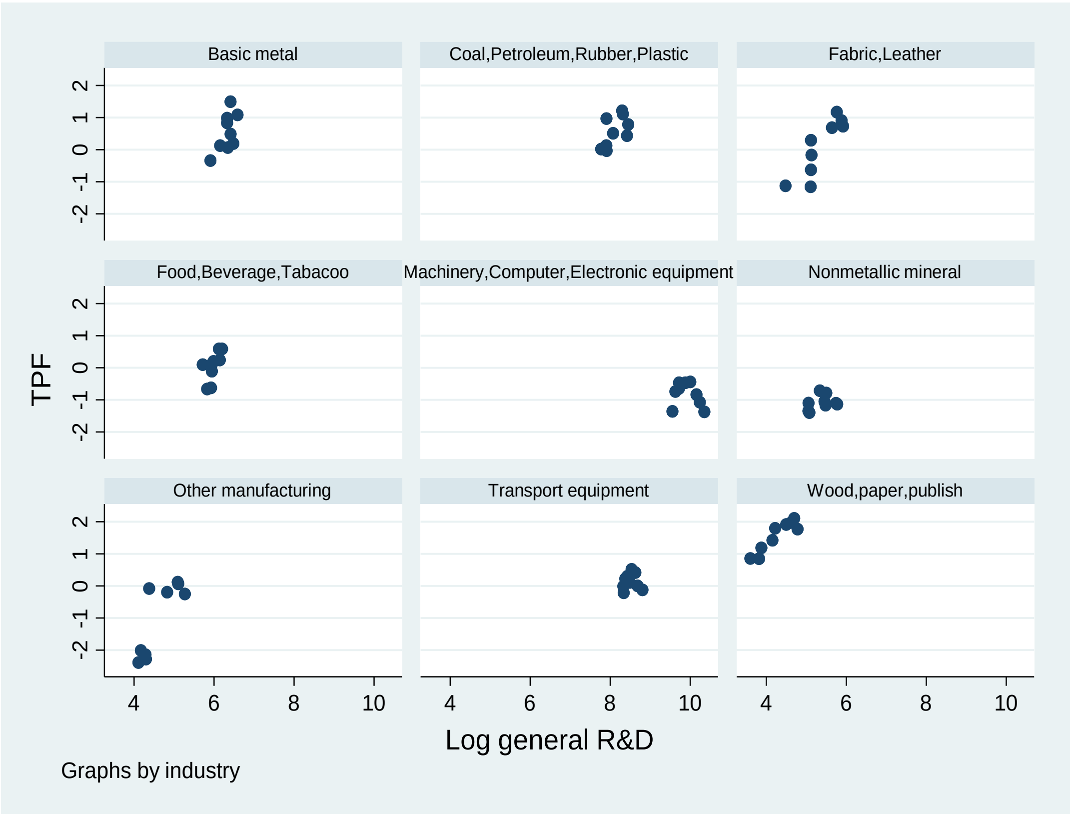
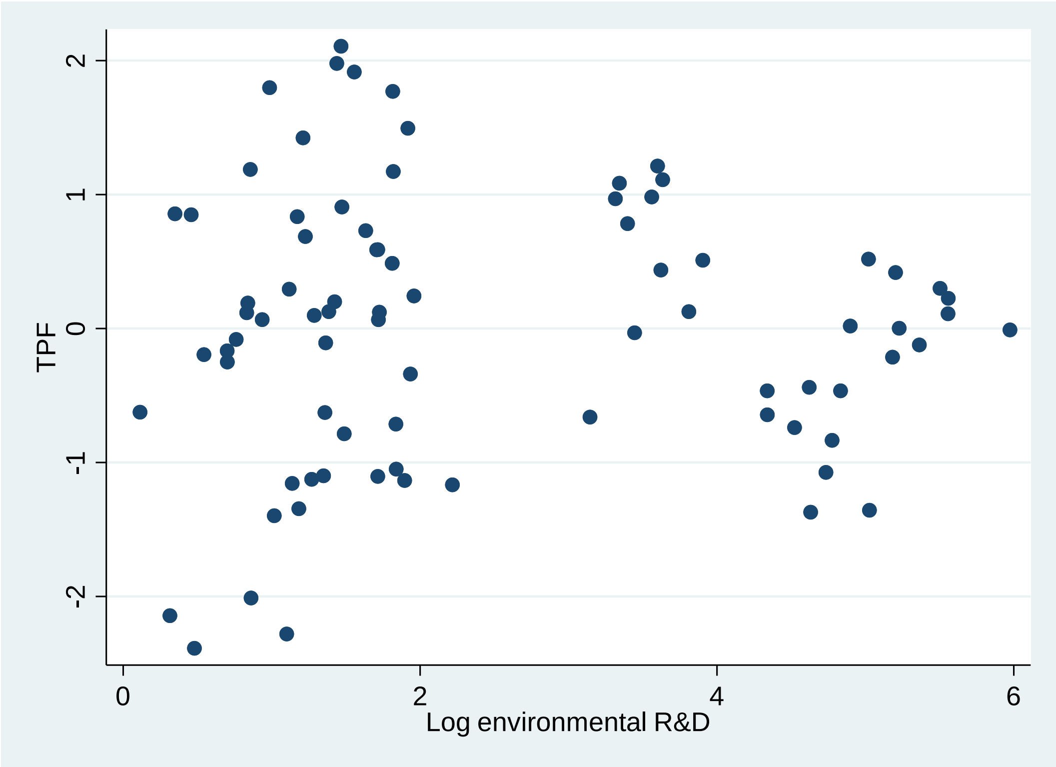


Figure 2.14: TFP and environmental R&D



4.4. Firm-level Total Factor Productivity

Besides industrial TFP, we will employ firm TFP data in order to check individual firm behaviour against burden of environmental regulations. As known, firms have experienced pressure by both government regulations and private NGO and local communities. Such aggressive influence has forced firm to establish pollutant abatement equipment and hire operation employees reluctantly or voluntarily. I believe that such effect could give burden to TFP of firms.

To create firm TFP, we used the dataset of The KIET[51] which is based on dataset collected by Korea Energy Agency in 2010-2014. Agency's dataset was created through random sampling & answer survey process. The aim of this survey

[51] Korea institute for industrial economics & trade

lied on collecting specific information about CO2 and energy consumption of individual firms. The dataset comprises firm name, greenhouse gas emission and energy consumption. The information of around 4,200 firms was collected. The KIET added number of employee, sales and tangible assets from National Information Credit Evaluation service cooperation (NICE) into the dataset. In addition, the KIET inserted a dummy for Target management system[52]; 1 if the firm is targeted of Target management system, 0 otherwise. After refining and sorting, the KIET finally crested 4,175 firm-level panel dataset. Lee and Kang (2016) showed that Target management system significantly reduced CO2 emission in five material industries[53] by using some part of this dataset.

We estimated firm level TFP by using tangible assets of the dataset The calculated firm TFP consists of 4,175 firms and 20,875 observations in 2010-2014. In terms of firms with more than 300 employees in manufacturing industry, the data has 382 firms which account for 55% in total number (701). Unless mistaken, firm level TFP dataset like our dataset has not been created in Korean case. The correlation coefficient between firm TFP and the EPE is -0.045[54].

[52] "The Government designates entities that emit greenhouse gas and consume energy in large volumes as controlled entities, imposes greenhouse gas emission and fossil energy consumption targets, and manages and supports them performance check." (Ministry of Environment).

[53] Five industries: Metal, Non-metallic, Oil & Chemical, Paper, Cement. Because Lee and Kang (2016) could not get firm level CO2 emission, they employ industrial CO2 emission data.

[54] See Appendix 4 (graph : Firm TFP and the EPE in 2010-2014).

4.5. Data Descriptive Statistics

Industry level dataset

Variable	Obs	Mean	Std. Dev.	Min	Max
Capital Stock (KW billion)	81	85047.41	87943.46	7287.089	361195.2
Employee	81	352289.3	303680.2	101400	1368187
Output (KW billion)	81	165491.4	171259.8	11430.25	628750.9
TPF	81	4.83E-14	1	-2.386712	2.107429
R&D (KW billion)	81	3464.59	6780.843	36.62721	31397.65
Portion of firm with more than 300 over total firms(Size: %)	81	15.6178	13.00848	1.125798	48.18618
Environmental protection expenditure (KW billion)	81	650.4478	694.3585	20.51897	2532.624

Firm level dataset

Variable	Obs	Mean	Std. Dev.	Min	Max
Firm controlled by Target management system (dummy)	20,875	.0464671	.2104994	0	1
Sale (KW one)	20,875	1.69e+11	2.42e+12	1.75E+08	1.58E+14
Number of Employee	20,875	226.3161	2025.702	2	101970
Tangible Asset (KW one)	20,875	5.94e+10	8.06e+11	942000	4.37E+13
Firm size (dummy)	20,875	2.086036	.2994261	1	3
Firm TFP	20,875	1.34e-13	1	-1.819466	2.210484

5. Empirical results

5.1. Results in terms of Industry level data

There are three perspectives about the effects of stringency of environmental regulations on total factor productivity (TFP); negative, positive and insignificant. As known, TFP is commonly used to test competitiveness of firms and industries (Dechezlepretre and Sato, 2014). Negative influence therefore means that additional production costs which environmental restrictions cause will undermine competitiveness of firm and industry, leading to losing profits in a market. Positive effect is related to the Porter Hypothesis. If environmental stringency increases TFP, we can believe that the strong version of the Hypothesis is proved (Jaffe & Palmer, 1997).

Table 2.1 reports estimation results of equation (2.1). Column (1) and (2) employ lagged environmental R&D and lagged EPE while Column (3) uses interaction variable (lagged environmental R&D × lagged EPE) in order to test the influence when an industry increase environmental R&D along with increasing the EPE. In lower body of table 2.1, Sargan tests do not reject the null hypothesis (Ho: overidentifying restrictions are valid), which means that overidentifed difference GMM is valid. Arellano-Bond test indicates whether or not there is no autocorrelation in first-difference errors (the null hypothesis). The results say that the null hypothesis is rejected at first order while the hypothesis is accepted at second order, which confirms that TFP at t-2 and TFPs after then can be used as instrumental variables for difference TFP at t-1. Such test results argue that difference GMM is an appropriate method for this study.

In all Columns, as a natural result, lagged TFP shows positive impact on current TFP. Past general R&D except environmental research also affects TFP positively. That is, we can say that other things being equal, for 10% increasing in general R&D at t-1, the difference in the expected mean of industrial TFP will be 0.029, 0.033 and 0.035[55] respectively in the TFP at t of Column (1) – (3). This plus effect confirms that R&D is an important determinant of productivity growth (Albrizio *et al*., 2017; Hall, 2011; Hamamoto, 2006).

On the contrary, past environmental R&D acts as burden on current TFP. That is, holding all other variables constant, 10% increase of environmental R&D at t-1 leads to 0.01[56] decrease of current TFP. Considering that environmental R&D could be considered as additional costs to defend pressure of environmental regulations, the negative value is consistent with intuitive thinking and descriptive graph analysis in section 4. The coefficients of Size have positive values in Colum (2) and (3). That is, when other variables are held, for one unit increase in portion (unit: %) of firms with more than 300 in total firms, there will be 0.103 and 0.098 difference in the TFP. It means that in Korean economy, companies with middle size or over play as leaders in TFP growth.

The main interest in this research is in the results of the EPE at t-1. Like environmental R&D, the sign is negative and significant. Specifically, holding the other predictor variables constant, 10% increase EPE at t-1 lead to -0.00004 [57] difference TFP at current time in Column (1) and (2). The small size value is consistent with the fact that the EPE accounts for tiny portion[58] of output in Korean

[55] 0.706*log(1.1)=0.025, 0.819*log(1.1)=0.033, 0.844*log(1.1)=0.035
[56] -0.250*log(1.1)=-0.01
[57] -0.001*log(1.1)=-0.00004
[58] The EPE over output in Korean manufacturing industry is just 0.37% in 2010

manufacturing industries. More important point lies on minus sign. It clearly shows that Korean industry consider the EPE as additional production costs and obstacle against TFP growth. The interaction term confirms that if a certain industry expends both environmental R&D and the EPE at the same time, the negative influence on the TFP will be expanded. We therefore can conclude that if Korean domestic environmental stringency at t-1 increase, current industrial TFP will deteriorate. Through comparing coefficients of environmental R&D, the EPE and interaction term, we can find out that in view of manufacturing industry TFP, paying costs for abating pollution is more desirable than investing in environmental R&D to abate pollution.

Table 2.1: Estimations in terms of industry

Industry TFP	**(1)**	**(2)**	**(3)**
TFP t-1	0.397***	0.321**	0.328**
	(0.1507)	(0.1490)	(0.1467)
Log general R&D t-1	0.706**	0.819**	0.844**
	(0.3542)	(0.3443)	(0.3435)
Log Environmental R&D t-1	-0.250***	-0.253***	
	(0.0917)	(0.0885)	
Log Environmental Protection Expenditure (EPE) t-1	-0.001*	-0.001*	
	(0.0003)	(0.0003)	
Log (environmental R&D t-1 × EPE t-1)			-0.263***
			(0.0851)
Size t		0.103**	0.098**
		(0.0422)	(0.0419)
Observations	63	63	63
Sargan test	28.63468	25.14692	24.56332
	[0.3788]	[0.5662]	[0.5989]
Arellano-Bond test			
First order	-2.0635 [0.0391]	-2.0782 [0.0377]	-2.1344 [0.0328]
Second order	-1.6042 [0.1087]	-1.3958 [0.1628]	-1.2329 [0.2176]

note: ***; ** and * denote significance at the 1%, 5% and 10% respectively. ( ) is standard error. [ ] is p-value. Industry and year effects controlled.

5.2. Results in terms of Firm level data

As mentioned previously, multilevel linear model consists of firm level TFP as dependent variable and for explanatory variables, industrial variables (general R&D, environmental R&D and the EPE) and dummy variables (Target management system and Firm size). Before analysing estimated coefficients in Table 2.3, we should consider the fact that unlike industrial panel data in 2006-2014, firm level panel data include information only in 2010-2014. In terms of output, there is meaningful difference between 2006-2014 period and 2010-2014 year. In other words, Korea experienced large increasing output growth in 2006-2010 while it faced static movement or a little decrease of manufacturing output in 2010-2014[59]. Firm level data deal with only time when Korean manufacturing sector was in economic depression and stagnation. We believe that this condition discrepancy is likely to lead to different results from industrial analysis.

Table 2.2 shows results of firm level TFP analysis. In lower section of Table 2.2, some tests are expressed. The p-value (0.0000) of Wald test says that coefficients of explanatory variables are not zero. The LR test (p-value: 0.0000) shows random intercept model is more appropriate than pooled OLS. The ICC test estimates intra-class correlation. The value of 0.9971 means that 99% of variation of firm TFP is due to between-group difference. That is, the value suggests that we should use multilevel model.

For results, the most interest lies on estimates of Environmental R&D, the EPE and Target management system which are related to environmental regulations. Like industrial case, the variables have negative signs. In addition, all estimates are significant at 1% level. Specifically, other things being equal, for 10% increasing in environmental R&D, the difference in the expected mean of firm TFP will be -0.00046[60]. For the EPE, holding all other variables constant, 10% increase of the expenditure leads to -0.007[61] decrease of current TFP. For Target management system dummy, holding the other predictor variables constant, when a firm become target

[59] See Appendix 7
[60] -0.011*log(1.1) = 0.00046
[61] -0.169*log(1.1) = -0.007

object controlled by Target management system, TFP of the firm will decreased by -0.030.

In terms of general R&D, unlike industrial result, the sign is negative. It means that even R&D could be burdensome for any firm in 2010-2014 when output growth is very low or minus[62]. That is, under economic recession, when a firm increases investment in R&D, such efforts do not have positive influence, rather, is considered as increasing costs affecting the TFP negatively. Other things being equal, for 10% increasing in general R&D, the difference in the expected mean of firm TFP will be -0.0041.Firm size dummies also have negative sign and significance at 1 % level. Holding all variables constant, when a firm moves to bigger size, TFP of the firm decreased. That is, if a firm with less than 10 employees moves up to more than 10 to 299, its TFP will decrease by -0.029. The estimates seem to be natural because in economy recession period without meaningful innovation, expansion of firm size only means increasing equipment and operating costs.

[62] KIET (2015) argues that China is rapidly catching up Korean technology in terms of iron, bulk ships, LCD panels and so on, while Korean car and general machinery technologies stays at 90 per cent, 70 per cent of German technology respectively, and IC (Information and Communication) technology below 90 per cent level of America in spite of high amount of R&D. Then, the KIET surely predict that unless Korea can increase effectiveness of R&D, it would face serious recession.

Table 2.2 : Estimations in terms of firm

Firm TFP		
Target management system		-0.030***
		(0.003)
Midium Size		-0.029***
		(0.007)
Large Size		-0.091***
		(0.007)
Log Environmental R&D t		-0.011***
		(0.002)
Log general R&D t		-0.099***
		(0.005)
Log Environmental Protection Expenditure t		-0.169***
		(0.007)
Wald test	Chi	5046.73 [0.0000]
LR test	Chi	88170.64 [0.0000]
ICC test		0.9971

note: ***; ** and * denote significance at the 1%, 5% and 10% respectively. ( ) is standard error. [ ] is p-value

6. Conclusions

As known, there are two representative perspectives about influence of stringency of environmental regulations on competition of firms, industries and countries. One represents negative effect while the other is the Porter hypothesis. In this chapter, we analysed whether Korean domestic environmental stringency has a negative or positive influence on both industry and firm total factor productivity in terms of manufacturing. For the aim of this study, we established dynamic panel models for industrial panel data in 2006-2014 and a multilevel linear model for firm level panel data in 2010-2014. Unless mistaken, industry and firm TFP panel data, dynamic panel approach for industry TFP and multilevel model for firm TFP have not been previously employed in Korean case. It therefore is very meaningful contribution for the study to expand data range and find out appropriate methods.

In terms of industrial analysis, employing difference GMM, we found that tougher stringency of Korean domestic environmental restrictions at t-1 will affect significantly negative effects on current TFP of manufacturing sectors. The pessimistic results were also estimated in firm-level panel data analysis. Such impacts imply that although the environmental regulations have made partially a contribution on improvement of environment, the measure is significant burden on Korean industry sectors enough to lead to down of TFP.

Considering that TFP is related to profitability and competition, Korean domestic environmental regulations protect environment at the expense of economic competition. As mentioned in introduction chapter, considering that the Korean

Government uses mainly command & control approaches[63], which strongly force plants to spend expenditures to reduce or pollutants, or to pay for emission charges, the negative estimation results is like to be consistent with intuitive thinking and real world. That is, in Korean case, the Porter hypothesis is invalid.

From the results, we can derive some policy implications. First, the Korean Government should try to find out appropriate level of the strictness of environmental regulations carefully, considering both competitiveness of Korean manufacturing firm & industry and importance of environmental protection. Second, because environmental R&D is considered as additional and unnecessary costs, the Korean Government must provide much incentive enough to offset negative impact of the costs. In addition, to complement lack of private investment, the Government should try to expand its investment in environmental R&D and then actively transfer technology performance to private sectors. Third, Korean environmental regulations should be converted into market based-friendly methods through removing redundant regulations, and extending opinion collecting period for firms & industries to express their concerns and alternatives, which gives less burden on economy than too strictly domineering & compulsory approaches.

[63] The main environmental regulations consist of strong and direct penalty methods such as the followings :

1. Environmental improvement charges, which levy charges on fuel and water used in factories.
2. Vehicle certification system, which if carmakers do no pass, their cars would be prohibited from selling.
3. Water pollutant emission charges, which was levied on waste water by plants.

CHAPTER III

The Effects of differences of the Environmental stringency between Korean and Counterparts on Korean outward FDI and Korean export

1. Introduction

In the chapter, our study tests whether or not differences of environmental stringency between Korea and counterparts have a significant influence on Korean outbound FDI and Korean export to the nations. As well known, global environmental regulations have been strengthened over time. In particular, greenhouse gas (GHG) emissions, the UNFCCC has led the world in taking part in global actions to reduce GHG although recently, some countries weakened the Paris agreement. In addition, apart from the UNFCCC, most developed and developing countries have tried to enact and enforce much tougher environmental stringency than before. The reason is that the income-induced development of public consciousness aggressively asks governments to enact and enforce more specific and stricter environmental laws and policies.

As mentioned in chapter II, there are two perspectives about influence of environmental stringency on TFP of firms and industries. These views are also applied to research on Korean outbound FDI and Korean exports in this chapter. Specifically, in terms of FDI, it is likely that the regulations may have a negative impact on business activities through imposing additional costs on production, then moving to countries with lax regulations, often known as the 'Pollution Heaven Hypothesis' (the PHH). On the contrary, some research argues that environmental measures could help to strengthen competitiveness of firms and industries where firms might not need to move outside or lead Korean investors to increasing domestic investment. Our aim is to test which results is reliable. Testing FDI influence will be main part in this chapter. Export influence will be analysed complementarily.

Previous research deals with the PHH but there is little research dealing with the PHH between Korea and other countries in terms of relative difference stringency of environmental regulations. Chung (2014) analysed whether Korean outward FDI to 50 host countries are affected by down of environmental stringency of host countries. With environmental laxity variables created by using Global Competitiveness Report of World Economic Forum for environmental stringency, Chung (2014) found that lower stringency of environmental regulations in host countries attract more Korean investment, confirming the PHH. For Korean export case, Oh and Myoung (2005) tried to check influences of environment improving efforts of Korean goods importers on Korea export using a gravity model and Environmental Sustainability Index (the ESI) of the World Economic Forum (the WEF) which is replaced by Environmental Performance Index (the EPI). They found that if the importers were to enhance their environmental efforts, Korea could export more goods to those countries.

For empirical estimation, this study will employ the gravity model as the baseline equation which is known for strong explanation ability including factors (like GDP, population as market size) of horizontal FDI. Then, the research will add some variables to represent comparative advantage (vertical FDI). Chung (2014) regarded environmental laxness of host countries as a main variable. The study however will consider difference of environmental stringency between Korea and host countries under the assumption that business parts would decide their investment behaviour through comparing business environment including relative environmental stringency. In addition, we will expand period range from 2000-2007 of Chung (2014) to 2000-2012.

Meanwhile, using the gravity model should consider “multilateral resistance”, which Anderson and van Wincoop (2003) argue must be included in the gravity model, otherwise the estimates could be biased. Likewise, because the logarithm-form of the gravity model causes zero and heterokedasticity problems in OLS, we will employ the Poisson pseudo maximum likelihood (the PPML) method of Silva and Tenreyro (2005) to solve the problems. Oh and Myoung (2005) do not contemplate these issues. As a proxy for environmental stringency across countries, we use Environmental policy stringency (the EPS) index of the OECD. The index has value range from 0 to 6 where tougher stringency has higher value. The properties of the index- that is, it is created to target the OECD & the BRIICS countries - limit this study range to the OECD & the BRIICS countries. Unless mistaken, this study is the first research dealing with relationship between Korea and the OECD & the BRIICS countries with EPS.

The finding is that increasing EPS gap[64] between Korea and host countries – holding host countries EPS be constant, relatively tougher environmental stringency of Korea - would lead to more Korean outbound FDI to host countries[65], supporting the PHH. In case of Korean exports, the increased gap would result in increase of Korean export to the nations. The reason lies in that increasing FDI would induce import growth of intermediate goods from Korea. The order of the chapter is as follows. The next section highlights the other papers in the literature dealing with gravity model in terms of theoretical development, usefulness, and environmental regulations. Section 3 then explains theoretical estimation equation and estimation methods of this study, where Korean outward FDI is employed as a dependent variable. Korean export will be inserted as a dependent variable complementarily. GDP, population, distance, EPS, physical & human capital and tariff will be included as explanatory variables. Section 4 describes the data. Section 5 shows the results of the estimations, and finally, section 6 presents the conclusions.

2. Literature Review

2.1. The Gravity model for the effects of environmental regulations on Trade & FDI

For the study, we will employ the gravity model to analyse influences of relative difference of environmental stringency on FDI movement and export between Korean and counterparts. In this literature review section, we will start from the introduction of the model in empirical analysis and then search theoretical basement. Next, expansion of the gravity equation will be studied to confirm usefulness of the model

[64] EPS gap = Korea EPS – Host countries EPS

[65] Strictly speaking, because we will employ lagged EPS gap, we could think that past increased gap lead to increase of current Korean outward FDI.

for diverse bilateral relations across countries. Then, the study will go further to papers with gravity equations dealing with influence of environmental stringency on FDI & trade.

Beginning and Theoretical development of the Gravity Model

At first, the gravity model was introduced by Tinbergen (1962) as an econometric model to analyse bilateral trade flows between two countries. Tinbergen built the model on the basis of intuitive empirical trade information and statistical suitability, not from trade theory. He argues that the volume of bilateral trade flows is dependent on three factors: the GDP of the exporting country, the GDP of the importing country and the distance between the two countries. That is, that the export volume could be determined mainly by the economic size of the exporter, the market size of the importing county and the transportation costs, which are assumed to be roughly consistent with the real distance between the two countries. The model is given by

$$ln\, X_{ij} = \beta_1 lnY_i + \beta_2 lnY_j + \beta_3 \ln D_{ij} + \mu_{ij} \qquad (3.1)$$

where X_{ij} is the exports of country i to importing country j, Y_i is the GDP of i, Y_j is the GDP of j and D_{ij} is the distance between i and j.

Linnemann (1966) extends the model by adding the potential foreign supply of the exporting country. This determines the volume of trade flows between the two countries and potential supply is dependent upon production and the ratio between the size of the domestic and foreign markets (DM/FM). Since the model supposes that the DM/FM ratio for any pair of countries is closely related to the differences in their population sizes, Linnemann also includes population in the model as a proxy for this ratio. Linnemann attempts to derive the gravity model theoretically from a Walrasian general model. As he himself admits however, this theory-based model is not useful in terms of carrying out empirical estimations because it has too many explanatory variables owing to its Walrasian properties.

Anderson (1979) is the first to derive a theoretical gravity model that includes assumptions regarding product differentiation, homothetic preferences and a frictionless economy. He assumes that products are differentiated by the country of origin (the so-called 'Armington Assumption'). For the theoretical procedure, Anderson employs the Cobb-Douglas expenditure system with constant elasticity of substitution (CES) preferences. Anderson explains the inclusion of the income variable in the model and its logarithm-linear type. In the subsequent literature, based upon Anderson (1979), the CES utility function has been principally used for deriving theoretical gravity equations.

Bergstrand (1985) also employs CES preferences, monopolistic competition and the Armington assumption regarding differentiation. He shows that the addition of price variables to the gravity model, utilising the tariffs and the exchange rate as price variables, captures the unobservable price effects using a GDP deflator for the trading partners. In a later paper, Bergstrand (1989) derives a theoretical gravity model with price variables, replacing the Armington assumption with product differentiation among firms in a monopolistic competitive market structure.

Several attempts have been made to establish a theoretical foundation for a gravity model. Anderson & van Wincoop (2003) argue that the price variables could be expressed as price indices of the exporter and importer, while retaining the Armington assumption from Anderson (1979). They believe that the two price index terms could be used to represent all trade obstacles between the exporter or importer and the rest of the world; referred to as 'multilateral resistance variables'. Because these variables 'multilateral resistances' cannot be observed, they recommended two methods to capture them. The first is to use non-linear least squares after removing the unobservable elements in the market equilibrium conditions. The second is to employ country-specific fixed effects for these variables. The major contribution of Anderson & van Wincoop is to highlight that bilateral trade flows are dependent upon multilateral resistance as well as bilateral trade costs. Furthermore, failure to considering these variables can cause omitted variable bias. In terms of our research, I employ the model of Anderson & van Wincoop because it has a theoretical basis and furthermore, as it can resolve the omitted variables bias. A later report by the same authors, Anderson & van Wincoop (2004), convincingly reminded us that trade costs matter, although they are hard to calculate, as some components of the trade costs are unobservable. The theoretical derivation of Anderson & van Wincoop (2003) is as follows:

$$ln\, x_{ij,t} = k + ln\, y_{i,t} + ln\, y_{j,t} + (1-\sigma) ln\, t_{ij,t} - ln\, \Pi_{i,t} - (1-\sigma) ln\, P_{j,t} + e_{ijt} \qquad (3.2)$$

$$\Pi_i \equiv (\textstyle\sum_j (\frac{t_{ij}}{P_j})^{1-\sigma} y_j) \quad . \qquad P_j = [\textstyle\sum_i (\beta_i p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)}$$

where: Π_i and P_j are inward and outward multilateral resistances, and $(1-\sigma) ln\, t_{ij}$ is bilateral trade costs.

Helpman *et al*. (2008) try to generalise the Anderson & van Wincoop (2003) model by allowing for heterogeneous firms and fixed trade costs so as to explain zero value trade. In addition, they argue that the effects of trade resistance can be classified as intensive (each firm's trade volume) or extensive (number of exporters) margin and, even using national level data, can produce two effects.

As an alternative to Anderson & van Wincoop (2003), Bergstrand *et al*. (2013) enhance a structural gravity equation using Krugman's (1979) monopolistic competition and increasing returns scale, so as to estimate the elasticity of substitution in consumption. Applying their equation to the 'McCallum border puzzle', they find different results to that of Anderson & van Wincoop (2003).

Novy (2013a) attempts to solve the difficult problem of calculating trade barriers by arguing that the trade costs are a function of collectable international and intra-national trade data. He then derives a trade cost equation from the Anderson & van Wincoop (2003) gravity model[66]. The merit of the derived trade cost calculation in this model is that, because it measures trade costs using available trade data, it does not need to assume distance as a proxy for trade costs and the omission of many unobservable barriers faced by most gravity models. In addition, this method can measure various trade costs according to different goods and industries. It also classifies drivers of trade increases into three groups and measures them using trade flow and cost data rather than estimation.

Using the trade cost equation, Novy (2013b) derives a translog gravity model using a 'translog expenditure function' and asymmetric trade costs. The clear difference between Novy's gravity equation and the CES assuming gravity model of Anderson & van Wincoop (2003) is that in the former, trade cost changes according to used trade data while in the latter, expenditure is constant. Novy's results support decreasing trade cost elasticity. As Novy (2013a) acknowledges however, the method may incur measurement errors and may be too comprehensive to separate out the environmental regulation costs.

[66] It also derives the cost calculation equations from the Ricardian model of Eaton & Kortum (2002) and the heterogeneous firm model of Chaney (2008).

Extensions of the Gravity Model toward diverse economic analyses

As mentioned previously, the gravity model was introduced to explain trade flow. Now, however, because of the strong explanation of the gravity model about real economic ability, application of the gravity model has been expanded to FDI. In addition, diverse bilateral pattern studies (stock markets, currency unions, economic integration, labour movement, education. etc) use the model.

[Trade analysis using the Gravity Model]

With regard to the analysis of trade patterns, Frankel *et al*. (1995) use an extended gravity model incorporating additional dummy variables into the model to capture the effect of the geographical situation of the trading countries on bilateral trade. They estimate the effect of adjacency and trading blocs (i.e., NAFTA, EU) between countries on bilateral trade flows for 63 countries over the period 1965-1990 using cross-sectional OLS. They find that the closer the countries are geographically, the greater the amount of bilateral trade. The main contribution of the paper is to show the empirical usefulness of the gravity model in analysing the relationship between trading blocs and bilateral trade flows.

McCallum (1995) extends the application of the gravity model by investigating the effect of the US-Canadian border on bilateral trade flows between the two countries using data on exports and imports by ten Canadian provinces and thirty US states. Employing cross-sectional OLS and a dummy variable for trade inside Canada as opposed to trade between Canada and the US, the border is found to have a significant effect on bilateral trade flows; the volume of inter-provincial trade in Canada is twenty-two times greater than that of trade between the two countries. McCallum's main contribution is the flexibility of the variables included in his model.

Anderson & van Wincoop (2003) however, point out that, if considering multilateral resistance, the volume of trade 22 times greater could be reduced to 16 times.

McCallum (1995) approach is also tested by Bergstrand *et al*. (2013). Bergstrand *et al*. (2013) attempt to analyse the effects of economic integration agreements, borders and distance on international trade. To solve the problems of previous papers not dealing with endogeneity and unobserved country-pair heterogeneity, they introduce country-pair fixed effects into a gravity model. Using the modified gravity equation, they find that negative border effects have decreased by 2.4 percentage changes per year over 1990-2002.

Zhang *et al*. (2018) apply a gravity model to identify the factors that affect the global liquid natural gas (LNG) trade, 2004-2015. They find that demand side size has a positive effect on LNG trade while increased use of pipeline has a significantly negative effect. In addition, the LNG trade is more sensitive to increases in import prices and R&D investment in Asia than at the global level. Further, they confirm that their findings are robust for different periods. The paper is notable in extending the trade gravity model to a non-manufacturing sector.

[FDI analysis using the Gravity Model]

Braninard (1997) employed the gravity model for the checking proximity-concentration hypothesis, where he argued that transport costs, trade and investment barriers, production scale economies and firm-specific advantage play a role in determining exports or the siting of foreign plants as alternative modes of foreign market penetration. Using the 1989 sales data of US Multinational Enterprises (MNEs) and the exports of 63 manufacturing and primary industries, he found that the share of affiliate sales increases when transport costs and trade barriers are high but plant scale economies and investment barriers are low. Such results support the proximity-concentration trade-off. It is notable that this paper tries to apply the gravity equation for analysing firms' location.

Braconier *et al*. (2003) argues that the knowledge capital model is useful to explain the activities of MNEs. They point out that the empirical results of previous papers show weak or confused evidence for the model; because the models employed in the former literature are indirectly mapped from theory, the explanatory variables could be inappropriate for checking the model. Unlike the previous literature, Braconier *et al*. (2003) establish a theoretical empirical equation utilising the GDP of the home and host country and geographical distance. Their results support the prediction of the knowledge capital model. The paper's main contribution is to show that a well-established gravity model can be employed to analyse FDI.

Bergstrand *et al*. (2008) attempt to analyse two-way flows of highly skilled workers within profit-maximising MNEs. They hypothesise that these movements are associated with foreign affiliate activity and trade flows and suggest an integrated theoretical and empirical model to explain the flows of bilateral expatriates, FDI and international trade, simultaneously. The model is estimated using the Poisson quasi-maximum likelihood estimator instead of OLS, owing to OLS's zero, heteroscedasticity and 'adding-up' problems[67]. They find that the greater the similarity between the economic size of the two countries, the higher are trade and FDI. The paper is noteworthy in establishing a theoretical gravity equation and in suggesting the use of the Poisson quasi-maximum likelihood method in place of OLS.

[67] The total estimated trade is larger than total actual one (Arvis & Shepherd, 2011).

Kleinert & Toubal (2010) derive a theoretical gravity equation for analysing MNEs sales. They suggest three theoretical equations: two models relating to horizontal FDI with a third showing vertical FDI. The first model assumes both monopolistic competition and symmetric firms, presuming that MNE production uses intermediate inputs from the home country. The second model relaxes the symmetric firm assumption and introduces heterogeneous firms along with distance-dependent fixed costs. Market entry associated with a firm′s productivity such that the most productive firms become MNEs while less productive ones are exporters and the least productive focus only on the domestic market. The third model resembles a factor proportion model of fragmentation, which suggests that firms divide their production process into various stages and then decide their location according to factor intensities and price. Kleinert & Toubal provide diverse theoretical gravity models for MNE sales and demonstrate their use in explaining MNE activities among countries.

Waglé (2010) applies the theoretical framework of Helpman *et al*. (2004) to analyse FDI flows, believing that firm productivity affects their activities; that is, the most productive firms decide to invest abroad. Waglé also finds two biases; from the zero problem and firm selection using OLS[68]. To correct these biases, Waglé employs a two-step estimation. The first step estimates a Probit model to obtain the inverse Mills ratio and the second regresses an augmented gravity model by including the ratio as an additional independent variable. Waglé also employs the Poisson pseudo maximum likelihood method (Silva & Tenreyro 2006), to deal with these two biases. The paper is notable because it derives a theoretical gravity model for FDI and also

[68] The former arises because the sample only includes countries with FDI data and omits other countries. The second bias occurs because of not considering the different productivities of different firms.

employs the findings from previous papers[69] addressing econometric problems with a standard gravity model.

Bruno *et al*. (2016) uses the gravity model to analyse bilateral FDI between 34 OECD countries, 1985-2013. For estimation, they use a Poisson and a Heckman model in order to consider zero flows to investigate the effects of EU membership on FDI between member countries. They find that EU membership has a positive effect on FDI growth between member countries of around 30 per cent. Additionally, they attempt to check whether *Brexit* would affect FDI. They find that, if one country joins the EU, this would increase its inward FDI by 28 per cent while if the same country leaves the EU, inward FDI would drop by 22 per cent. Zero flows and *Brexit* provide good examples for subsequent studies analysing the impacts of leaving an economic bloc.

Falk (2016) applies the gravity analysis to FDI flow in the hospitality industry such as hotel projects. Using 2,420 FDI projects by 50 parent countries in 104 host countries, 2005-2011, he shows that market size and a common language have a positive influence while government regulations against business, tax rates and increasing minimum wages have a negative effect.

Chenaf-Nicel & Rougier (2016) study the relationship between FDI flows and economic instability. They assume that, if firms face instability in their home markets, they increase FDI abroad in countries with stable economic trends. Using a gravity model, they analyse FDI flows from Europe and the Mediterranean region to the four main host countries in the Middle East and North Africa region over 1985-2009. They

[69] Anderson & van Wincoop (2003) and Helpman *et al*. (2008).

find that, if home countries' GDP is unstable but that of host countries is stable, FDI flows increase. The authors acknowledge however, that the influence of such instability will decline when considering factor price discrepancies between home and host countries.

[Other analyses using the Gravity Model]

Migration: The gravity model has also been used to analyse migration flows in addition to trade and FDI. Karemera *et al*. (2000) use a gravity model to analyse the determinants of international migration flows from 70 countries to the United States and Canada 1976-1986. They find that a large home country population and the high income level in North America have a positive influence on migration.

Migration: Ramos & Surinach (2017) apply a gravity model to the study of migration patterns from countries neighbouring the EU to the EU for around 200 countries 1960-2010. They find that the population in the EU is an obstacle to migration from origin countries and that addition, distance and contiguity increase and decrease immigrant volume respectively. They also show that a common language or a colonial relationship leads to a significant growth in migration.

Education: A gravity model is also introduced to analyse education part. Sá *et al*. (2004) test the major drivers of high school graduates entering university in the Netherlands in 2000. They show that distance between living region and university city has a negative effect on students' motivation while high educational quality plays an important role in attracting students.

Stock market: The gravity equation is employed by Flavin *et al*. (2002) to analyse correlations between international stock markets of 27 countries. In the study, GDP in the traditional gravity model is replaced by stock market capitalisation in 1999. They find that distance between markets has a negative effect while a common currency and sharing a common border leads to increased correlation between markets.

The Gravity Model dealing with the Effects of Environmental regulations

The objective of this thesis is to analyse the effects of environmental regulations on FDI and trade (export) using the gravity model approach. This Section summarises those papers dealing with this subject matter.

[The Effects of Environmental stringency on FDI]

Kukenova & Monterio (2008) analyse the impact of environmental regulation on FDI flows using a gravity-like equation based upon the assertion that bilateral FDI flows can be explained by components of the gravity equation (e.g., country size, distance etc.). They use SO_2 per capita, CO_2 per capita and the number of ratified international environmental treaties as proxies for environmental stringency. Using an OECD investment data-set covering the period 1981-2005, they find that the level of environmental regulation of both the host and neighbouring countries have statistically negative effects on MNE activities. This paper shows that FDI analysis should consider 'third-country' effects although they do not show the theoretical derivation of why they should be done.

Naughton (2014) tests the pollution haven effect using panel data for 28 OECD countries 1990-2000, since FDI flows between developed countries account for the bulk of global FDI. The paper considers the stringency of environmental restrictions in both home and host countries, unlike previous papers which focus solely on stringency in host countries. To capture the stringency of environmental regulation, it uses pollution intensity (divided by GDP) of five pollutants: sulfur dioxide (SO2), nitrogen oxides (NOx), carbon dioxide (CO2), greenhouse gases (GHG), and particulate matter smaller than 2.5 microns (PM25). Naughton uses a gravity model with country-level data and finds that an increase in stringency in host countries leads to lower inward FDI flows while at high level, tougher stringency in home countries results in increased outward FDI. It is notable that this paper attempts to analyse effects of environmental stringency on inward and outward FDI in terms of both home and host countries.

Very few papers analyse the relationship between the level of environmental regulation and FDI flows with specific reference to Korea. Jung & Eun (2011) analyse the relationship between Korean FDI outflows and the environmental stringency of host countries. Using the gravity equation, their empirical investigation suggests that 'dirty' industries tend to be reluctant to invest in host countries with strong environmental stringency. Jung & Eun however, also argue that the pollution haven effect is insignificant in the Korean case because their results do not show significant movements of Korean firms to host countries with relatively lax environmental regulation.

Lee & Han (2011) also study Korean outward FDI flows using the gravity model for a panel of 54 countries with CO_2/GDP as a proxy for environmental stringency. They show that there is no statistically significant relationship between Korean FDI outflows and changes in environmental measures in host countries. When the sample of host counties is narrowed to include only non-OECD host countries however, this result changes; more lax environmental regulation in these countries has a positive and statistically significant effect on Korean FDI outflows.

Both of these papers (Jung & Eun and Lee & Han) show the usefulness of the gravity equation for analysing the relationship between FDI and environmental stringency for the case of Korea case. It is important to note however, that their models are not based on a theoretical approach and do not consider the zero problem of FDI of OLS.

Kahouli & Omri (2017) apply diverse gravity models to both international FDI and trade to analyse the effects of environmental regulation. Using 14 home countries and 39 host countries in 1990-2011, they investigate the relationship between environmental regulation and flows of FDI and trade. They begin with the traditional static gravity model including FDI as an explanatory variable, and then, to consider dynamic movement, they establish dynamic panel models. In the final stage, they also suggest simultaneous gravity equations based on arguments that trade and FDI are important determinants of each other. As a proxy for environmental regulation, they use CO_2 emissions per capita. In the econometric estimation, Kahouli & Omri use diverse methods; Fixed Effects, Random Effects and Hauseman-Taylor ways for static gravity models but difference GMM and system GMM for dynamic gravity models. They find that both trade and FDI increase with a drop in stringency of environmental regulation in terms of difference GMM while only FDI growth remains in system-GMM. The simultaneous approach shows that trade is one determinant of an increase in FDI. Kahouli & Omri (2017) is notable in trying to arrange the relationship between FDI and trade flow in terms of the effects of environmental regulation and applying diverse econometric methods, including dynamic panel models. This provides useful insights for the study here. Because they do not consider zero and logarithm-form of the gravity model, however, we will apply the Poisson pseudo maximum likelihood (PPML) of Silva and Tenreyro (2005) to solve the issues.

[The Effects of Environmental stringency on Trade]

Van Beers & van den Bergh (1997) analyse the effect of environmental regulations on trade flows between 21 OECD countries utilising a gravity equation. They point out that a gravity model has a power to analyse bilateral trade flow. To test for the effects of the stringency of environmental regulations, they construct two indices: the broad index[70]comprising seven indicators and the narrow index[71] using just two indicators directly linked to production process. Through summing up values of each indicator and dividing the outcome by the number of countries, the index has a range of from 0 (weak environmental policy) to 1 (strict environmental policy). The results from cross-sectional OLS analysis using 1992 trade data of 21 OECD countries show that the narrow index has a negative effect on export. Their main contribution is that they open up the gravity method to analyse the effect of environmental restrictions on trade.

Harris *et al*. (2002) demonstrate that the results of van Beer & van den Bergh (1997) are invalid when the fixed effects of the importers and exporters are considered. Harris *et al*. create a three-dimensional panel data-set using information from 24 OECD countries 1990-96. They also argue that, as their panel data-set takes into account country and time effects, it is more trustworthy than the cross-sectional information used by van Beer & van den Bergh since bilateral trade flows are often

[70] The index comprises seven indicators : (i)protected areas as a percentage of national territory in 1990, (ii) market share of unleaded petrol in 1990, (iii) recycling rate of paper in 1990, (iv) recycling rate of glass in 1990, (v) percentage of population connected to sewage treatment plant in 1991, (vi) change of energy intensity during period 1980-1991, (vii) level of energy intensity in 1980 measured in mega tons oil equivalent per 1000 units of current GNP.

[71] The narrow index use only (vi) and (vii).

subject to significant year-on-year changes. They inserted an additional NAFTA dummy variable into the gravity model of van Beer & van den Bergh; this takes a value of one if both *i* and *j* are members of NAFTA in year *t*, or zero otherwise. They then take into account three specific effects: the importing country; the exporting country; and time (business cycle). As a proxy variable for the stringency of environmental regulation, they create their own ranking index through the use of energy consumption, energy supply, GDP and population. They find no relationship between bilateral trade flows and environmental regulation. It is worthwhile noting that unlike van Beer & van den Bergh however, Harris *et al*. point out the importance of using panel data as well as country and time effects in estimating the impact of environmental regulation on bilateral trade flows.

Grether & de Melo (2003) also employ a gravity model to analyse the effect of the substantial gap in environmental regulation between developed and developing countries on bilateral trade flows. They use a panel data-set for 52 countries for the period 1981-98. For the specific estimation, they classify manufacturing industries into two groups: non-polluting and polluting. They then distribute the 52 countries into northern countries, with tough regulations, and southern countries, with more lax restrictions, on the basis of income per capita. They create their own pollution intensity index as a proxy variable for environmental restriction then rank the index on the basis of income per capita in each of the 52 countries such that the top ranked country was the one with the highest income per capita and the strictest environmental regulation. They find that the regulatory difference between developed and developing countries do not lead to significant changes in bilateral trade flows between them. One particularly interesting point of this paper is that it develops their own pollution intensity index.

Jug & Mirza (2005) investigate whether export flows inside Europe are affected significantly when more stringent environmental policies are enforced. They create a panel data-set, where the importers and exporters consist of 12 and 19 EU countries respectively over the period 1996-99. For the environmental regulation variable, they employ the 'current environmental expenditure of the manufacturing sector' provided by *Eurostat*. They find that environmental regulation has a negative effect on total trade inside the EU. Specifically, Eastern EU countries experience a drop in exports while the influence of stringency on Western EU exporters is insignificant. They also show that, contrary to expectations, 'dirty' sectors among the exporters are not more affected by environmental policies than are 'clean' industries. They argue that this is because 'dirty' – i.e., pollution-intensive – firms have difficulty in changing their location easily when they are dependent on the natural resources of that location.

Oh & Myoung (2005) analyse the effects of environment regulation on importers on Korean exports using a gravity model. They create a data set consisting of information (e.g., trade, GDP, distance, population) for 83 countries in 2001. To measure the stringency of the environmental regulation, they employ the World Economic Forum's Environmental Sustainability Index (ESI). They find that the tougher the environmental restriction polices of importing countries, the greater the volume of Korean exports to these countries. This paper provides an important prompt to this study by showing the usefulness of the gravity model to analyse the effects of environmental measures on Korean exports.

Conclusions

From the literature review, I can find out that the gravity model is very useful tool to analyse bilateral trade flow and FDI movement. In addition, many papers confirm that the equation is appropriate for effects of stringency of environmental regulations on not only outward & inward FDI between host and home countries but also trade flow between exporters and importers. Meanwhile, following 'multilateral resistance' of Anderson & van Wincoop (2003), I will add appropriate variables for Korean case on the base of theoretical gravity equation of Anderson & van Wincoop (2003)

2.2. The Measurement of Environmental Stringency

Selecting different measures of environmental stringency is likely to lead to different results. In this part, diverse measurements are discussed and evaluated. Because we consider FDI as a main study object, the measurement is sought with reference to FDI. Moreover, many papers dealing with environmental regulations want to check the pollution heaven hypothesis which is closely related to FDI. In this part, we will not define range of literature review in only papers with the gravity model. That is, we will investigate and understand both advantage and disadvantage across many papers dealing with relationship between FDI and environmental stringency.

Pollution Abatement Costs

As mentioned in Chapter II, pollution abatement costs are very commonly used in many researches, specially US case. Eskeland & Harrison (2003), using panel data for the 1980s and 1990s, show that there is no evidence that pollution abatement costs affect FDI inflows to four countries (Mexico, Venezuela, Morocco and Cote d'Ivoire). They also find that the energy efficiency of foreign-owned factories was higher than that of domestic ones. In addition, they argue that US firms facing low pollution abatement costs have a tendency to increase their FDI.

Javorcik & Wei (2004) employ a Probit model and find, using pollution intensity, no evidence of firms relocating to countries with lax environmental regulations (in the case of Eastern Europe and the former Soviet Union). In addition to pollution abatement costs, they also use various proxies such as entering in international environment-related treaties, indices of air and water quality, the WEF Environmental Sustainability Index and reduction of lead and CO_2.

Keller & Levinson (2002) also analyse the effects of environmental regulations on inflows of FDI to US states using pollution abatement costs as a measure of environmental stringency. Unlike previous papers however, they transform these costs to an index so as to avoid problems of industrial composition in expenditure and utilise panel analysis to consider unobserved effects. To avoid difficulties in comparing across countries, they focus solely on US states and find that stringency affects FDI negatively.

Cole & Elliott (2005) point out that the 'the pollution haven' and 'capital-labour' hypotheses conflict with each other and suggest that studies of the effects of environmental regulations on outward FDI should consider factor endowments. Using the gravity model based upon Eskeland & Harrison (2003) and US industrial pollution abatement costs 1989-94, they find that the FDI is attracted to Mexico and Brazil with high capital abundance relative to environmental stringency.

Ljungwall & Linde-Rahr (2005) study the relationship between China's inward FDI and its environmental policies. As a proxy of environmental stringency, they use the average cost incurred by firms investing in pollution abatement equipment. They employ panel data 1987-1998 and show that the Chinese government's effort to improve environmental conditions had no significant effects on FDI inflows at the national level. They argue however, that the environmental measures of less developed Chinese provincial governments did affect inward FDI to those regions.

Manderson & Kneller (2012) test the pollution haven hypothesis for the UK case using a heterogeneous firm-level trade model which argues that firms with better performance become MNEs. They find that, using firm-level pollution abatement operating costs or surveyed country-level data (from the World Economic Forum, 2006), Probit equations show that MNEs prefer countries with lax stringency of environmental regulation.

A major problem in using pollution abatement costs however, is that the survey period and coverage are different across countries so it has limitations as an international standard proxy.

Specific Environmental Regulation

The second way of measuring environmental stringency is to use specific environmental regulations, such as the US Clean Air Act Amendments (CAAA) which is generally employed to avoid multidimensionality and simultaneity. List *et al*. (2004) investigate the effect of the CAAA on firm location in New York state 1980-1990. Considering different reactions between domestic and foreign firms, they find that the opening of home firms is sensitive to changes in the CAAA while foreign companies are unaffected.

Hanna (2010) analyses whether or not the US CAAA has an impact on MNE activity, using firm-level panel data for 1966-1999, by investigating the claim that enhanced environmental restriction raises the cost of domestic production and forces MNEs to move their factories abroad or to outsource production to foreign firms. He uses an environmental regulation variable represented by the percentage of US firms' factories controlled by the CAAA, which emitted carbon monoxide, O_3, SO_2 or TSP. He finds that US-based MNEs increased foreign investment and production under the CAAA. The author also insists however, that as improved air conditions can provide considerable monetary and health benefits, environmental laws such as the CAAA should not be criticised. As in the case of pollution abatement costs, this method is not applied for comparison between countries.

Pollution Emissions & Energy Use

The third proxy is pollution emissions and energy use. Xing & Kolstad (2002) criticise the use of pollution abatement costs, arguing that average abatement costs per unit output does not properly represent environmental stringency. Instead, they employ the SO_2 emissions of host countries as the stringent level of environmental regulations. The result is that, for pollution intensive industries, the laxity of environmental restrictions in host countries has a positive effect on US FDI inflows to the countries.

Gamper-Rabindran & Jha (2004) show that changes in environmental regulation affect FDI inflows to India. They employ a pollution-intensity measure, calculated by the use of an industrial pollution projection system (IPPS), as a proxy for environmental stringency.

Mihci *et al*. (2005) also find the same result for the OECD countries. They create an index as a proxy of the level of environmental regulation consisting of climate change (CO_2, CH_4 emissions), acidification (SOx, NOx emissions), intensity of the use of water resources and waste generation. They find that enhanced environmental stringency in the OECD countries leads to an increase in outward FDI of the OECD countries.

Dardati & Saygili (2012) test the issues of whether FDI reduces emissions and whether the pollution haven hypothesis is valid. Using firm-level data for Chile 1995-2001, they create a variable for emissions using total fuel over total sale and input. Adopting this proxy and the monopolistic heterogeneous firm model (Helpman *et al*., 2004), they find that increases in the number of foreign firms reduces emission. In addition, with the difference-in-difference method, the introduction of emission control regulation leads to a drop in the number of domestic firms. They explain that this reduction is the result of the productivity discrepancy between domestic firms and foreign plants. They argue however, that the model is limited in that it only captures horizontal FDI, so that conclusions regarding the lack of validity of the PHH should not be hasty. These proxies are criticised because of the misunderstood direction between cause and effect.

Besides the above papers, Kukenova & Monterio (2008) employ SO_2 per capita, CO_2 per capita and the number of ratified international environmental treaties. Naughton (2014) utilizes five pollutant emissions (SO2, NOx, CO2, GHG and PM25) over GDP. Kahouli & Omri (2017) adopt CO_2 emissions per unit of GDP.

Composite Indices

To overcome multidimensionality and analyse international comparison across countries, some papers attempt to employ international index or create their own composite index. Kheder & Zugravu (2012) analyse the impact of regulation in France using a logistic model using as a proxy for environmental stringency a ‘super’ variable that integrates several elements; the number of NGOs, energy efficiency

(GDP/unit of energy used), ratified international environmental agreements and ISO 14001 certifications/GDP in the host country. They find that French firms prefer countries with more lax environmental stringency over those with stricter regulation.

Rezza (2013) extends this study of the pollution haven hypothesis to Norwegian manufacturing, using sales data of MNE subsidiaries 1999-2005. He argues that Norwegian parent firms reduce investment in their affiliates in those countries with more harsh environmental regulation. He constructs an index as a proxy for stringency of environmental regulations using two elements of the WEF Global Competitiveness Report; the 'level of environmental stringency' and 'consistency of the regulation enforcement'.

Rivera & Oh (2013) employ firm-level data for 94 European Fortune Global 500 firms in 77 countries 2001-2007. Unlike other studies, they show that MNEs increase FDI host countries with more stringent environmental restrictions than their home countries. Moreover, they argue that certainty of environmental regulations is an important determinant of FDI. For country-level discrepancies in stringency between countries, they adopt the surveyed executive opinions of the WEF.

Chung (2014) investigates the pollution haven hypothesis in the case of Korea. Using Korean outward FDI data to 50 countries in 121 industries in 2000-2007, he finds that countries operating lax environmental regulations lead to increases in both Korean outward FDI to these countries and Korean imports from them in terms of pollution-intensive industries. As a measure of environmental stringency, he uses surveyed executive answers from the Global Competitiveness Report of World Economic Forum. In addition, for pollution intensity he uses energy use per output.

Poelhekke & Ploeg (2015) test the pollution haven hypothesis for The Netherlands for outward FDI by 12 Dutch industries to 188 countries 1999-2005. As in other studies, they use WEF survey data to construct their own index of combined regulation and enforcement. They show that Dutch outward FDI increases in natural resources extraction and refining, food processing and construction when host countries have relative lax environmental regulations, so supporting the pollution haven hypothesis. In the machinery, electronics and transportation sectors, it is attracted to host nations with tougher level and stronger enforcement – referred to as the 'green haven effect'.

Kozluk & Timiliotis (2016a) employ industry- and country-level data from the OECD & the BRIICS countries 1990-2009. Unlike previous studies, they use domestic value added of manufacturing exports in gravity models. For cross-country analysis in terms of environmental regulation, they use the OECD's 'Environmental Performance Stringency (EPS) Index', which includes energy-related policies dealing with climate and air pollutants along with deposit and refund schemes[72]. Composite index has also disadvantage. WEF index is based on survey of CEOs, which implies that there might be CEO's bias against environmental stringency. In addition, the EPS and other composite indices could not include all indicators related to stringency of environmental regulations.

Conclusions

It is important to keep in mind that there is no perfect measure for the stringency of environmental regulations. That is, each measurement has merits and limitations. We therefore should consider object and range of research before choosing a measurement.

[72] The EPS will be discussed more in the data explanation section.

In this thesis, we intend to compare environmental stringency across countries. We therefore will choose the EPS of the OECD. In comparison to other measurements, the EPS is only created to represent stringency of environmental regulations in the OECD & the BRIICS countries by the OECD. It means that the EPS has strong explanation ability for the countries. In addition, the index has advantage to reflect the most important global environmental issue (GHG mitigation) because it include climate and air quality polices.

3. Econometric Specification & Estimation Method

For estimation, I will establish specific gravity equations with environmental stringency. Korean outward FDI and Korean export will be used as dependent variables. Market size, Traditional trade and FDI costs, and factor abundance will be added as explanatory variables in the right side of gravity equations. Meanwhile, to get consistent estimated results, we will deal with some econometric issue : zero and heteroscedasticity.

3.1. Specific Gravity Equations for estimation

Since Tinbergen (1962) first presented the gravity model, it has been widely used to analyse FDI and bilateral international trade flows. In his model, the GDPs of bilateral trade partners and the distance between them have long been regarded as key determinants of trade. In addition, diverse variables have been added to the model by various researchers leading to 'the augmented gravity equation'.

The original gravity model lacked a theoretical foundation but was supported by its empirical usefulness. It was not until the end of the 1970s that the model first encountered the serious task of establishing its theoretical foundation (Anderson

1979). The most important milestone in the field was presented by Anderson & van Wincoop (2003), who attempt to correct the excessive estimates of McCallum (1995) when adding a border effect into the equation. They show the existence of 'multilateral resistance' in the theoretical gravity model and argue that considering this effect would lead to more consistent estimates.

The gravity model equation used in this study starts from the basic model of the theoretical derivation of Anderson & van Wincoop (2003). The basic model is as follows:

$$ln\, x_{ij,t} = k + ln\, y_{i,t} + ln\, y_{j,t} + (1-\sigma) ln\, t_{ij,t} - ln\, \Pi_{i,t} - (1-\sigma) ln\, P_{j,t} + e_{ijt} \quad (3.3)$$

$$\Pi_i \equiv (\textstyle\sum_j (\frac{t_{ij}}{P_j})^{1-\sigma} y_j) \quad . \qquad P_j = [\textstyle\sum_i (\beta_i p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)}$$

where Π_i and P_j are inward and outward multilateral resistances of Anderson & van Wincoop (2003). Bilateral trade costs, $(1-\sigma) ln\, t_{ij}$, can be specified as the following[73]

$$(1-\sigma) ln\, t_{ij,t} = \beta_1 ln\, Dist_{ij} + \beta_2 ln\, Lang_{ij} + \beta_3 ln\, Clny_{ij} + \beta_4 ln\, RAT_{ji,t} + \beta_6 \tau_{ij,t} \quad (3.4)$$

where $Dist_{ij}$ is bilateral distance, $Lang_{ij}$ represents common language[74], $Clny_{ij}$ is colonial ties[75] and $RAT_{ji,t}$ shows a regional trade agreement. All of these are dummy

[73] Piermartini & Yotov (2016) specify the costs with some components such as bilateral distance, contiguous borders, common language, colonial ties, regional trade agreement, tariff and trade policy variables.

[74] In Korea – the OECD & the BRIICS countries case, language variable is not necessary because all values have zero-that is, Korea does not have any common language neighbour.

[75] We will not consider colony because only japan has a value. Moreover, trade with Japan is dependent on geographic closure, not colony (KITA, 2008). We can catch such effect with distance.

variables. $\tau_{ij,t}$[76] explains tariff coefficient of which can be interpreted as 'trade elasticity of substitution' because tariff plays a role in increasing price directly.

This study expands equation (3.3) into three groups, following the approaches of Kahouli & Omri (2017) in terms of the Korean case and includes an additional variable to measure the stringency of environmental regulation (the OECD's Environmental Performance Stringency, EPS), discussed further below.

<FDI gravity models>

$$
\begin{aligned}
OutwardFDI_{\mathrm{ijt}} &= \mathrm{k} + \beta_1 ln\, \mathrm{y_{it}} + \beta_2 ln\, \mathrm{y_{jt}} + \beta_3 ln\, POP_{\mathrm{it}} + \beta_4 ln\, POP_{\mathrm{jt}} + \beta_5 ln\, Dist_{\mathrm{ij}} \\
&+ \beta_6 \mathrm{EPSgap_{ijt-1}} + \beta_7 ln\, \mathrm{PC_{it}} + \beta_8 ln\, \mathrm{PC_{jt}} + \beta_9\, \mathrm{HC_{it}} + \beta_{10}\, \mathrm{HC_{jt}} \\
&+ \beta_{11}\, ASEAN_{\mathrm{t}} + \beta_{12}\, APTA_{\mathrm{t}} + \beta_{13}\, EFTA_{\mathrm{t}} + \beta_{14}\, \tau\mathrm{ratio_{ji,t}} + \theta_c + \theta_t \\
&+ \mathrm{e_{ijt}}
\end{aligned}
\tag{3.5}
$$

where $OutwardFDI_{\mathrm{ijt}}$ is Korea's FDI outflow to host countries (the OECD & the BRIICS countries), $\mathrm{y_{it}}$ is Korean GDP and $\mathrm{y_{jt}}$ is the GDP of host countries, we expect that $\mathrm{y_{jt}}$ has positive sign because large market size and capacity of host countries would attract more FDI from Korea. POP_{it} is population of Korea and POP_{jt} is population of host countries. Like GDP, the sign is expected positive at the same reason.

$\mathrm{EPSgap_{ijt-1}}$ is [Korea $\mathrm{EPS_{it-1}}$ − host country $\mathrm{EPS_{jt-1}}$], $\mathrm{PC_{it}}$ and $\mathrm{PC_{jt}}$ are the physical capital of Korea and host countries, and $\mathrm{HC_{it}}$ and $\mathrm{HC_{jt}}$ are the human capital

[76] Heid & Larch (2016) show the derivation of a gravity model with tariff.

of Korea and host country (the UNDP Human Development Index is used for this, which considers long and health life, knowledge and standards of living comprehensively). We expect positive sign of human capital of host country because skilled labour with healthy condition in good living standards could be an important production factor for Korean state of art goods. $ASEAN_{\mathrm{t}}$ is Association of Southeast Asian Nations, $APTA_{\mathrm{t}}$ is Asia Pacific Trade Agreement, and $EFTA_{\mathrm{t}}$ is European Free Trade Association. If this regional agreement could reassure foreign investors investment safety and reduce investment costs, the sign will be positive. $\tau\mathrm{ratio}_{\mathrm{ij,t}}$ is host country tariff/Korean tariff. If increasing tariff of host country would damage export, Korean investors could raise outward FDI as an alternative to keep their market share and power in host countries, which could lead to positive sign. Meanwhile, θ_c *and* θ_t reflect country and time fixed effects, respectively.

<Trade gravity models>

$$Export_{\mathrm{ijt}} = \mathrm{k} + \beta_1 ln\, \mathrm{y}_{\mathrm{it}} + \beta_2 ln\, \mathrm{y}_{\mathrm{jt}} + \beta_3 ln\, POP_{\mathrm{it}} + \beta_4 ln\, POP_{\mathrm{jt}} + \beta_5 ln\, Dist_{\mathrm{ij}} + \beta_6 \mathrm{EPSgap}_{\mathrm{ijt-1}} + \beta_7 ln\, \mathrm{PC}_{\mathrm{it}} + \beta_8 ln\, \mathrm{PC}_{\mathrm{jt}} + \beta_9\, \mathrm{HC}_{\mathrm{it}} + \beta_{10}\, \mathrm{HC}_{\mathrm{jt}} + \beta_{11}\, ASEAN_{\mathrm{t}} + \beta_{12}\, \tau\mathrm{ratio}_{\mathrm{ji,t}} + \theta_c + \theta_t + \mathrm{e}_{\mathrm{ijt}} \quad (3.6)$$

$$ln\, Export_{\mathrm{ijt}} = \beta_0 + \gamma ln\, Export_{\mathrm{ijt-1}} + \beta_1 ln\, \mathrm{y}_{\mathrm{it}} + \beta_2 ln\, \mathrm{y}_{\mathrm{jt}} + \beta_3 ln\, POP_{\mathrm{it}} + \beta_4 ln\, POP_{\mathrm{jt}} + \beta_5 ln\, Dist_{\mathrm{ij}} + \beta_6 \mathrm{EPSgap}_{\mathrm{ijt-1}} + \beta_7 ln\, \mathrm{PC}_{\mathrm{it}} + \beta_8 ln\, \mathrm{PC}_{\mathrm{jt}} + \beta_9\, \mathrm{HC}_{\mathrm{it}} + \beta_{10}\, \mathrm{HC}_{\mathrm{jt}} + \beta_{11}\, ASEAN_{\mathrm{t}} + \beta_{12}\, \tau\mathrm{ratio}_{\mathrm{ji,t}} + \theta_c + \theta_t + \mathrm{e}_{\mathrm{ijt}} \quad (3.7)$$

$$\begin{aligned} ln\ Export_{\mathrm{ijt}} = {} & \beta_0 + \gamma ln\ Export_{\mathrm{ijt-1}} + \delta ln\ outward\ FDI_{\mathrm{ijt}} + \beta_1 ln\ \mathrm{y_{it}} + \beta_2 ln\ \mathrm{y_{jt}} \\ & + \beta_3 ln\ POP_{\mathrm{it}} + \beta_4 ln\ POP_{\mathrm{jt}} + \beta_5 ln\ Dist_{\mathrm{ij}} + \beta_6 \mathrm{EPSgap_{ijt-1}} \\ & + \beta_7 ln\ \mathrm{PC_{it}} + \beta_8 ln\ \mathrm{PC_{jt}} + \beta_9\ \mathrm{HC_{it}} + \beta_{10}\ \mathrm{HC_{jt}} + \beta_{11}\ ASEAN_{\mathrm{t}} \\ & + \beta_{12}\ \tau\mathrm{ratio_{ji,t}} + \theta_c + \theta_t + \mathrm{e_{ijt}} \end{aligned} \tag{3.8}$$

where $Export_{\mathrm{ijt}}$ is Korean export to its trade partner. In addition, assuming that previous export is a basis of current activity, a dynamic gravity equation is also estimated. This is because firms in an exporting country which already have an established network for selling their goods in importing countries have strong intentions to maintain their exports.

3.2. Econometric Issues

In general, OLS estimations can be considered as a basic econometric approach. The zero problem and heteroscedasticity of the error term in the gravity model however, can lead to an estimation bias in terms of OLS (Silva & Tenreyro, 2005). To overcome this problems, the Poisson Pseudo Maximum Likelihood method has been recommended for the gravity model (Silva & Tenreyro, 2005; Shepherd, 2012) . In addition, because the dynamic model has an inborn endogenous problem, it should be dealt with.

The Zero problem and Heteroscedasticity of the Gravity model

[The Zero Problem]

The logarithm of the gravity model is the root cause of the zero problem. To look over the reasons, first, consider that Korean export data shows a zero for some countries. It means that Korea does not export goods to the countries. The reason lies on the fact that in terms of trade, the countries cannot afford to buy Korea's relatively expensive goods or the trade costs outweigh the benefits from export while excessive investment costs in host countries could prohibit FDI. On the other hand, think that FDI and export are calculated and published in units of millions or billions of Dollars or Korean currency (KW). In this case, some actual FDI and export data will be excluded and appear simply as a zero in the published data. Helpman *et al*. (2008) claim that almost half of bilateral trade flows show zero values when using aggregate trade data.

A multiplicative equation could consider zero values in the estimation but applying logarithms removes these zero values. That is, the gravity model can have a sample selection problem through eliminating the zero data. Considering zero plus one may be an alternative option to overcome this problem. Both Silva & Tenreyro (2005) and Gomez & Milgram (2010) however, argue that applying methods without strong theoretical support could risk distorting the real data and result in inconsistent estimators of the coefficients.

[Heteroscedasticity]

Applying logarithms leads to the risk that the error term is dependent upon the explanatory variables because of Jensen's Inequality. This implies that the estimators of OLS are inconsistent (Silva & Tenreyro, 2005; Gomez & Milgram, 2010; Shepherd, 2012). It is said that even the multilateral resistance of Anderson and Van Wincoop (2003) cannot remedy this heteroskedastic problem (Silva & Tenreyro, 2005)

The Poisson Pseudo Maximum Likelihood Method for the Gravity model

Silva & Tenreyro (2005) suggest employing the Poisson Pseudo Maximum Likelihood (PPML) estimator to deal with the zero and heteroscedasticity problems. The merits of the Poisson estimator for the gravity model are explained by Shepherd (2012).

First, the Poisson estimator produces consistent coefficients with the introduction of Fixed Effects. Because this study employs the theoretical gravity model form of Anderson & van Wincoop (2003), with Fixed Effects representing outward and inward multilateral resistance, this advantage of the Poisson estimator is regarded as important for the estimations. Second, zero values can be included in the Poisson estimation while OLS drops such observations because of the use of the logarithmic form in the gravity equation. The Poisson estimator embraces zero data naturally. Lastly, interpretation of the coefficients from the Poisson estimation is similar to interpretation using OLS. That is, although dependent variables do not have a logarithmic form in Poisson regression, the coefficients of the explanatory variables in a logarithmic form can be interpreted as elasticities.

Silva & Tenreyro (2005) outline the advantages of PPML in comparison to non-linear least squares (NLS), stating that NLS has a tendency to give more weighting to observations with a larger variance. This means that an NLS estimator may be inefficient and can be severely affected by even small and unique observations while PPML gives equal weighting to each observation. They also comment that operating NLS can be complicated, especially when it involves a lot of regressors.

Endogenous issue of Environmental regulations

An endogenous problem is an often stated concern when studying the impact of environmental regulations on targeted objectives (Cole *et al*., 2017). This is because there is a possibility that FDI or trade flows might affect environmental regulation. Governments facing declining inflows of FDI might reduce the stringency of environmental restrictions[77]. On the contrary, if there is an increase in competitors' FDI, lobby groups may in fact press for harsher stringency (Cole *et al*., 2017)[78].

Several means have been suggested to solve this endogenous problem. One is the use of instrumental variables. Miliment & Roy (2015) explain three relevant instrumental variables. The first is past environmental restrictions (Cole & Elliott, 2005; Jug & Mirza 2005) although it is only valid however, if the error term is not auto-correlated (Miliment & Roy, 2015). An alternative is a geographic instrumental variable such as that used by Levinson & Taylor (2008) to create the instruments in terms of US states. Another one includes special variables which are believed not to affect FDI or trade flows but environmental regulation, such as political variables (corruption, enforcement process etc.). It however is possible that even these might have endogenous problems. Brunnermeier & Levinson (2004) argue that 'as is always true of instrumental variable analyses, the instruments are open to critique'. The another solution lies in finding an external measure of environmental regulations, like the US CAAA.

As mentioned already, we will use the OECD's EPS. It is likely that the EPS does not have serious endogenous problems under the following perspectives. First, the EPS represents overall environmental stringency of one country. It therefore is

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[77]List *et al*. (2013) say that policymakers might increase or decrease level of environmental stringency in pollution intensive industries according to inbound (outbound) FDI. Cole *et al*. (2006) argue that inward FDI could result in tougher or softer level of environmental stringency in low or high level of corruption

[78] Besides, the omission of critical variables, measurement error of environmental stringency and connections between environmental stringency and lagged or current economic impacts could contravene the exogenous assumption of environmental regulations although they are not main concerns.

not likely that certain local industries and firms could directly affect level of the EPS (Albrizio *et al*., 2017; Kozluk and Garsous, 2016b). Second, kinds of indicators of the EPS and their weigh are determined by the OECD, not a certain country and specific industry and firms. Third, threshold to decide score (0-6) of each indicator is also determined by the OECD through considering a normalized distribution composing all values of the indicator of the OECD countries (Botta and Kozluk, 2014). We however, will employ lagged EPS to avoid any critics about endogenous issue like Albrizio *et al*. (2017). Moreover, it is highly likely that FDI could be affected by past environmental stringency because current investment could be determined on the base of past information.

Meanwhile, Baier & Bergstrand (2007) offer country-pair fixed effects[79] or first-differencing, to solve endogenous problems of regional trade agreement rather than using instrumental variables, arguing that even a method with an instrument shows ‘at best mixed evidence of isolating the effect of free trade agreements on trade flows’. Their first-differencing could be considered in a dynamic panel model with lagged dependent variables.

Dynamic panel model for Korean export

For Korean export estimation[80], we will create our own dynamic panel model which has lagged dependent variables as ones of explanatory variables. Intuitively, we could think that companies refer to past export and import patterns and networks when deciding current trade volume (Kahouli & Omri, 2017). As mentioned in chapter II, in

[79] This study does not deal with multi-countries FDI and trade with many home and exporters– that is, Korea is only home and export. Country pair effects therefore are dropped because of collinearity

[80] In FDI case, no tests are satisfied. Moreover, lagged outward FDI does not have significant effects for current outward FDI even at the 10% level.

the dynamic panel model, there should be correlation between the variables and error term violating condition for consistent estimators. To solve the problem, the Generalized Method of Moments (GMM) of Arellano & Bond (1991) (called as difference GMM) and the GMM of Arellano & Bover (1995) and Blundell & Bond (1998) (called as system GMM) are recommended. To use difference and system GMM, the model must pass two tests: Sargan or Hansen test and Arellano-Bond test. The former checks whether or not overidentified model of GMM is valid. If the condition is not satisfied, we cannot use GMM. The latter test autocorrelation of error terms. If the null hypothesis (no autocorrelation) at first order is rejected or accepted while the hypothesis at second order is not rejected, using lagged level and difference variables as instrumental variables is correct. In this chapter, I will employ difference & system GMM. In Stata, xtabond & xtdpdsys are for difference & system GMM respectively.

Conclusions

For estimation, we will employ the gravity model with Korean outward FDI and Korean export as dependent variables. The components of explanatory consist of market size, physical & human capital, regional trade agreement, The EPS, and tariff. Because of the zero and heteroskedastic issues, we will use the Poisson Pseudo Maximum Likelihood (PPML) method. Additionally, to consider dynamic movement in terms of export, we will also use the dynamic panel model for Korean export applying difference & system GMM.

4. Data Description

In this section, we will describe properties of Korean outward FDI, Korean export and Environmental policy stringency (the EPS) of the OECD. All data are collected at national level because the EPS is announced publicly at the same level. The period is from 2000 to 2012 because many explanatory variables are available in all the OECD & the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa) at only the period.

4.1. Korean outward FDI

Korean total investment in foreign countries sharply increases from 5,402 million dollars in 2000 to 35,249 million dollars in 2016. In accumulation of 1980-2016, manufacturing industry accounts for 32% of total Korean outward investment. Mining (16%), wholesale & retail (13.4%), and finance & insurance (11.5%) are ranked second, third and fourth, respectively. In addition, Asia is the first investment place, holding 38%, and North America and Europe catch 23% and 15 %.

As mentioned previously, under the limitation of Environmental policy stringency index, our study will focus on the OECD & the BRIICS countries. Like total investment, the Korean outward investment in the countries also increases from 1,452 million dollars in 1995 to 19,701 million dollars in 2012 over eight times. Figure 3.1 shows the increased FDI over the period. In terms of industries, manufacturing industry (35.3%), mining (16%), wholesale & retail (15.6%), and finance & insurance (8.7%) and estate rental & leasing (8.2%) attract Korean investors in sequence. In manufacturing sectors, computer, electronic & communication, motor vehicles & trailers and Basic metals account for 28.9 %, 16.8% and 8.7 %, respectively. Like total FDI, in comparison to 1,452 million dollars in 1995, FDI increased to 6,068 million dollar in 2012. After 2007, however, FDI decreased until 2009 but then turned to upward. In addition, after 60.2 % in 2006, portion of manufacturing in total FDI decreased until 30.8% in 2012. It means that

Korean investment in non-manufacturing sectors (such as mining, wholesale & retail and finance & insurance) increased at the same period.

Figure 3.2 says that America and China are the majority of receivers from Korean outward FDI. Considering that America has the largest markets and China also has large market and relative cheap factor prices, it is reasonable that FDI in the two countries has high record. Meanwhile, the concentration on two countries may cause a spurious result. Because America has higher EPS (3.1) while China does lower EPS (2.0) in comparison to Korean EPS (2.63) in 2012, however, it is likely that influences of two countries' EPS on FDI could offset each other. Concentration issue therefore should not be a concern.

Figure 3.3 shows relationship between Korean outward FDI (2000-2012)and GDP in the OECD & the BRIICS countries. The graph indicates that Korean outward FDI increased along GDP with the correlation coefficient (0.49). It means that Korean outward FDI in the OECD & the BRIICS countries intends to pursue market expansion and access to new market[81]. Figure 3.4 says relationship between Korean outward and lagged EPS[82] in terms of descriptive graph. We could find that there is a little positive appearance. It implies that if the gap is expanded-that is, Korea EPS increases relatively higher than the host country, it is likely that the FDI could rise. The correlation coefficient is 0.2267.

[81] Using Korean outward FDI in 2000-2012, Hwang (2016) argue that Korean FDI in developed countries are used as a useful tool for market expansion and access to new market (horizontal FDI).

[82] Lagged EPS gap = Lagged (Korea EPS – Host country EPS)

Figure 3.1: Korean outward FDI to the OECD & the BRIICS countries

(unit: USD thousand)

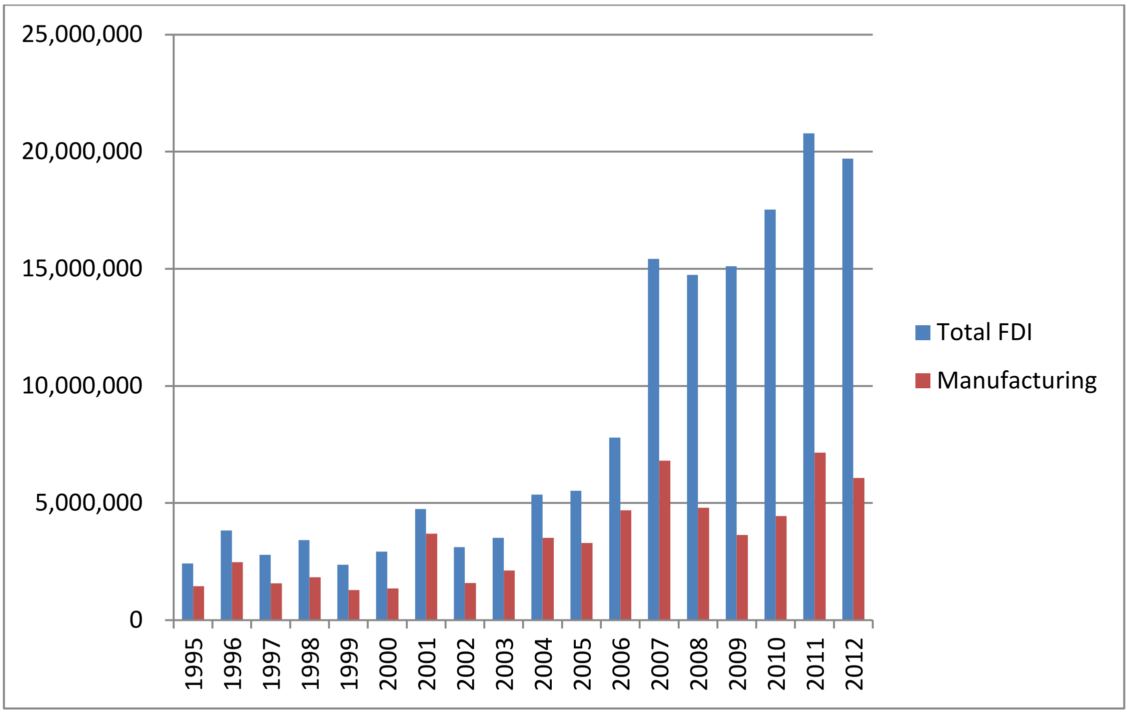


Figure 3.2: Distribution of Korean outward by region in 2012

(unit: USD thousand)

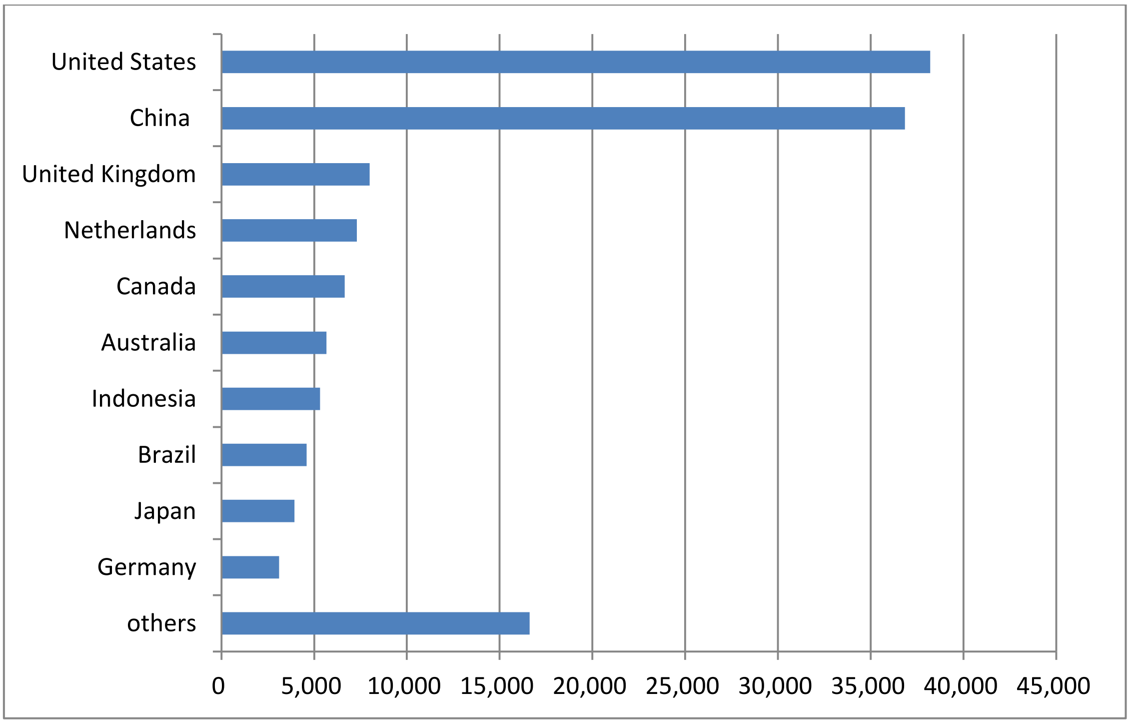


Figure 3.3: Korean outward FDI and GDP in 2000-2012 (unit: USD thousand)

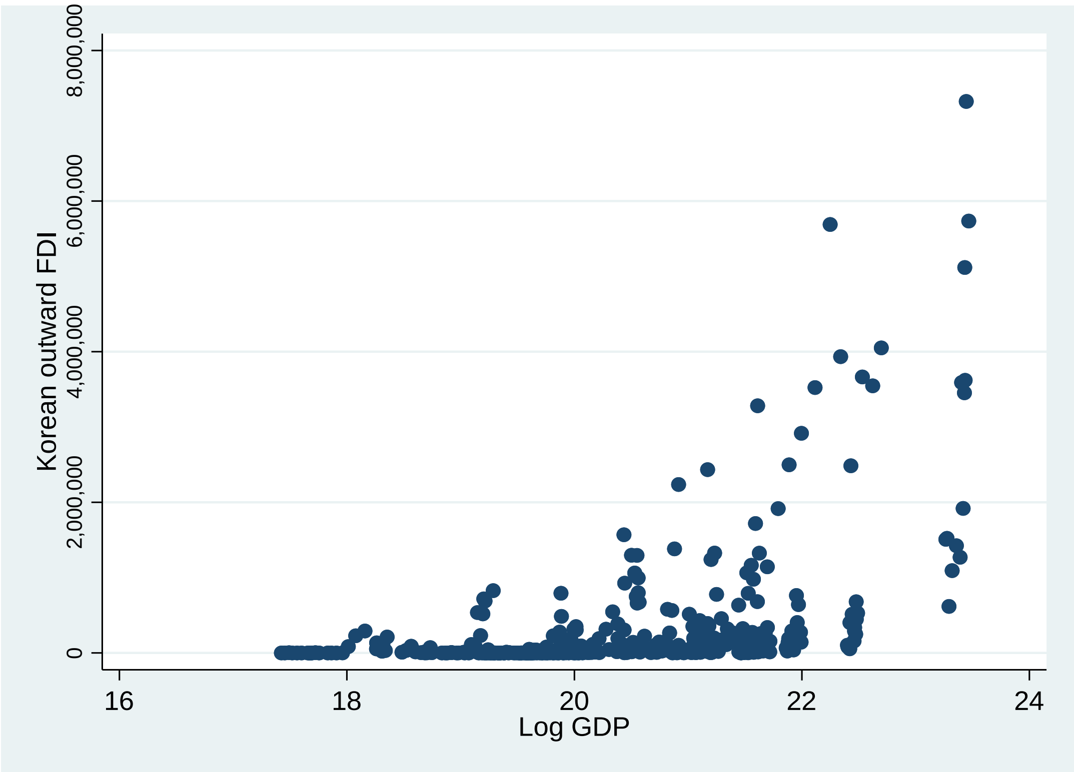
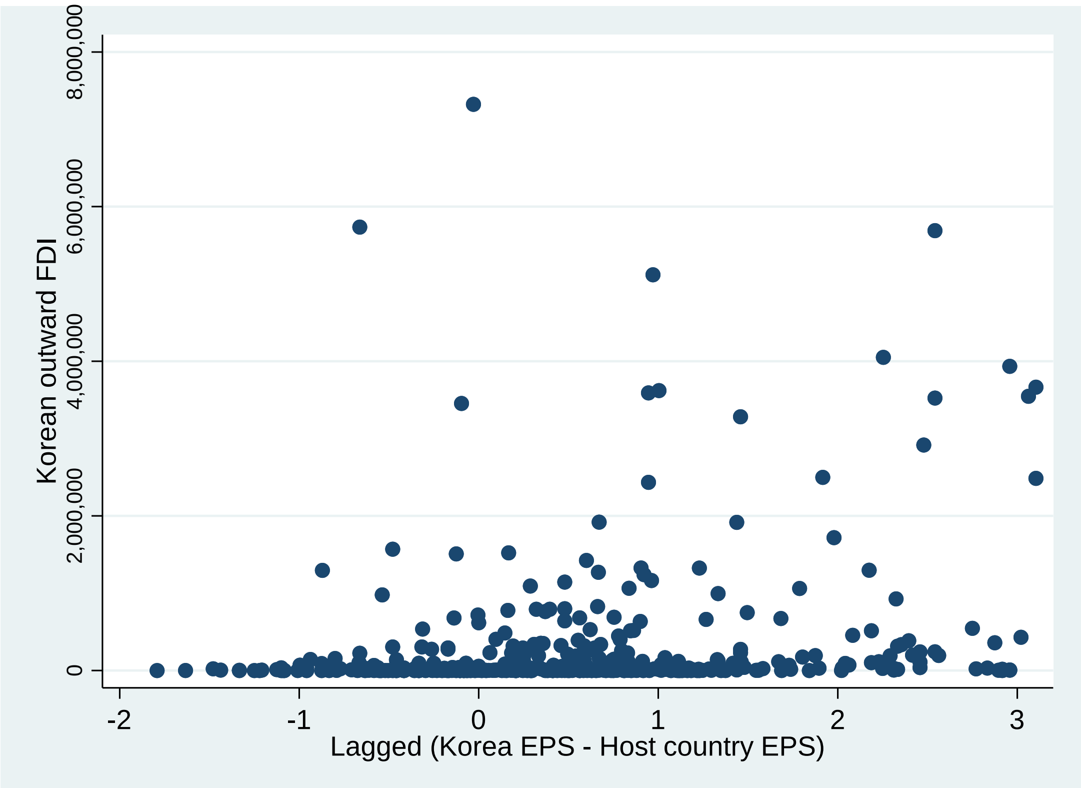


Figure 3.4: Korean outward FDI and the EPS gap in 2000-2012

(unit: USD thousand)



4.2. Korean Export

Data of Korean exports to the OECD & the BRIICS countries are provided by the Korea International Trade Association (KITA). Figure 3.5 shows that except 2008, export volume has increased over 1995-2012. In comparison of 2000, export in 2012 reaches almost three times growth. The sharp down in 2008 seems to be due to US and Europe financial crisis. In terms of each country, the top 5 countries (China, the US, Japan, India and Germany) account for around 58% of all Korean exports in 2012 (Figure 3.6). In particular, China and Japan, as close neighbouring countries, rank first and third, respectively. The US – the largest market in the world – is the second most important country for Korean exports. Because the OECD & the BRIICS countries are major importing countries of Korean goods, if difference of environmental stringencies between Korea and the importing countries cause change of Korean export to the nation, the results are meaningful for Korean policymakers. In terms of descriptive graph, Figure 3.7 shows that there is a little positive relationship between Korean export and discrepancy of lagged EPS. The correlation coefficient is 0.3674. According to descriptive graph appearance and correlation coefficients in Korean outward FDI and Korean export, we could think that there are could be any relationship between FDI and export in Korean case. Figure 3.8 shows a positive shape between them. The correlation coefficient is 0.5427. Such relationship could be explained from the fact that most of export is dependent on intermediate goods[83]which is likely to be related to FDI.

[83] Intermediate goods export accounts for 63% of total export in 2012.

Figure 3.5: Korean exports to the OECD & the BRIICS countries (unit: USD million)

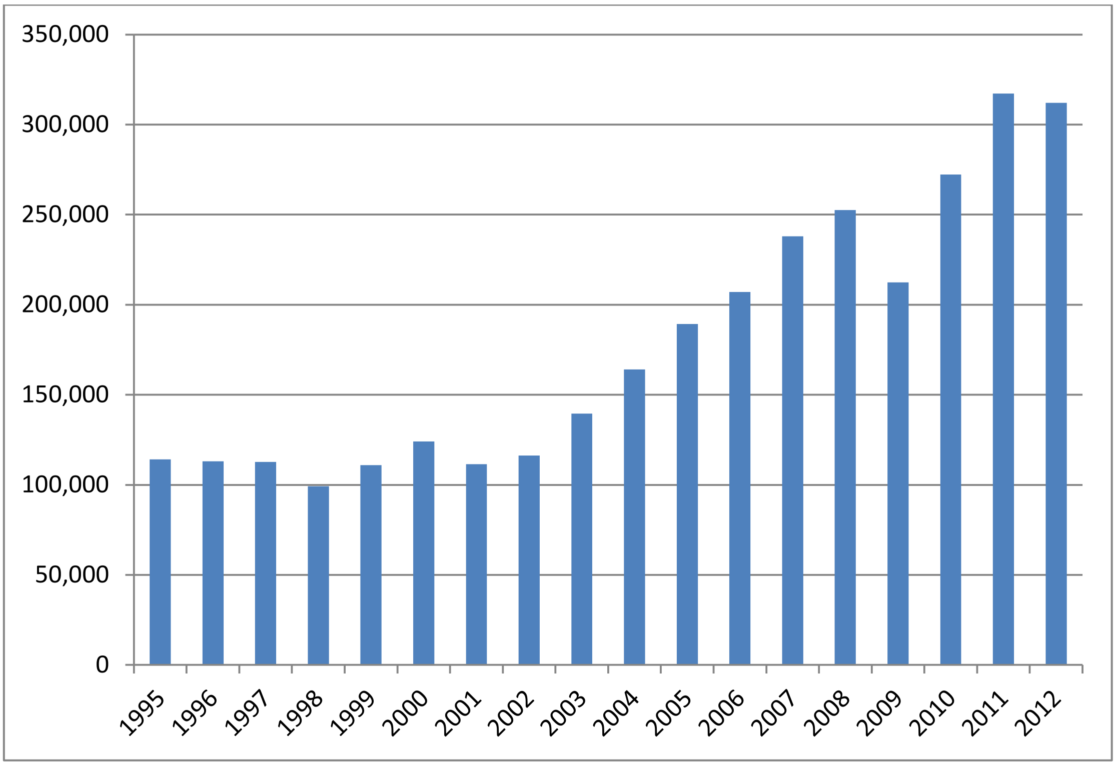


Figure 3.6: Korean exports by country in 2012 (unit: %)

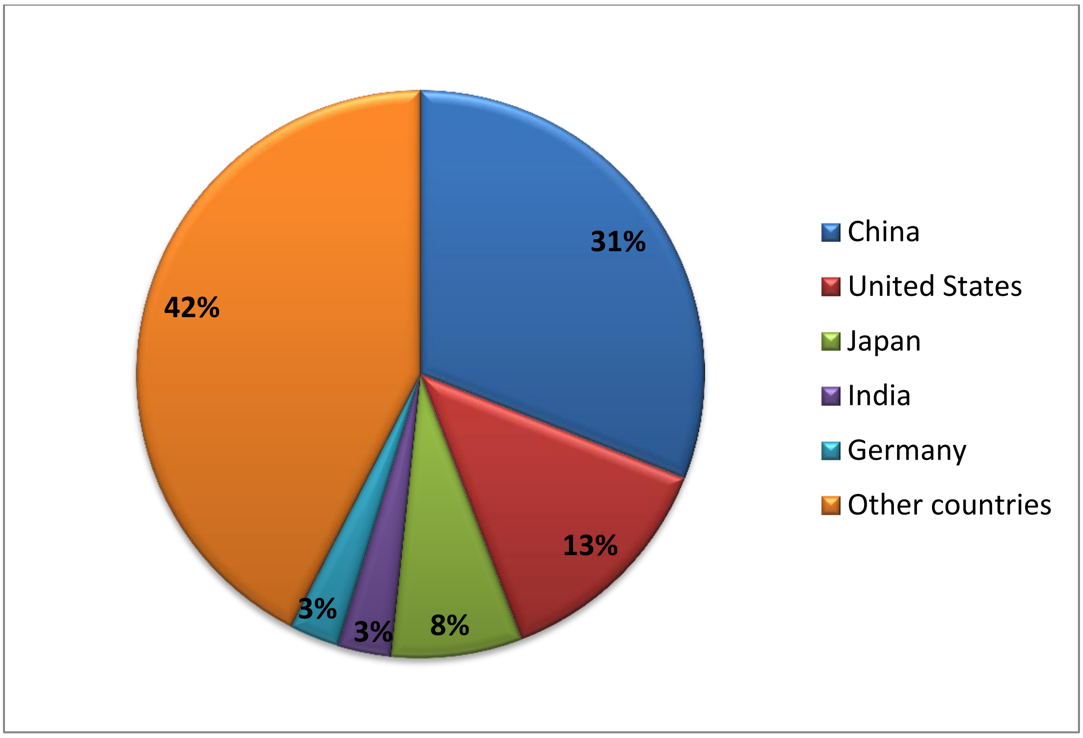


Figure 3.7: Export and the EPS gap

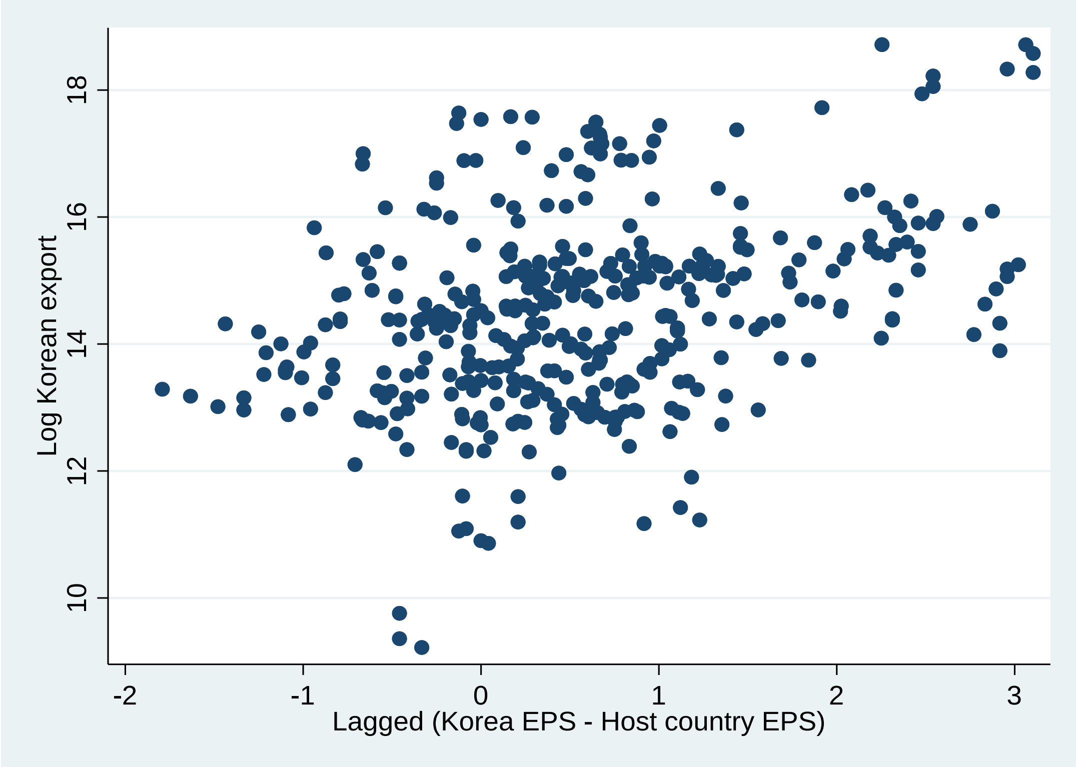
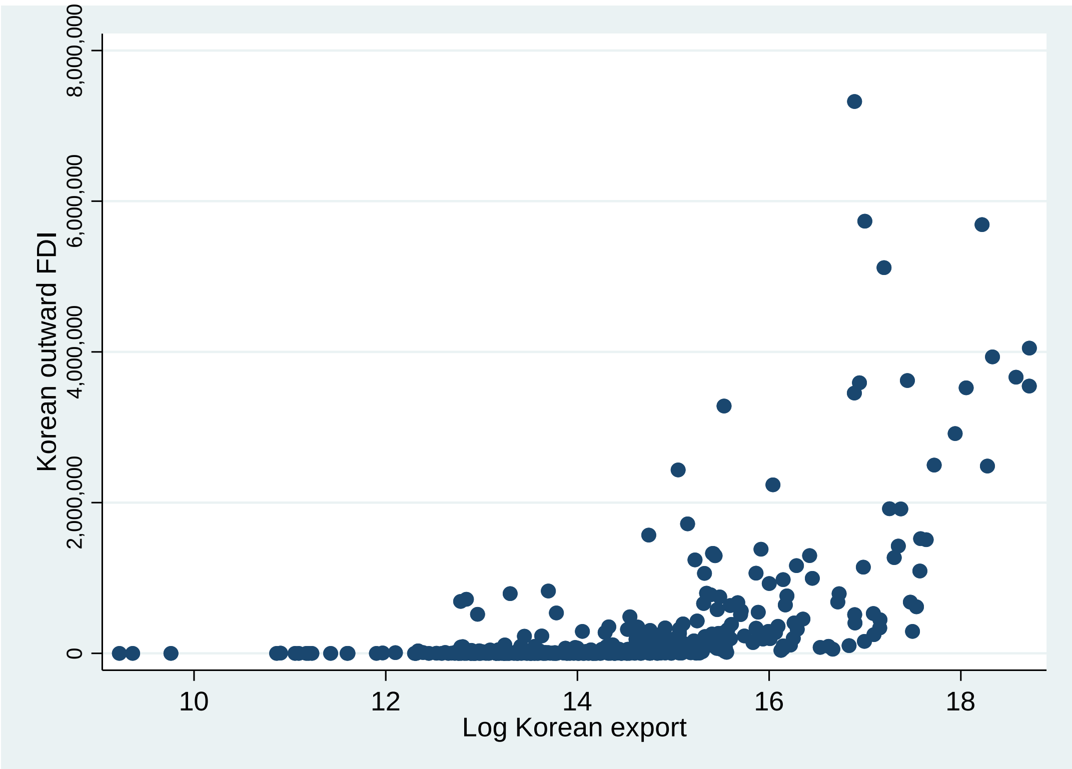


Figure 3.8: Outward FDI and Export (unit: KW billion)



4.3. Environmental Policy Stringency

The study will use the EPS of the OECD as a measurement of stringency of environmental regulations. It covers the period of 1990 to 2015[84]. Botta and Kozluk (2014) explain the structure and properties of the EPS. The EPS consists of two policies and six sub categories: (i) Market based policies (taxes, trading schemes, FITs, Deposit&Refund) (ii) Non-Market based policies (emission standard, R&D subsidies). Table 3.1 shows specific structure, indicators and weight. The process of constructing the EPS is the following. The first stage is that instruments related to each sub groups are chosen, which are policies to improve climate and air quality such as emission trading scheme (CO_2), CO_2 tax, Particulate matter emission limit value for newly built coal-fired plant and so on. The next is that value of each instrument is transformed to common tax rate value through using electricity price. The third step is that according to threshold based on distribution of the normalized values across countries, each value is classified into 7 phrases (from 0 to 6). Finally, the score of each instrument is aggregated by allocated weight: at first by similar type, at second by two groups (market and non-market) and then, composite index.

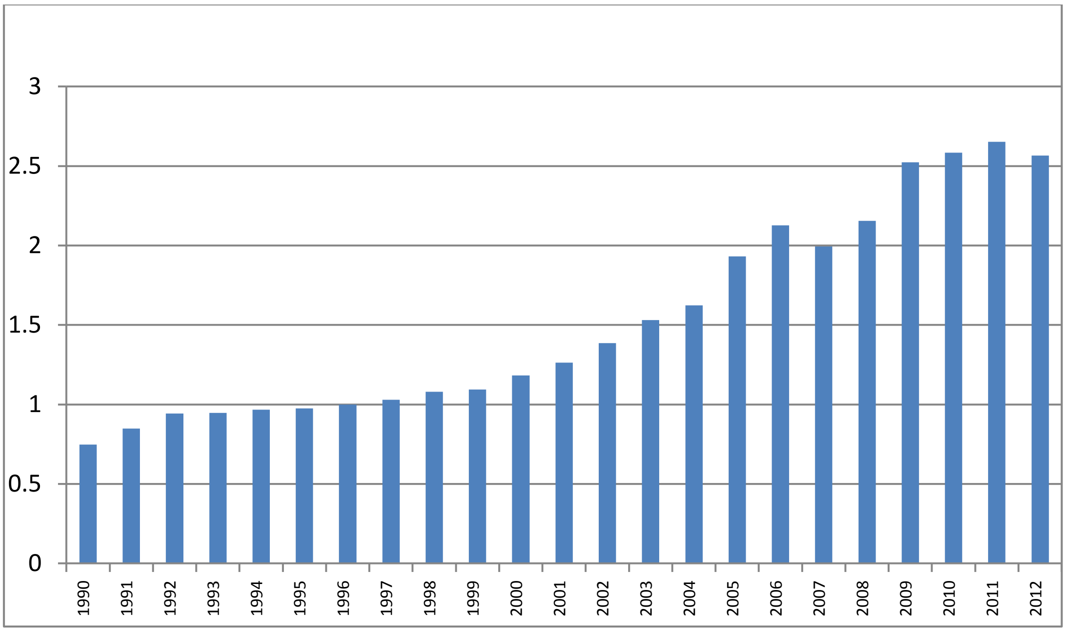
Botta and Kozluk (2014) show that such approach of the EPS has some advantages. First, the energy sector has taken similar important position in most of the OECD countries for long time. That is, it covers largest scope of time and country compared to other regulations. It means that useful panel data analysis is possible. Next, it is relatively easy to update the EPS because we just do check change of indicators' values of the EPS which are regularly published by the OECD or other international institutes. Third, because indicators of the EPS are concentrated on

[84] Twelve countries (Austria, Belgium and so on) however have data only until 2012.

climate and air polices[85], the EPS is very effective measurement when analysing influence of global trend (GHG mitigation) on economy.

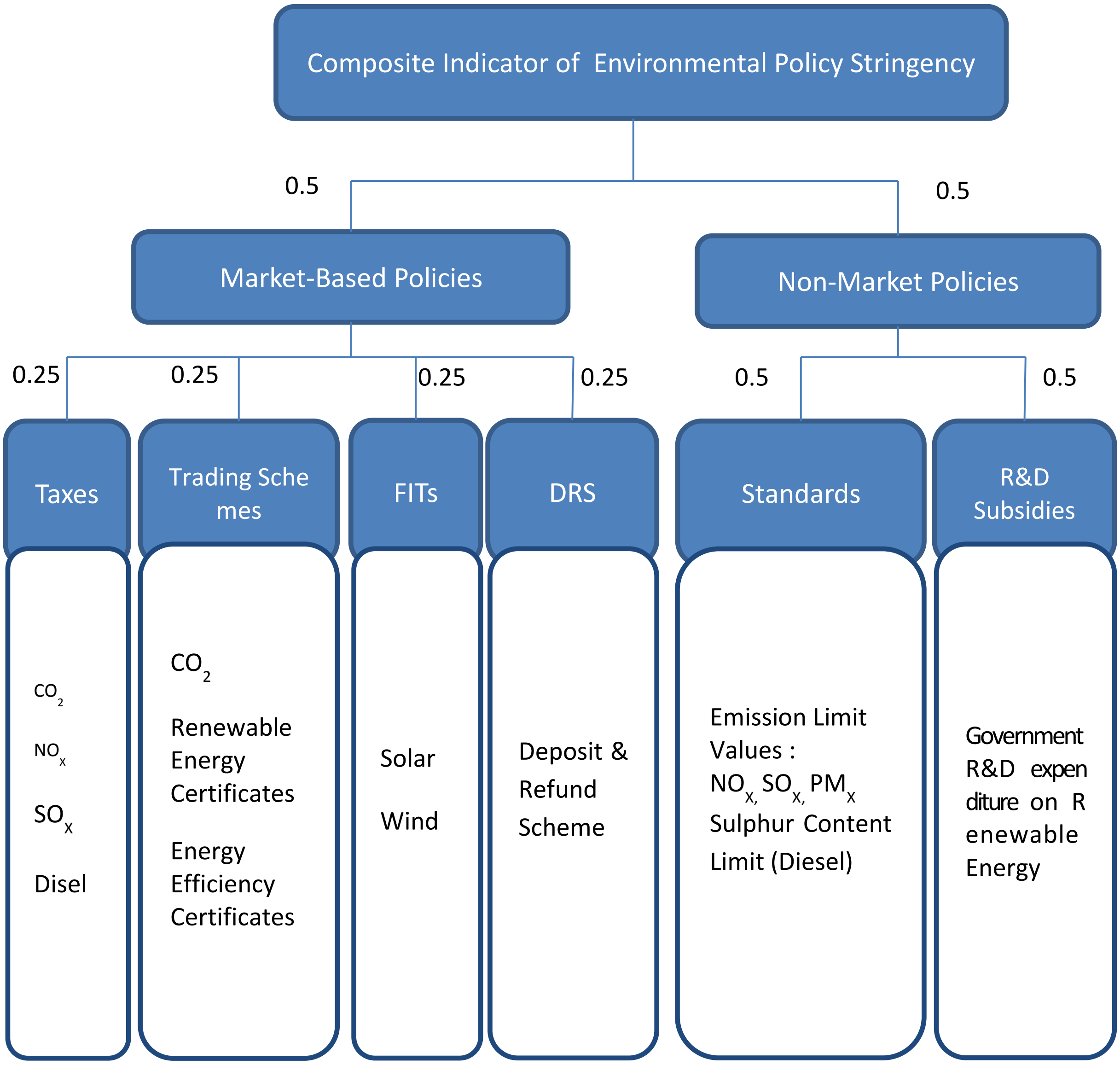
Figure 3.9 shows that average value of the EPS has increased during around twenty years, which is consistent with the fact that the OECD countries have faced increasing demand of citizen for better environment and have introduced tougher environmental regulations. Figure 3.10 indicates value of the EPSs of the OECD & the BRIICS countries in 2012 in sequence. Korea ranks 18 among thirty two countries, which means that Korea locates beneath the middle position in terms of the EPS and has similar value to average EPS (2.56). Figure 3.11 says that GDP per capita and the EPS has positive correlation, which represents high explanation of the EPS for environmental stringency considering that as mentioned already, the higher income is, the higher asking for improved environment is.

Figure 3.9: Average EPS of the OECD & the BRIICS countries (1990-2012)



[85] The sector has a very close connection to greenhouse gas emission which has been the hottest issue. Since Kyoto protocol, many developed countries have tried to mitigate GHG. After Paris agreement, even developing countries should make a contribution to arrive world target or their own goals of GHG decreasing.

Table 3.1: The structure of the EPS



(Source : the OECD)

Figure 3.10: The EPS in 2012

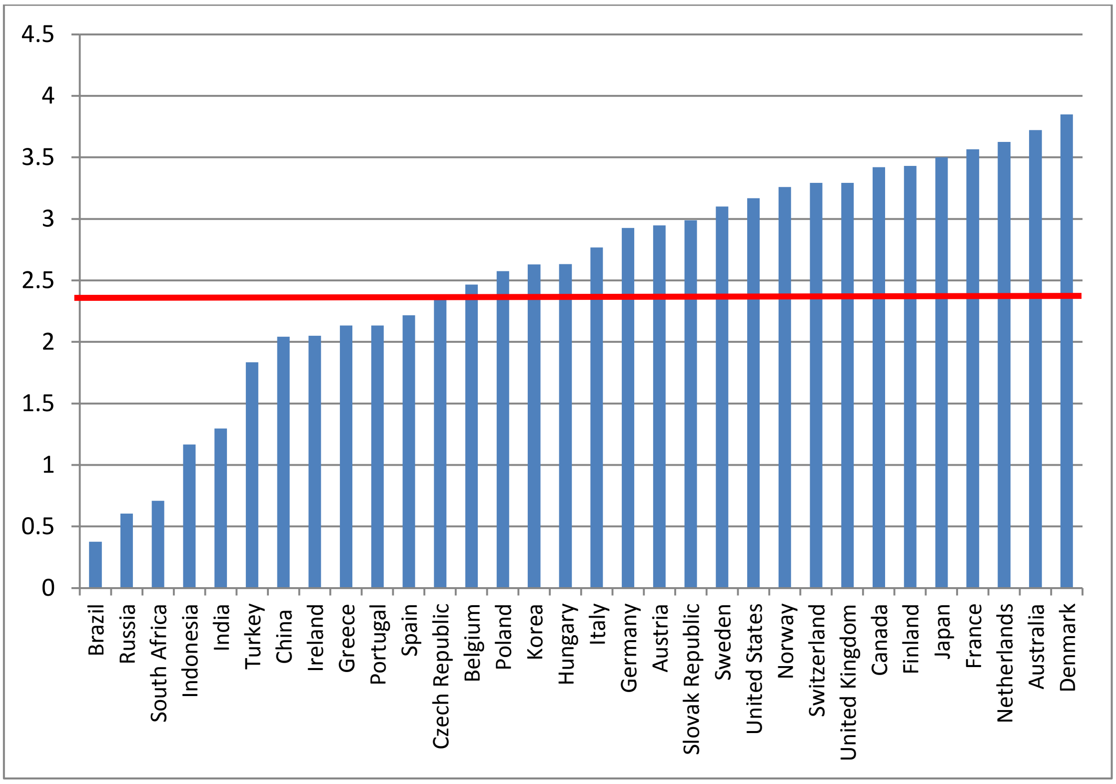
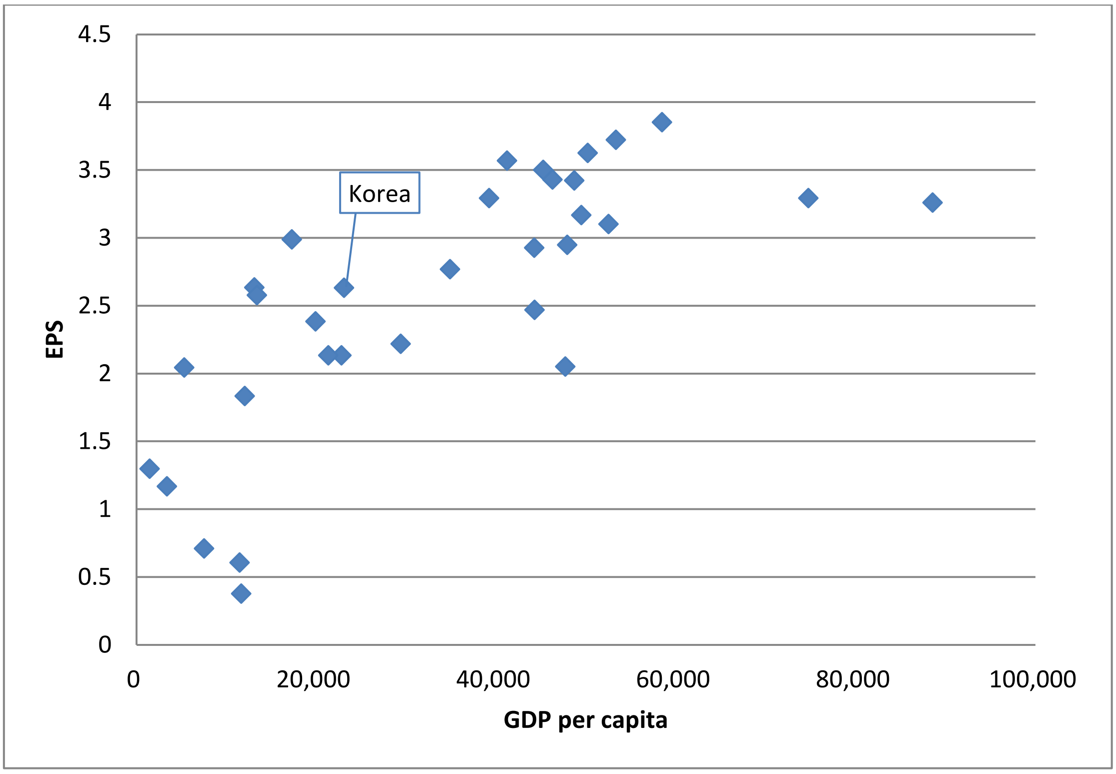


Figure 3.11: The EPS and GDP per capita in 2012 (unit: US dollar)



4.4. Physical and Human capital

[Physical capital]

In order to calculate the stock of physical capital, many papers use the perpetual inventory method. The study follows the equation used in Bernanke and Gurkaynak's (2001) method that Barro and Lee (2010) also employed[86].

[Human capital]

In terms of traditional concept, human capital is defined as the stock of competences and knowledge which are acquired through education and experience, and incorporated in the labour (Kim, 2004). That is, the definition of human capital is derived from production-oriented view. In a similar perspective, Rosen (1999) identifies human capital as "an investment that people make in themselves to increase their productivity". There however are some critics against measurement (using wage, education period. etc) of human capital on the base of the conventional term. First, such approach does not represent qualitative influences of human capital such as improvement of family health (Lewin *et al*., 1983; Woodhall, 2001). In addition, the way does not consider key indicators like social capital which affect human capital to some degree (Bassani, 2008).

Recently, therefore, more comprehensive measurement has been considered. Kwon (2009) strongly recommends that new measurement should include human development like UN Human development index (HDI). Following its idea, this study

[86] In the physical capital calculation method: $K_{i,0} = I_{i,1}/(g_{i,1}+\delta)$, where K_0 is the capital stock, I_1 is that capital flow at year 1 or the year after the initial year, g_1 is that 5-year average annual growth rate around year 1, and δ is the depreciation, which is assumed to be the same across countries (0.06) and which Barro and Lee (2010) set up. After excluding the first 5 years of capital stock estimates, the capital stock series is constructed using the perpetual inventory method: $K_{i,t} = g_{i,t-1}(1-\delta)+ I_{1,t}$

adopts the HDI which has an advantage of comparison across countries. HDI consists of 'life expectancy index', 'education index (Knowledge)' and 'GNI index' (Figure 4.11). It means that HDI is beyond traditional human capital concept[87].

Table 3.2 : Framework of Human Development Index

Dimensions	**Long and Healthy life**	**Knowledge**	**A decent standard of living**
Indicators	Life expectancy at birth	Expected years of schooling Mean years of schooling	GNI per capita
	↓	↓	↓
Dimension index	Life expectancy index	Education index	GNI index
	↘	↓	↙
		Human Development Index (HDI)	

(Source: UNDP)

[87] Barro and Lee (2013) also suggest the educational attainment information which is five-year interval dataset. However, because of year lag, missing data should be interpolated which could cause serious measurement error.

4.5. Data Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Korean outward FDI	416	327501.3	860473.9	0	7323099
Korean export	416	6385182	1.54E+07	10109	1.34E+08
Log GDP of Counterpart	416	20.34184	1.266966	17.42469	23.46682
Log Korean GDP	416	20.64784	0.15427	20.38082	20.87238
Log Population of Counterpart	416	17.21569	1.61379	14.50311	21.02389
Log Korean Population	416	17.69824	0.019687	17.66583	17.73152
Log Distance	416	8.926149	0.555675	6.858289	9.786563
Lagged EPS gap	403	0.565995	0.967981	-1.79167	3.104167
Human capital of Counterpart (Human development index)	416	8.23805	0.98333	4.94	9.42
Korean Human capital	416	8.60462	0.22701	8.2	8.91
RatioTariff (Counterpart /Korea)	416	0.664263	0.742419	0	5.896761
Log Capital of Counterpart	416	21.30201	1.367839	18.23607	24.35821
Log Korean Capital	416	21.81911	0.15899	21.54834	22.05243
ASEAN	416	0.007212	0.084716	0	1

5. Empirical Results

5.1. Estimates in terms of Korean outward FDI

Testing the relationship between FDI flow and environmental stringency is to analyse whether or not the Pollution Heaven Hypothesis (the PHH) is confirmed in real world. As known, if harsh environmental restrictions add significant burden (costs) on production costs enough to weaken competiveness of firms and industries, investors in business part would determine to move their plants to foreign countries with relatively lax environmental regulations. The opposite perspective is that rather, such stronger stringency would lead to increase of innovation and competitiveness which could offset raised costs and then result in profitability growth. Through chapter II, we checked whether or not the latter could happen in TFP of Korean manufacturing sector. The result was that the Porter hypothesis was rejected and the TFP of Korean manufacturing industry was decreased by tougher Korean domestic environmental stringency.

This chapter attempts to expand study range of chapter II toward difference of environmental stringency between Korea and host countries (the OECD & the BRIICS countries). Although domestic environmental restrictions would affect negatively firm or industry activity, if host countries have much tougher stringency level of environmental regulations, it is likely that Korean investor would not decide to move to the countries actively. It therefore is very meaningful that we try to consider level of environmental restrictions of host countries. For empirical estimation, we adopt the gravity model. According to econometric issues in section 3, we employed the Poission Pseudo Maximum Likelihood (PPML) method with panel data. Table 3.3 shows several results of the PPML model. Besides traditional variables, to consider some determinants of FDI, we add human & physical capital, tariff, and regional trade agreement. Through inserting or eliminating some variables, we could confirm that signs of basic variables of the gravity model are not changed. In terms of GDP and population of host countries, the values are positive and significant which is consistent with intuitive thinking. That is, increased market size and capacity are attractive factors for investors to consider, who want to get new market access. Because in PPML, a dependent variable is acknowledged as having a logarithm form, the coefficients of GDP and population could be interpreted as elasticity term. Specifically, in Colum (8), holding the other variables being constant, for a 1% increasing in GDP of host country, the difference in Korean outward FDI will be 1%. In terms of population, 1% increase will lead to 1.5% growth of the FDI, given the other variables are held constant.

The result displays negative sign of distance variables. It means that Korean investor have propensity to prefer closer region for investment. Human capital of host country has positive and significant signs across all models (Colum (1) – (8)). According to the fact that the Human development index (HDI), used as a proxy for human capital, represents not only knowledge stock but also living standards, the estimates show that Korean investors prefer countries with skilled workers and high living level. For tariff, the value represents ratio of host country tariff over Korean tariff. Its increase means that Korean goods which are imported to the host country faces increased trade barriers. In this case, Korean business investors could select FDI instead of export. That is, holding the other predictor variables constant, one unit increase (100%) of tariff ratio will cause 21.4%[88] difference in Korean outward FDI. All regional trade agreements have significant and positive values across Column (1)

[88] 0.214*100= 21.4%

– (8). Such results could imply that Korean investors might receive benefits of the trade agreements by reducing investment costs such as instability and information costs. Specifically, for APTA in Colum (8), holding the other variables being constant, APTA that entered into force between 2000-2012 on average have raised Korean outward FDI to APTA countries by 53%[89].

The most interest lies on lagged EPS gap variable. The main purpose of this study is to check whether or not change of the variable could lead to change of Korean outward FDI. The variable has positive and significant value across all models. It implies that expansion of the gap could cause increase of Korean outward FDI. Considering that the gap consists of Korea EPS minus Host country EPS, the widen gap means that Korea EPS increased relatively higher in comparison to host country EPS or the EPS of host country decreased relatively lower than that of Korea. Specifically, holding all other variables constant, for one unit increase of lagged EPS gap, there will be 14%[90] unit increase in Korea outward FDI. This result supports the PHH.

[89] [exp(0.430)-1]*100 = 53% (Yotov *et al*., 2016)

[90] [exp(0.131)-1]*100 = 14%

Table 3.3 : Estimations in terms of Korean outward FDI in the PPML

Korean outward FDI	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log GDP of Host country	0.947***	1.187***	1.087***	1.115***	0.909***	1.130***	1.023***	1.053***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log population of Host country	1.570***	1.499***	1.573***	1.431***	1.613***	1.573***	1.654***	1.518***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log Distance	-0.162***	-0.208***	-0.192***	-0.136***	-0.179***	-0.243***	-0.227***	-0.173***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Lagged EPS gap	0.157***	0.140***	0.144***	0.108***	0.168***	0.160***	0.165***	0.131***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital of Host country	1.599***	1.553***	1.617***	1.578***	1.717***	1.770***	1.846***	1.801***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log Physical capital of Host country	-1.540***	-1.698***	-1.656***	-1.572***	-1.552***	-1.728***	-1.686***	-1.607***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Tariff Ratio					0.119***	0.215***	0.221***	0.214***
					(0.000)	(0.000)	(0.000)	(0.000)
APTA				0.461***				0.430***
				(0.001)				(0.001)
ASEAN		1.102***	1.099***	1.407***		1.267***	1.270***	1.553***
		(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
EFTA			0.693***	0.524***			0.723***	0.564***
			(0.001)	(0.001)			(0.001)	(0.001)
Observations	403	403	403	403	403	403	403	403

note: ***; ** and * denote significance at the 1%, 5% and 10% respectively. ( ) is standard error. Fixed effects controlled.

5.2. Estimates in terms of Korean export

Table 3.4 displays results of Korean export. As mentioned previously, we applied the PPML model with panel data. This part show Korean export competitiveness along with change of lagged EPS gap. Like Korean outward FDI, GDP and population have positive and significant values across all models of Column (1) – (10). Such results are consistent with many previous papers and intuitional thinking that larger market size and income needs more imported goods such as mobile phone, car, intermediate goods and so on. Considering that export in PPML is considered as log export, when other variables are held, in Column (10), 1% increase of GDP and population of host country will lead to 0.4% and 0.8% increase of Korean export respectively. Distance is negative. It is natural that the longer the distance is, the larger the trading cost which decease export. Unlike Korean outward FDI, ratio tariff has negative values. It implies that because Korean goods face higher price along with increasing tariff in market of importing country, the export will be decreased. Specially, in Column (10), holding the other predictor variables constant, one unit increase (100%) of tariff ratio will lead to 14.2%[91] decrease in Korean export. Meanwhile, like Korean outward FDI, ASEAN helps Korean export increase. When other things being equal, ASENA which entered into force between 2010 and 2012 on overage have increased Korean export by 50%[92].

The main aim of this study checks influence of change of lagged EPS gap on Korean export. All Column shows positive and significant values. It implies that the

[91] -0.142 *100 = -14.2%
[92] [exp(0.406)-1]*100=50%

expansion[93] of the gap (Korean EPS – Importer EPS) leads to Korean export increase. The reason could be found in the properties of Korean export That is, as explained in section 3 (data description), intermediate goods export account for 63% in 2012. The goods export could be increased along with increased Korean foreign investment [94]because new established plants needs input goods from Korea. High correlation coefficient (0.5427) and graph of presenting relationship between FDI and export in section 3 also support our thinking[95]. Although the gap has positive values, however, we should not form a hasty conclude that Korean domestic environmental stringency must give benefits to Korean industries and economy. That is because each industry and each economic unit would face different influence. In addition, this study does not deal with trade performance (export and import). We should consider possibility that harsher Korean domestic environmental regulations could have a negative impact on trade performance[96].

Table 3.5 shows dynamic panel models in terms of Korean export. As mentioned previously, we could think that past export could affect current export (Kahouli & Omri, 2017). That is, once the firms set up distribution networks, personnel connections and branch offices & employees, they could not refrain from exporting goods. Moreover, consumers in importing countries are habituated to past imported goods, resulting in constant and/or increased export flow (Kahouli & Maktouf, 2015). It therefore is likely that companies will continue to export products

[93] Expansion could be caused by the case where holding importer EPS constant, Korea EPS increases while when Korea EPS is held, importer EPS deceases or where when two EPS increase, Korea EPS increase higher than importer EPS.
[94] Some papers argue that FDI promotes trade flows (Fukasaku *et al*., 2000; Rose and Spiegel, 2004; Driffield and Love, 2007).
[95] Lee *et al* (2012), Jae (2012) and Jun & Wang (2015) argue that Korean outward FDI affect positively Korean export.
[96] We will deal with the theme of relationship between Korean domestic environmental stringency and Korean trade performance in next chapter IV.

at the following year. Considering this pattern, we estimated dynamic panel models as well. All Hansen tests do not reject the null hypothesis (Ho: overidentifying restrictions are valid), which implies that overidentified model of system GMM is valid. All Arellano-Bond tests shows zero autocorrelation in first-difference errors. This means that difference and system GMM in Column (1) - (3) are an appropriate approaches. The results are the same at those of Column (10) in Table 3.4 in terms of sign and significance. The interesting result is the coefficient of Korean outward FDI of Column (3) in Table 3.5. When we explain increase of Korean export under the expansion of lagged EPS gap, we suggest that Korean export should be linked to Korean outward FDI. That is, we are based on the premise that Korean export could be affected by Korean outward FDI. The estimate of Column (3) in Table 3.5 indicates that Korean outward FDI has a positive and significant influence on Korean export. Through including Korea outward FDI in a model, the values are reduced except EPS gap.

Table 3.4 : Estimations in terms of Korean export in the PPML

Export	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log GDP of Host country	0.778***	0.616***	0.629***	1.235***	1.020***	1.058***	0.026***	0.043***	0.500***	0.467***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log population of Host country	0.195***	0.362***	0.352***	0.141***	0.281***	0.264***	0.913***	0.903***	0.876***	0.865***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Distance	-0.401***	-0.360***	-0.363***	-0.457***	-0.416***	-0.423***	-0.412***	-0.415***	-0.475***	-0.449***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Lagged EPS gap	0.269***	0.243***	0.244***	0.288***	0.259***	0.262***	0.247***	0.248***	0.272***	0.257***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Human capital							0.807***	0.801***	0.844***	0.737***
							(0.000)	(0.000)	(0.000)	(0.000)
Log Physical capital				-0.447***	-0.355***	-0.372***			-0.473***	-0.415***
				(0.000)	(0.000)	(0.000)			(0.000)	(0.000)
Tariff Ratio		-0.323***	-0.307***		-0.246***	-0.223***				-0.142***
		(0.000)	(0.000)		(0.000)	(0.000)				(0.000)
ASEAN	0.525***		0.280***			0.384***		0.480***	0.520***	0.406***
	(0.000)		(0.000)			(0.000)		(0.000)	(0.000)	(0.000)
Observations	403	403	403	403	403	403	403	403	403	403

note: ***; ** and * denote significance at the 1%, 5% and 10% respectively. ( ) is standard error. Fixed effects controlled.

Table 3.5 : Estimations in terms of Korean export in Dynamic panel model

Log Export	Difference GMM (1)	System GMM (2)	System GMM (3)
Lagged Log Export	0.082***	0.112***	0.084***
	(0.021)	(0.022)	(0.029)
Log Korean outward FDI			0.092***
			(0.014)
Log GDP of Importer	0.627***	0.583***	0.420***
	(0.182)	(0.197)	(0.146)
Log Population of Importer	0.605***	0.691***	0.571***
	(0.123)	(0.136)	(0.104)
Log Distance	-0.548***	-0.533***	-0.504***
	(0.014)	(0.016)	(0.016)
Lagged EPS gap	0.049*	0.114***	0.142***
	(0.027)	(0.025)	(0.038)
Human capital of Importer	0.347***	0.442***	0.369***
	(0.116)	(0.127)	(0.092)
Tariff Ratio	-0.193***	-0.295***	-0.275***
	(0.035)	(0.028)	(0.035)
Log Physical capital of Importer	-0.373***	-0.434***	-0.330***
	(0.045)	(0.053)	(0.050)
ASEAN	0.335***	0.336*	0.171
	(0.120)	(0.201)	(0.139)
Observations	390	403	358
Hansen test	12.61	12.61	7.38
	1	1	1
Arellano-Bond test			
First order	-3.44	-3.4367	-3.1886
	0.001	0.0006	0.0014
Second order	-0.75	-1.4345	-0.20004
	0.454	0.1514	0.8414

note: ***; ** and * denote significance at the 1%, 5% and 10% respectively. ( ) is robust error. Industry and year effects controlled.

6. Conclusions

This chapter wanted to analyse whether or not change of lagged EPS gap could affect Korean outward FDI and Korean export. The main focus lies on Korean outward FDI because the effect could show whether or not the Pollution Heaven Hypothesis is valid in Korean case. We adopted the gravity model to find out the evidence because the model has strong power to explain real phenomenon in in economy world. To deal with important problems (the zero and heteroscedasticity problems) of the gravity model, we employed the Poisson Pseudo Maximum Likelihood (PPML) model. Using panel data in 2000-2012, this study found out some significant results of Korean outward FDI in the OECD & the BRIICS countries.

Most of all, the results of the PPML model for Korean outward FDI showed that the expansion of lagged EPS gas would lead to increase of the FDI. It implies that because of relatively higher stringency of Korean environmental regulations in comparison to host countries, Korean investors would prefer host countries to Korea. The reason is that harsh Korean environmental restrictions could give more burden and cost increase on Korean business sector. Through the estimates, we could think that the PHH is valid in Korean case.

For Korean export estimation, we also used the PPML. The results showed that GDP and population have positive and significant values while tariff and distance affect negatively Korean export. The influence of lagged EPS gag has positive and significant values. It means that relatively tougher Korean environmental stringency could lead to Korean export increase. We found out the reason on the premise that the Korean export could be affect by Korean outward FDI. That is, increased lagged EPS gap would cause increase of Korean outward FDI in host countries. Then, expanded or new cooperation and plants in host countries need more intermediate goods from Korea. Through the fact that most of export consists of intermediate goods, decent value of the correlation coefficient (0.54) between Korean outward FDI and Korean export, and significance of Korea outward FDI in system GMM on Korean export, we could confirm the connection.

The policy implication is as follows. Because the PHH in Korean outward FDI could reduce economic potential and job while the increased Korean export does not always confirm improved trade performance and economic growth[97], the Korean Government should scrutinize meticulously relative stringency of Korean environmental regulations in comparison to level of host countries. Then, it should not raise excessively the stringency more than host countries, and try to find out appropriate point to satisfy both industry & country competitiveness and environmental clean level. In addition, the Korean Government should try to transform too domineering & compulsory regulation system into market friendly methods which would not excessively distort firms' management and expel plants toward other countries.

[97] Even though Export volume (million US dollar) has expanded from 162,470 (2002) to 555,214 (2011), rather, Economic growth rate (%) has been decreased : 7.4 (2002), 3.7 (2011) and Unemployment rate (%) has not been improved : 3.3 (2002), 3.4 (2011).

CHAPTER IV

The Effects of Korean Domestic Environmental Regulations on Korean Trade Performance in Korean Manufacturing Industries

1. Introduction

With scarce resources and a dense population, Korea has placed particular emphasis on the expansion of export since the early 1960s in order to overcome poverty and to accelerate economic growth. The Asian financial crisis in 1997-8 cast new light on the increasing export. Before the crisis, it was thought that only an increase in exports could lead to development of the Korean economy. The shortage of foreign exchange holdings at the time of the crisis; however, threw emphasis on the level of net exports (trade performance). It was believed that even though exports were growing annually, that the faster import growth might have a negative effect on the sustainable growth of the Korean economy. After the crisis, the aims of trade surpluses became major trade policies. Meanwhile, some analyses and papers[98] were apprehensive of increasing stringency of environmental regulations in Korea. In particular, there were concerns that such environmental restrictions could have negative effects on the achievement of the Korean Government's trading aims, namely export expansion and trade surpluses.

In chapter III, we analysed the influence of relative difference of environmental stringency between Korea and Korean goods importing countries on Korean export. Such approach could suggest two further studies. One is to study Korean trade performance. The other is to focus on the effect of Korean domestic environmental stringency per se on trade. To deal with two themes, this chapter is to test the relationship between Korean domestic environmental regulations and trade performance. That is, the main aim of this chapter is to show whether or not domestic environmental restrictions will have a significant effect on Korean trade performance. An outcome of this work should provide important information for establishing appropriate trade and economic policies.

In the Korean case, few papers deal with the relationship between domestic environmental regulations and Korean trade. Kim (1997, 2001, 2004) sought to find the relationship although he used only cross-sectional data. He found the negative influence of environmental regulations on Korean export. Song & Sung (2014) also tried to analyse the relationship in terms of thirteen industries. Unlike Kim, using panel data in 1991-2009, they established a dynamic equation with pollution abatement capital expenditure which they created. Employing difference-GMM of Arellano & Bond (1991), they found that environmental stringency has a positive effect on Korean export, supporting for the Porter Hypothesis.

[98]Korean Prime Minister's Office (2015, 2016), Lim (2004), Lim & Oh (2007).

Considering components of the equations of Levinson & Taylor (2008) and Song & Sung (2014), this study will establish a dynamic panel model using environmental protection expenditure (the EPE) which is officially surveyed by Ministry of Environment. Employing difference-GMM, I found that stringency of Korean domestic environmental regulations has a negative influence on Korean trade performance (export/import ratio). The result is different from that of Song & Sung (2014). We believe that the discrepancy might be due to proxy for environmental stringency and time range. As I am aware, this study is the first thesis using industrial official costs for environment and the latest data.

The order of this chapter is as follows. The next part introduces other papers in the literature that report research on the effects of trade determinants, including stringent environmental regulations, on trade. Section 3 explains dynamic panel model and the estimation methods. Section 4 describes a panel data-set, consisting of nine sectors and covering the period 2006 to 2014. Section 5 presents the results of the estimations, and finally, section 6 puts forward conclusion including policy suggestions for the Korean Government.

2. Literature Review

Analysing the connection between environmental regulation and trade performance can be considered as a process of carrying out empirical tests and checking their trade outcome, where green regulatory costs might increase the production cost of regulated firms, resulting in an elevated price of their goods and potentially a reduction in their trade competitiveness. Therefore, it is desirable for the environmental regulatory costs to be regarded as one of the determinants of trade performance (Kalt, 1988).

For the purpose of this study, a regression model was created, where the dependent variable was trade performance, while the explanatory variables consisted of all the trade determinants, including environmental regulation. A review of the papers dealing with the relationship between trade and the trade determinants helped identify the most appropriate regression model for this analysis. Papers dealing with the effect of environmental regulations on trade flow could be divided into two sets of papers: (1) those concerning domestic (Korean) environmental restrictions, and (2) those considering the differences between the environmental regulations of countries other than Korea. Both parts provided important motivation and ideas for this study. Second set of papers was already dealt with in chapter III. In this chapter, we will focus on the first set of papers.

2.1. Focusing on Domestic Environmental Regulations

Kalt (1988) regarded domestic environmental regulation as one of the determinants of trade. That is, governmental environmental intervention levies additional production costs on the regulated firms, resulting in higher costs, which could hamper the competitiveness of affected companies in export markets. In order to establish a trade component model that included environmental regulation, Kalt (1988) borrowed the frameworks developed by Branson & Monoyios (1977) and Stern & Maskus (1981). Kalt added pollution abatement costs as a proxy variable of the stringency of environmental intervention into the four-factor trade model. The results showed that the environmental regulatory costs negatively and significantly affected the US's net export figures. In addition, using the method proposed by Leamer (1980), based on Vanek's generalised Hecksher-Ohlin theorem, Kalt found that, in 1977, environmental resources in the US were an insufficient factor relative to the other input factors. That is, environmental regulation was regarded as a source of comparative disadvantage in the US. Kalt's model might be reasonable, because the introduction of pollution abatement costs did not contravene the widespread research results concerning the character of unskilled labour, capital, human capital and R&D as determinants of trade structure. Intuitively, the cost caused by new regulations should be separable from other capital costs directly linked to production.

Borrowing Kalt's (1988) idea and model, Kim (1997) considered environmental regulatory costs to be one of the major determinants of Korean trade performance and then showed the impact of pollution intensity on international competitiveness using 1993 Korean cross-sectional data. He found that those industries that employed more environmental resources had a higher comparative advantage, which implied that Korean firms are endowed with more abundant environmental resources than other countries. Kim (1997) also showed that Korea's environmental regulation level could be considered to be excessively generous compared to Korea's real environmental capacity, which then distorts the inter-industry comparative advantages. Kim (2002**)** expanded the initial analysis through including the 1998 Korean cross-sectional data. Later, Kim (2004) tried to improve the estimation of the pollution abatement and control cost by using PAC consisting of four costs (i.e. operation, investment, opportunity and transfer costs), compared to earlier models (e.g. Kim, 2002) that were made up of only three costs (i.e. operation, investment and opportunity costs). The results of both studies were similar to the results of Kim (1997). The main contribution that Kim (1997) made to the field was to take the environmental factor into account in analysing Korean trade achievements. Nevertheless, because of the limitation of the cross-sectional data, it did not show the effects of changes in the environmental regulations on trade performance.

Grossman & Krueger (1991) evaluated whether or not the pollution abatement costs in the US manufacturing sector had a significant effect on US imports from Mexico or on US investment in Mexico. They believed that if the environmental regulations were more stringent in the US than in Mexico, then US producers could lose their competitive advantage, which may lead to them moving to Mexico. For the estimations, they established a regression model, where one dependent variable was the imports from Mexico and the explanatory variables consisted of production factors, tariffs and the pollution abatement cost faced by US manufacturing industries. The result of their cross-sectional analysis in 1987 showed that the PAC did not affect US imports from Mexico. Even in terms of imports by maquiladoras[99], they did not find a significant positive effect of the PAC. It is worth noting that they suggested calculating each variable and considered tariffs as one of the key import determinants because the tariffs could distort the price of foreign goods. However, it is likely that the use of cross-sectional analysis and endogenous issue of the environmental regulations put a limitation on attempting to capture the exact relationship between the PAC and imports.

Ederington & Minier (2003) hypothesised that environmental restrictions could serve as a second trade barrier. That is, they believed that just as trade is a function of the environmental regulations, so the stringency of the environmental control measures is dependent on trade performance. In other words, unlike previous studies that regarded the policies as exogenous, Ederington & Minier considered that the stringency of the environmental control measures could be decided endogenously.

[99] A maquiladora is a manufacturing firm in a free trade zone in Mexico, which can import equipment and resources without tariffs, and which then exports products.

Moreover, to capture the unobservable effects, they employed panel data. For a trade function, they used Grossman & Krueger (1991)'s model, where:

$$M_{it} = \mu_i + \mu_t + \beta_1 t_{it} + \beta_2 \tau_{it} + \beta_3 F_{it}^n + \eta_{it} \qquad (4.1)$$

where M_{it} is net imports (imports minus exports) scaled by domestic production, t_{it} measures the stringency of the environmental regulations in industry i at time t, τ_{it} is the industry-level tariffs, F_{it}^{n}[100] is the production factor variables, and μ_i and μ_t control the industry and time specific effects.

The environmental regulation function employs previous empirical research results. For instance, Trefler (1993) believed that the openness of trade cannot be determined exogenously and should be determined endogenously. That is, the level of trade protection is affected by the net imports, unemployment, unions, growth and the number of firms. Ederington & Minier considered the variables as the determinants of environmental regulations, e.g.

$$t_{it} = \alpha_i + \alpha_t + \delta_1 \tau_{it} + \delta_2 M_{it} + \delta_n P_{it}^n + \varepsilon_{it} \qquad (4.2)$$

where M_{it} is the industry-level net imports, P_{it}^n is a vector of the political economy variables (such as unemployment and the number of firms), α_i is an industry-specific indicator variable, and α_t is the time dummy variable to capture the effect of economy-wide trends in environmental regulations over time. Through this new approach, Ederington & Minier showed that there is positive relationship between net imports and the stringency of environmental policies. The contribution of their paper

[100] It is recognised by empirical trade economists that cross-industry regressions of trade flows on factor intensities are not a valid test of the Heckshert-Ohlin model of international trade. The motivation for including factor intensity variables in the regression is simply to act as industry controls to better address the relationship between environmental regulations and trade flows.

was to show that environmental regulations could be endogenous and that some dummy variables (i.e. industry and time) should be included to capture the unobservable effects, which could otherwise distort the estimation if not captured.

Antweiler *et al*. (2001) also showed that environmental regulations are affected by trade flow. Their original research aim was to investigate whether or not international trade had an effect on pollution intensity. They utilised an improved theoretical model to classify the influence of international trade on sulphur dioxide intensity into scale, composition and technique effects. Then, they estimated the theoretical equation by employing panel data, which allowed them to analyse the scale effect and technique effects separately. They showed that a trade-induced expansion of economic activity (i.e. a scale effect) and an increase in the capital ratio to labour (i.e. a composition effect) could lead to an increase in the pollution intensity, while trade-raised increases of GDP per person lead to stricter environmental regulations, resulting in a reduction in pollution emission intensity (i.e. a technique effect). Overall, the mixed effect result says that trade liberalisation is good for the environment.

Levinson & Taylor (2008) established a theoretical estimation model to analyse the influence of the stringency of environmental regulations on trade flows. In the model, they assume that even though pollution is produced as a by-product, the output can be a Cobb-Douglas framework of pollution and production factors (i.e. labour and capital), since companies distribute some of their factors to abate the pollution. Therefore, production costs also consist of pollution abatement costs and factor costs. Levinson & Taylor thought that if a home country’s cost is less than the foreign country’s cost, then the home country will produce and export more, and so they derived a criteria point to determine the level of exports and imports, and which was dependent on the costs and environmental regulations of the home and foreign countries. Then, they created the following model by using the definition of a criteria point:

$$N_{it} = \alpha_0 + \alpha_1 s_{it} + \alpha_2 C_{it}^{F} + \alpha_3 C_{it}^{F*} + \alpha_4 \tau_{it} + \alpha_5 \tau_{it}^{*} + \varepsilon_{it} \quad (4.3)$$

where N_{it} is the net imports scaled by production. $s_{it}$is the home country's share of world spending in sector i and time t, C_{it}^{F} is the home country's factor costs and τ_{it} is the home country's pollution taxes, and where * means foreign country. For an empirical test, Levinson and Taylor replaced the variables in the above equation with observable tariffs and pollution abatement costs, and inserted industrial and time dummies in to the model to capture the unobservable effects:

$$N_{it} = \beta_0 + \beta_1 \theta_{it} + \beta_2 T_{it} + \sum_{i=1}^{n} \alpha_i D_i + \sum_{t=1}^{T} d_t D_t + e_{it} \quad (4.4)$$

where θ_{it} is the pollution abatement cost and T_{it} is the tariffs, and *Di* and *Dt* are the industrial and time dummies. Levinson and Taylor also assumed that the pollution abatement costs are endogenous. Then, they employed income and pollutant emissions as instrumental variables. Their results showed that there is positive relationship between pollution abatement costs and net imports. It is worth noting that they also provided a theoretical model for testing the pollution haven effect.

Song and Sung (2014) tried to analyse the relationship between stringency of domestic (Korean) environmental regulations and Korean export performance in terms of thirteen industries. Using panel data in 1991-2009, they established a dynamic equation assuming that filed lagged trade performance has an influence on present trade results. The model consisted of pollution abatement capital expenditure (costs of installing equipment for preventing pollution), physical capital and human capital as explanatory variables. Employing difference-GMM of Arellano & Bond (1991), they found that environmental stringency has a positive effect on Korean export, supporting for the Porter Hypothesis. It is notable that unlike previous Korean papers dealing with partial equilibrium analysis, they use panel data, establish dynamic model and then apply difference-GMM to consider unobserved characteristics, dynamic adjustment of economic activity and endogenous problems. Such approach gives this study insight for using dynamic panel model. Pollution abatement capital cost however, is artificially created by authors. Specifically, they use 5 year interval survey data collecting investment plan and then multiply this data by capital price[101] related to environmental capital, which obtained by dividing net value-added by the real value of tangible assets (Lee, 2007; Lee, 2011 [102]). That is, unlike pollution abatement cost of the US, the cost is not officially announced by the Korean Government. In addition, it does not reflect operation costs for environmental equipment. It therefore is likely that the cost could not comprehensively represent a burden which Korean industries face.

Lee (2013) attempted to check whether or not increased power rate and fuel price affect output price in Korean manufacturing sectors (Chemical products, Basic metals, and TV & communication equipment). Although Lee's study does not deal with trade performance, we can refer to how increased production costs led by the Korean Government have effects on output price. The finding is that increased fuel price results in increase of output price. Through Lee's study, we know that the

[101] Physical capital is created by similar method to calculation of pollution abatement capital costs.

[102] Lee (2007, 2011) analysed effects of environmental regulations on Korean manufacturing productivity. Lee showed how to calculate physical capital and pollution abatement capital costs.

Korean Government led production costs could have a negative influence on market competitiveness of Korean industries by way of increasing output price

2.2. Conclusions

After careful consideration, we would refer to the component of Levinson & Taylor and Song & Sung (2014). Specifically, trade performance (export/import ratio) will be dependent variable. Lagged dependent variable, traditional factors (physical and human capital), tariff and some factors which might affect trade intuitionally will be comprised of as explanatory variables. In terms of estimation method, to deal with a dynamic panel equation, different GMM will be used. Then to test the appropriation of the model, overidentified and Arellano-Bond test will be done.

3. Econometric Specification & Estimation Method

3.1. Specification of Dynamic panel model

As mentioned previously, we study will create our own dynamic panel model which has lagged dependent variables as ones of explanatory variables. Intuitively, we could think that companies refer to past export and import patterns and networks when deciding current trade volume (Kahouli & Omri, 2017). That is, the companies already established distribution networks, personnel connections and branch offices & employees which could be called as barriers to entry and exit under irremediable situation. They therefore could not stop export and import. In addition, consumers in domestic and foreign countries are already familiar with imported goods, leading to ceaseless and increased trade flow (Kahouli & Maktouf, 2015). It therefore is likely that companies will continue to export and/or import products at the following year.

Finally, we can conclude that past trade flow is a basis for current international business activities (Kahouli & Omri, 2017).

For other determinants of trade, we will refer to components of Levinson & Taylor (2008) and Song & Sung (2014). The equation of Levinson & Taylor (2008) is the following.

$$N_{it} = \alpha_0 + \alpha_1 s_{it} + \alpha_2 C_{it}^{F} + \alpha_3 C_{it}^{F*} + \alpha_4 \tau_{it} + \alpha_5 \tau_{it}^{*} + \varepsilon_{it} \qquad (4.5)$$ [103]

where N_{it} is the net import scaled by production, C_{it}^{F} is the typical production cost (labour and capital), $C_{it}^{F*}$is the foreign production cost, $\tau_{it}\ and\ \tau_{it}^{*}$ are the pollution tax at home and in the foreign country, and ε_{it} is both an approximation error and a standard measurement error. For the empirical test, Levinson and Taylor replaced the variables of equation (4.5) with the observable variables and dummy variables. They applied the pollution abatement costs(θ_{it}), which are scaled by the value added to represent τ_{it} of equation (2.7). Likewise, they used a tariff rate (T_{it}: the ratio of duties paid to customs value) to capture the effects of C_{it}^{F*}. Except for the tariff rates,. In terms of C_{it}^{F}, they did not consider specific costs because they believe that traditional costs (i.e. labour and capital) adjust slowly over time. Instead, they assumed that the industrial fixed effects reflect the effect of C_{it}^{F}. In addition, Levinson and Taylor believed that sector and time dummies could be used to capture changes in the unobservable elements ($\text{i.e.}\ s_{it}, \tau_{it}^{*}$). In the equation of Song & Sung (2014), they expressly include physical and human capital as determinants of Korean export. Their model consists of export as a dependent variable, physical and human capital, and pollution abatement capital costs as explanatory variables.

[103] See Appendix 13 for the detailed theoretical derivation.

In the study, we will create our own dynamic panel model using trade performance (export/import ratio) as a dependent variable, is selected in order to consider importance of export relative to import.

$$\frac{Export}{Import}\ ratio_{\mathrm{it}}$$

$$= \beta_0 + \beta_1 \frac{Export}{Import}\ ratio_{\mathrm{it}-1} + \beta_2 ln\ \text{physical capital per output}_{\mathrm{it}}$$

$$+ \beta_3 ln\ \text{human capital per output}_{\mathrm{it}} + \beta_4 ln\ \text{EPE per output}_{\mathrm{it}-1}$$

$$+ \beta_5\ industrial\ export\ ratio_{\mathrm{it}-1} + \beta_6\ Size_{\mathrm{it}} + \beta_7\ tariff_{\mathrm{it}}$$

$$+ \beta_8\ industrial\ real\ effective\ exchange\ rate_{\mathrm{it}} + \theta_i + \theta_t + \mathrm{e}_{\mathrm{it}}$$

(4.6)

where i is industry and $\text{physical capital per output}_{\mathrm{it}}$ is calculated by using industrial capital stock, scaled by output. $\text{human capital per output}_{\mathrm{it}}$ is calculated through multiplying employee by average wage[104] in each industry (Lee, 2007; Lee, 2011; Lee, 2013). $industrial\ export\ ratio_{\mathrm{it}-1}$ represents importance of i industry in terms of manufacturing at t-1. It is calculated by i industry export over total manufacturing industry exports (Shin 2007). If i industry has high portion of total manufacturing sector at t-1, it would has increased export at current year. We therefore guess positive sign. $Size_{\mathrm{it}}$ shows portion of firms with more than 300 employees in i industry.

Considering that the firms have export potential, the sign will be positive. $tariff_{\mathrm{it}}$ is a barrier of import leading to positive sign of $\frac{Export}{Import}\ ratio_{\mathrm{it}}$. $industrial\ real\ effective\ exchange\ rate_{\mathrm{it}}$ is said to be relative price of export and import. The sign is likely to be dependent on reactivity of export and import to change

[104] To consider high level wage which skilled workers could receive, we used average wage of firms with over 500 employees which is larger than total average wage.

of exchange rate. The most interest lies on EPE per output_{it-1}. To avoid a concern that $\frac{Export}{Import}\ ratio$ is endogenous related to EPE_t, we will employ lagged EPE_{t-1}.

3.2. Estimation Method

As mentioned in Chapter II, in dynamic panel model, there should be correlation between the variables and error term violating condition for consistent estimators. To solve the problem, both difference GMM and system GMM are recommended. The two models however, must pass two tests to be used: Sargan test and Arellano-Bond test. The former checks whether or not overidentified model of GMM is valid. If the condition is not satisfied, we cannot use GMM. The latter test autocorrelation of error term. If the null hypothesis (no autocorrelation) at first order is rejected or accepted while the hypothesis at second order is not rejected, using lagged level and difference variables as instrumental variables are correct. In this chapter, we will employ system GMM. In Stata, xtdpdsys is for system GMM.

4. Data Description

The empirical equation consists of export, physical capital, human capital, environmental protection costs, tariff and industrial real effective exchange rate. Information on each variable is available from the Korean Government, the Bank of Korea and the OECD. Like Chapter II, the panel data-set consists of 9 industries and covers the period 2006-2014.

4.1. Trade Data

To obtain annual trade data in the period 2006-2014, we utilised the export data from the Korea International Trade Association (KITA). However, as the information from

MKE and KITA followed the goods category system, reclassification in terms of industry was needed to fit the data to other data. Its classification follows three code criteria: the Harmonised System of Korea code (HSK), the Ministry of Trade and Industry code (MIT) and the Standard International Trade Classification code (SITC). We utilised the HSK code, which consisted of over 500 commodities, mostly because its grouping was most similar to the industry category. The last task was to distribute the data from 6,500 goods in the 2006-2014 sample into the relevant industry categories following classification system of environmental protection expenditure (The EPE).

The Korean trade data in 2006-2014, in terms of real price[105], shows that exports increased rapidly until 2008 due to the boom in the world economy – for example, the volume ($386,575 million) of Korean exports in 2008 was almost double to the figure ($172,268 million) in 2000. In 2009, however, export went down sharply by 13.9% because of the US and Europe financial crisis, and world economic recession from the risk. Korean export restarted from 2010. Recently, the volume of export represented static increase.

With regard to the data, manufacturing sector exports accounted for average 91% of the total export volume in 2006-2014. Therefore, the change in competitiveness of the manufacturing sector had a great impact on Korean export performance. Figure 4.1 shows that over the 2006-2014 period, manufacturing, exports and total were positive. As mentioned above, the blip in 2009 is due to the US and Europe financial crisis.

[105] Base year is 2010 (100).

The analysis of each industry sector's export/import shows that mainly 'transport' industry had the highest value in 2006-2014. In addition, 'coal, petroleum, rubber, plastic' and 'machinery, computer, electronic equipment' experienced relatively better values than other industries. From the graph, we could think that 'transport', 'machinery, computer, electronic equipment' and 'coal, petroleum, rubber, plastic' were the most important goods in the Korean exports.

Figure 4.1: Export Data in 2006-2014 (unit: USD million)

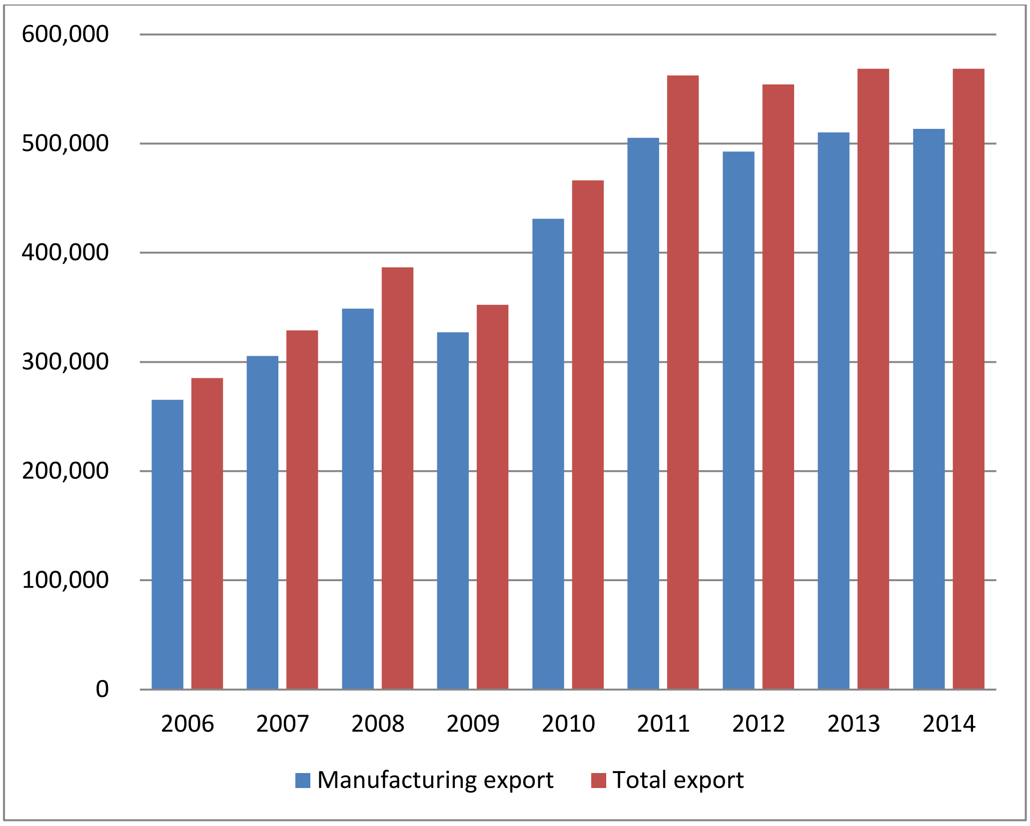
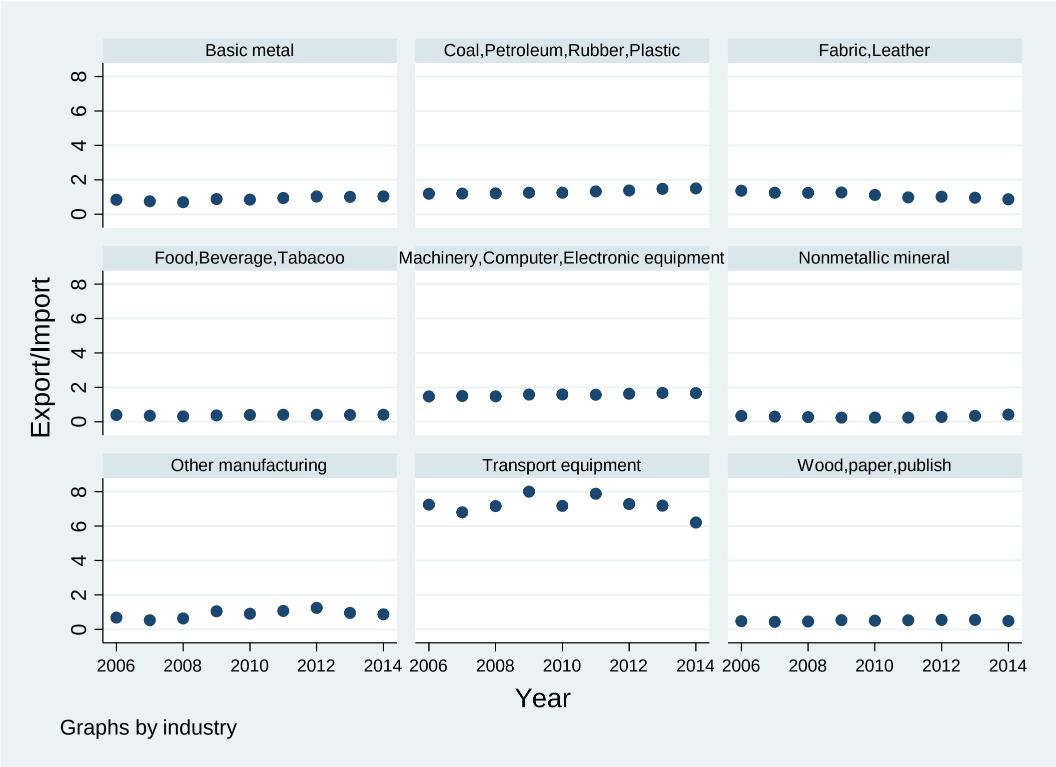


Figure 4.2: Export/Import in terms of Industry in 2006-2014



4.2. Industrial Real Effective Exchange Rate

The industrial real effective exchange rate (the IREER) measures the weighted average value of a country's currency relative to the currencies of its major trade partners. The rate is adjusted for the effects of inflation of countries. The weights are dependent on the relative trade balance between the country and other countries. Goldberg (2004)[106] presented a method for creating the IREER. By using Goldberg (2004), Lee & Lee (2005) and Bang (2010) were able to determine the Korean industrial real effective exchange rates and to then analyse the relationship between Korean exports and this exchange rate. They reported that the exchange rate had an important role in increasing exports before 1999, but after 2000, it had little influence on changes in exports.

[106] See Appendix 14

For determining the IREER, like Lee & Lee (2005) and Bang (2010), this study employed the export-weighted way of Goldberg (2004), in order to consider exports, using the formula given in equation 2.12:

[Trade-weighted]

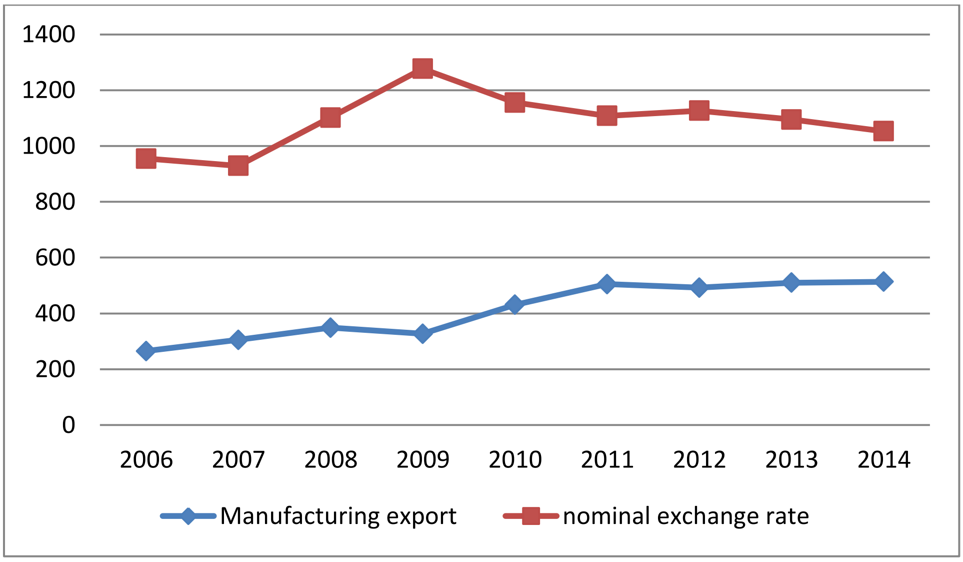
$$xer_t^i = \sum_c [(\frac{x_t^{ic}}{\sum_c x_t^{ic}}) * rer_t^c] \qquad (4.7)$$

where x_t^{ic} is the exports of sector i to the trading counterpart c at time t and rer_t^c is the bilateral real exchange rate of each Korean trading partner c.

For selecting the set of trading partners with Korea, 11 countries[107] were chosen, based on the trade volume in 2014. Figure 4.3 shows the relationship between manufacturing exports and nominal exchange rate. We can identify that there is a little negative relationship between them. It implies that unlike general thinking, increasing exchange rate could give negative influence on export. The correlation coefficient is -0.17.

Figure 4.3: Exchange rate and Exports in 2006-2014

(exchange rate: KW one, trade : USD billion)

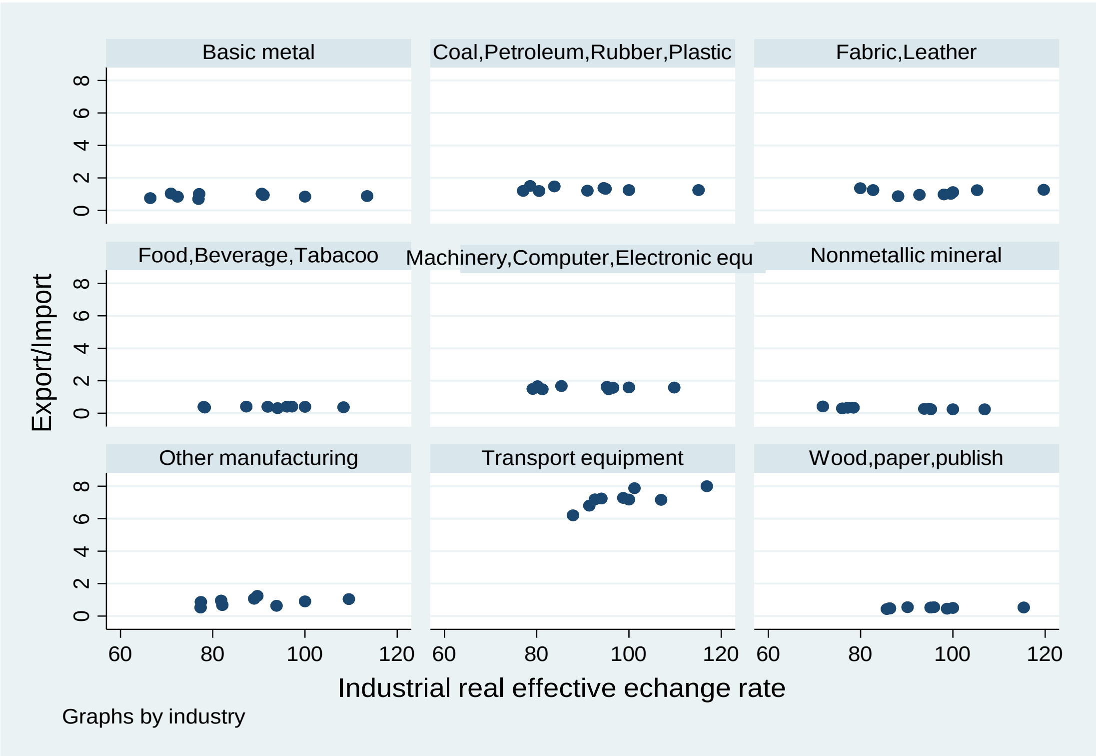


[107] China, USA, Vietnam, Hong Kong, Japan, Australia, India, Mexico, Germany, UK and India.

Figure 4.4 shows relationship between export/import and industrial real effective exchange rate, for individual industry sectors. It indicates that except transport industry, we could not find out systematic relationship. This result is similar to the research results of Lee & Lee (2005) and Bang (2010). The correlation coefficient is 0.08.

Figure 4.4: Exchange rate and Export/Import ratio in 2006-2014

(exchange rate : 2010=100)



4.3. Tariff Rate

Levinson and Taylor (2008) employed the tariffs as a variable for foreign countries' production costs. For the empirical tests, they used the effective tariff rates, which refer to the ratio of duties paid to the customs value, which is also the rate favoured by the US Customs Service.

$$\text{Effective tariff rate} = \frac{\text{Duties paid}}{\text{Customs value of imported goods}} \qquad (4.8)$$

This study also employed the Korean effective tariff rate, following their method. To determine the industrial effective tariff rate for the panel data, the duties paid and the customs value needs to be available. The Korean Customs Service, however, has only production type of data, and does not have information on the industry breakdown. Therefore, we had to do this task manually, and consequently distributed the data of over 130,000 goods into the relevant industry categories and then calculated the industrial effective tariff rate. Figure 4.5 shows that the average effective tariff rates show decreasing trend over the period 2006 to 2014. This means the openness of trade in Korea increased gradually in the same time period. Figure 4.6 says the relationship between tariff rate and export/import. We can find out low positive appearance. The correlation coefficient is 0.2063.

Figure 4.5: The average effective tariff rate in 2006-2014 (unit: %)

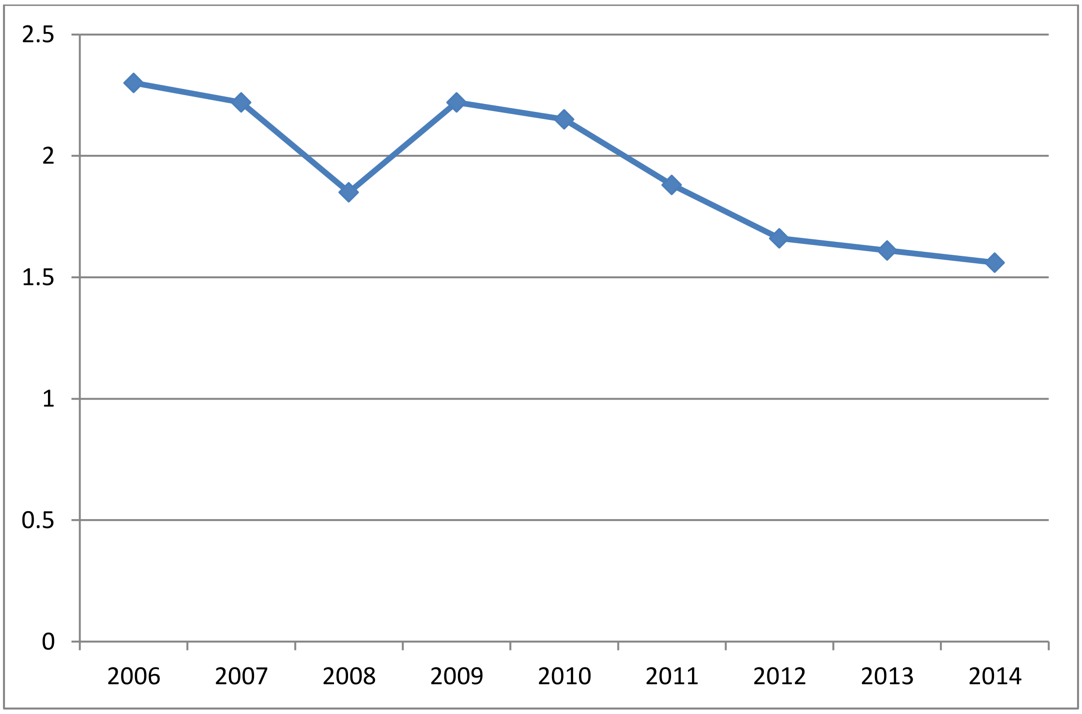
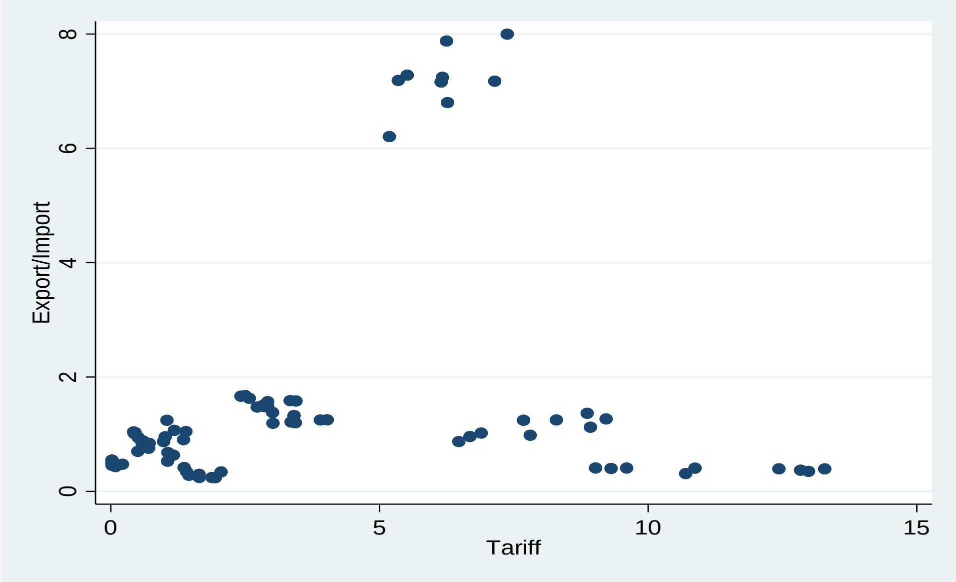


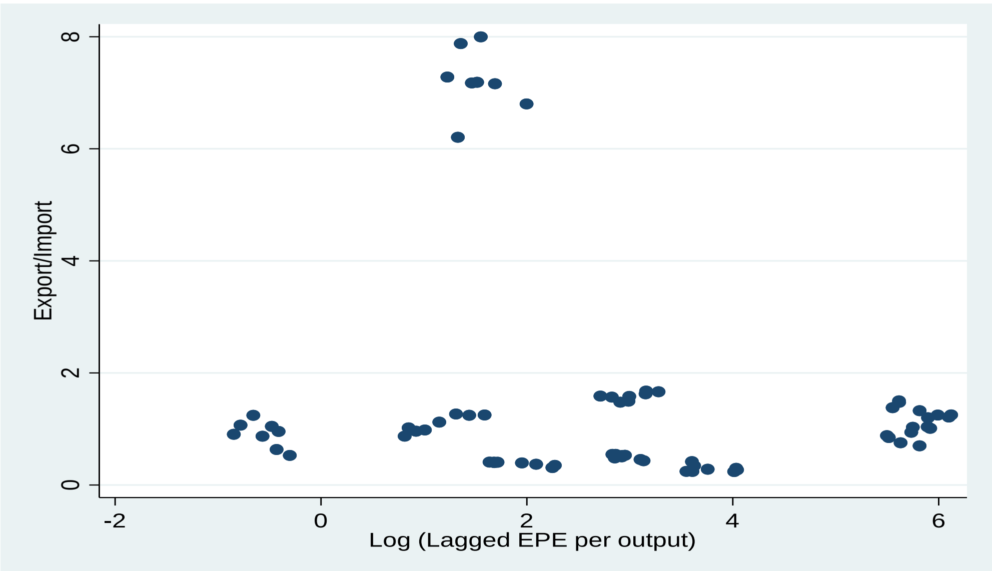
Figure 4.6: The industrial tariff rate (unit: %) and Export/Import ratio in 2006-2014



4.4. Environmental Protection Expenditure

As mentioned in Chapter II, Environmental protection expenditure (the EPE) represent costs to prevent, reduce and eliminate pollution. We will employ confidential industrial values. Relationship between the EPE and Export/Import in Figure 4.7 is quite similar to negative shape. The correlation coefficient is -0.1989.

Figure 4.7: Lagged EPE per output and Export/Import ratio in 2006-2014



4.5. Data Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Export/Import	81	1.574991	2.056425	0.240795	7.997765
Physical capital (KW billion)	81	85047.41	87943.46	7287.089	361195.2
Log (physical capital per output)	81	-0.51529	0.23788	-1.06331	-0.07086
Human capital (KW billion)	81	4274.056	1264.387	2285.127	7965.406
Log (human capital per output)	81	-3.79715	0.60006	-4.93474	-2.85187
Export of an individual industry/total Manufacturing export	81	0.111111	0.144089	0.003053	0.48441
Industrial Real Effective exchange rate (2010=100)	81	91.77336	11.68674	66.4738	119.698
Industrial Tariff (%)	81	3.871016	3.658411	0.020108	13.2869
Size (%) (Portion of firm with more than 300 over total firms)	81	15.6178	13.00848	1.125798	48.18618

5. Empirical results

Table 4.1 shows estimation results of equation (4.6). Sargen test do not reject the null hypothesis (Ho: overidentifying restrictions are valid), which implies that overidentifed model of system GMM is valid. Arellano-Bond test shows zero autocorrelation in first-difference errors. This means that export/import ratio at t-2 and the ratio after then can be employed as instrumental variables for the difference ratio at t-1. Such test results argue that system GMM is an appropriate approach in this chapter.

The estimate of the first variable show significant influence. It implies that past proportion of export to import affects current ratio. That is, the estimate meets assumption[108] which I established to use dynamic panel model. Human capital has also a significant result. Human capital is related to knowledge stock and high skill which could lead workers to achieve higher performance (Gendron 2004; Song and Sung 2014). Human capital therefore is very important factor of TPF growth leading to increasing competiveness like profitability and export growth, which is necessary one of economic drivers for new industrialized countries (Griliches & Regew, 1995; Lee, 2005; Lee & Hong, 2012; Teixeiraaa & Anabela, 2016). From this view, a significantly positive estimate of human capital is appropriate (Song & Sung 2014). Other things being equal, for 10% increasing in human capital, the difference in the expected mean of export/import ratio will be 0.057[109].

Industrial export/manufacturing export ratio at t-1 represents importance of a certain industry in total manufacturing sector in terms of export (Shin 2007).

[108] In section 3 (specification of dynamic panel model), I assume that past export and import could have an influence on current change.
[109] 1.397*log(1.1)=0.057

Intuitionally, if status of an industry in terms of export at t-l increases, we could understand that export of the industry would increase at current year. The estimate reflects such thinking. Holding all other variables constant, 0.1 unit (10%) increase of the ratio at t-1 leads to 0.78 increase of current export/import ratio. Size have a positive coefficient. That is, when other variables are held, for one unit increase in portion (unit : %[110]) of firms with more than 300 in total firms, there will be 0.104 difference in the dependent variable. This means that companies of middle size or larger make a good contribution to Korean export increase. Tariff has also positive sign. Considering that tariff plays a barrier against import, it is natural that the ratio of export/import increases. Specifically, holding the other predictor variables constant, 1% increase of tariff[111] leads to 0.126 difference of a dependent variable.

The main interest in this research is in the results of the EPE per output at t-1. Unlike other significant variables, the sign is negative and significant. Specifically, holding other things being equal, 10% increase of the EPE per output at t-1 results in -0.022[112] difference of current value. The impressive point lies on the minus sign. It implies that increase of domestic environmental costs in an industry affect negatively trade performance in the sector. That is, the expenditure caused by command and control system of Korean environmental regulations could be burden on competitiveness of manufacturing sector.

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[110] Size variable has % value

[111] Tariff variable also has % value.

[112] - 0.537*log(1.1)= - 0.022.

Table 4.1 : Estimations in terms of Trade Performance

Dependent variable (Export/Import ratio)	
Export/Import ratio t-1	0.292*
	(0.153)
Log(Physical capital per output) t	-0.441
	(0.684)
Log(Human capital per output) t	1.397**
	(0.612)
Log (EPE per output) t-1	-0.537*
	(0.305)
Industrial export/manufacturing export ratio t-1	7.804**
	(3.451)
Size t	0.104***
	(0.028)
Tariff t	0.126*
	(0.072)
Industrial real effective exchange rate t	-0.001
	(0.011)
Observations	63
Sargan test	44.78782
	[0.1021]
Arellano-Bond test	
First order	-1.6059
	[0.1083]
Second order	1.1608
	[0.2457]

note: ***; ** and * denote significance at the 1%, 5% and 10% respectively. ( ) is standard error. [ ] is p-value. Industry and year effects controlled.

6. Conclusions

Export is a very important driver of Korean economic growth. After the Korean financial crisis in 1998, trade performance (surplus) has also been considered as one of crucial factors for sustainable economic development. To involve trade performance, the study set up export/import ratio as a dependent variable and then adopted industrial environmental protection expenditure (the EPE) like Chapter II as a proxy for stringency of environmental regulations.

From estimates of the dynamic panel model, we found that the expenditure has a significant negative effect on trade performance. It implies that higher stringency of Korean environmental restrictions leads to down of export/import ratio. As generally known, it is likely that increasing additional costs like the EPE could raise production costs in the concerned industries (Lee, 2013), leading to reduction of their competition in domestic market. For example, the raised production cost could weaken competition against imported goods from other countries. Such influence could lead to increase import and down of trade performance.

To date, Korean environmental regulations have focused on compulsory command & control system. In this obligatory way, increasing change of environmental stringency could become serious burdens on firms' business activities. The Korean Government therefore should try to transform its direct regulatory system into market friendly methods which would not excessively distort firms' management but give companies elbowroom.

CHAPTER V

Concluding Remarks

In this thesis, we wanted to analyse how stringency of environmental regulations inside and outside Korea affect Korean economy. Specifically, three hypotheses, suggested in chapter I, were tested. First is that Korean domestic environmental stringency has a negative effect on TFP. Second is that relatively higher Korean stringency lead Korean investors to prefer host countries. Final hypothesis is that trade performance is also affected by Korean domestic environmental stringency. The process and results are as the following.

Chapter II investigated the effect of Korean domestic environmental regulations on total factor productivity in manufacturing part. For estimation, dynamic panel models were used. In addition, to consider not only economic change in industry trend but also individual firm reaction, I employed both industry level and firm level panel data. The most important process lies on finding an appropriate proxy for domestic environmental stringency. Unlike previous Korean papers, I could get the industrial environmental protection expenditure (the EPE) from Ministry of Environment which are not open publicly. Through adding general R&D and environmental R&D into the dynamic panel model, I found out that the EPE had a negative influence on Korean TFP in terms of both industry and firm levels. It means that tougher stringency of environmental regulations could lead to down of profitability and competitiveness.

Chapter III attempted with two tests. Main analysis was to check up and down of Korean outward FDI in host countries according to relative change of Korean EPS to other countries' ones. The other test was for Korean export to importing countries, which was additional analysis to check Korean export growth on the condition that there was a link between the FDI and export. For estimation, I employed national level data which consists of GDP, distance, bilateral trade barriers and so on in the gravity models. As a proxy presenting stringency of each country's environmental regulation, I adopted the EPS of the OECD in the equations. Meanwhile, to solve the zero and heteroskedasticity problems due to the logarithm of the gravity model, I employed the Poisson pseudo maximum likelihood method. The result was that if host countries have relatively lower stringency than Korea, they could attract more Korean investment, which supports the PHH. For Korean export, the volume was increased at the same condition as FDI because increased FDI could lead to export growth of intermediate goods.

In chapter IV, we wanted to know the influence of Korean domestic environmental stringency on Korean trade performance. Considering that economic structure with high dependence on trade[113], it is meaningful to test the impact. For

[113] Share of trade (import and export) in GNI of Korea is 99.8 % in 2010, 112.8%in 2012 and 98.6% in 2014 respectively.

estimation, I referred to components of Levinson and Taylor (2008) and Song and Sung (2014). Using a dynamic panel equation and the EPE used in chapter II, I found out that Korean domestic restrictions against pollution could affect negatively Korean performance. From the negative estimates of chapter II, III and IV except Korean export, we could believe that the additional production costs by environmental regulations would weaken competitiveness in terms of firm’s TFP, investment place and trade performance. Specially, we could confirm that the Porter hypothesis is invalid while the PHH is valid in Korean case which is the same as that of Chung (2014).

These results suggest policy implications that the Korean Government should try to find out appropriate level of the strictness of environmental regulations carefully, considering both competitiveness of Korean manufacturing firm & industry and importance of environmental protection. In addition, it should try to change compulsory command & control system to market friendly regulations. It is likely that such improvement could reduce burden of firms and give a chance to find out the most efficient management system, adjusting to environmental regulations. Meanwhile, negative influence of environmental R&D on Korean industry and firm level TFP in chapter II suggests another implication. That is, from the results, it is not to be expected that firms would strive to increase investment in environmental technology development. It therefore is recommended that Korean Government should provide more incentives (such as expansion of tax exemption or deduction) to have an interest in environmental R&D. In addition, to complement lack of private investment, the Government should try to expand its investment in environmental R&D and then actively transfer technology performance to private sectors.

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Appendixes

1. Environmental regulations in main countries

Country or Region	Environmental regulations	Enforcement year	contents	Targeted industries
EU	ELV	2000	Regulating producer's costs and recycling portion in scrapping a car	Car industries
	EuP	2005	Prohibiting goods without eco-design energy from market access	Goods using energy
	WEEE	2005	Waste Electrical and Electronic Equipment recovery and recycle duties	Electrical and Electronic industries
	RoHS	2006	Prohibiting electrical and electronic goods from holding six toxic substances	Electrical and Electronic industries
	REACH	2007	Regulating registration and permission on chemical substances in imported goods	All industries
America	CAFE	1979	Regulating car fuel efficiency	Car industries
	Califonia Electronic waste recycling act	2005	Charging recycling fee on waste electronic products	Electrical and Electronic industries
	New York Electronic waste recycling act	2011	Electronic waste acceptance program	Electrical and Electronic industries
China	China RoHS	2007	Regulating permission criteria of six toxic substance in electronic and ICT products	Electronic and ICT industries
	China WEEE	2009	Producer, repairer and A/S companies must notice collection information	Electrical and Electronic industries

		2011	Regulating eco-design Levying compulsory duties on firms about collecting waste electronic goods	Electronic industries
Japan	PC recycling law	2003	Regulating toxic substance collection and disposal in PC	PC
	Home applice recycling law	2006	Regulating recycling duties of producers and importers	Electronic industries
	J-MOSS	2006	Regulating notice way of special chemical substances in electric and electronic products	Electrical and Electronic industries

2. The Number of Redundant Regulations In Korea

Type	Number (one)	Portion (%)
Environment	32	18.9
Construction	21	12.4
Land	20	11.8
Industrial safety	16	9.5
Fair trade	15	8.9
Business	14	8.3
Technology approval	13	7.7
Tax	11	6.5
Finance	10	5.9
Circulation	7	4.1
Advertisement	4	2.4
Others	6	3.6

3. TFP estimation

Model

$$\text{output(y)} = \text{A} \times K^{\alpha} \times L^{\beta} \quad \text{(A3.1)}$$

where K is capital stock and L is labour. $\alpha + \beta = 1$

$$\text{OLS : lny} = \alpha\text{lnK} + \beta\text{lnL} \quad \text{(A3.2)}$$

Number of obs	=	81
F(2, 78)	=	1390.35
Prob > F	=	0
R-squared	=	0.9727
Adj R-squared	=	0.972
Root MSE	=	0.18406
multiple correlation coefficient	=	0.986263

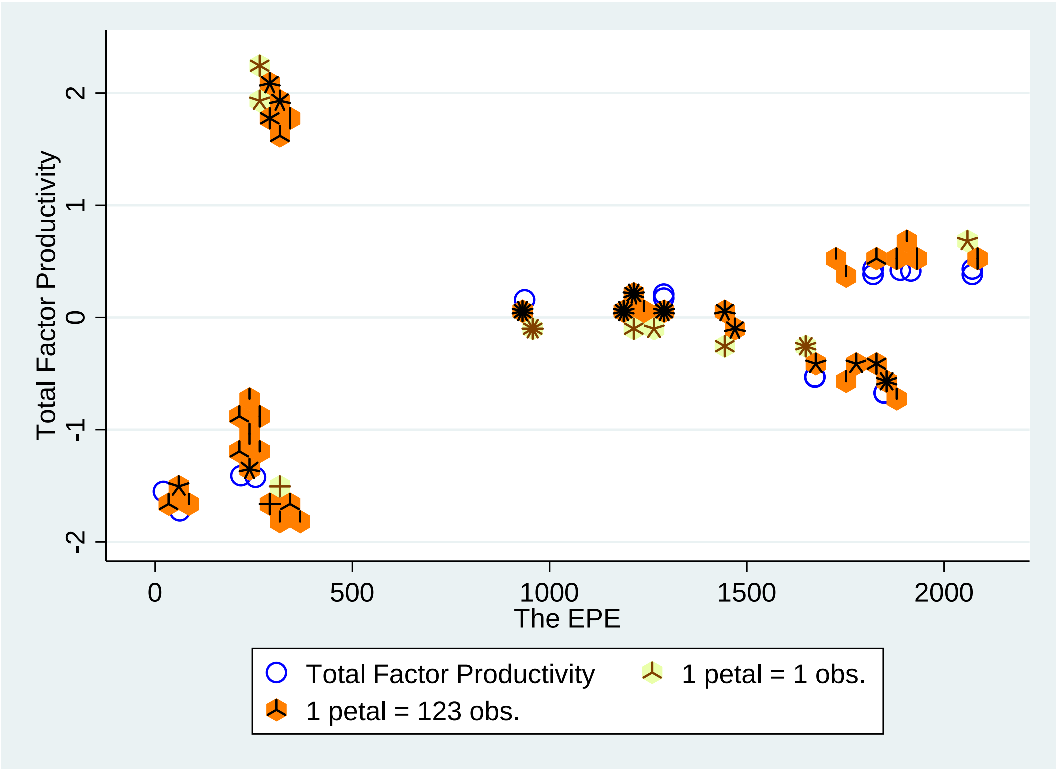
Source	SS	df	MS
Model	94.20426	2	47.1021315
Residual	2.642475	78	0.033877883
Total	96.84674	80	1.21058422

	Coef.	Std. Err	t	P>t	[95% Conf. Interval]	
lnK	.7365624	.0262785	28.03	0	0.684246	0.788879
lnL	.4187438	.0419026	9.99	0	0.335322	0.502166
_cons	1.696251	.3714543	-4.57	0	-2.43576	0.956742

Obs	Predicted output	residue	Standard residue	Obs	Predicted output	residue	Standard residue
1	11.21587	-0.14131	-0.75245	33	12.64506	0.225874	1.202716
2	11.26238	-0.13266	-0.70639	34	12.71104	0.206939	1.101891
3	11.30394	-0.03043	-0.16201	35	12.75497	0.148383	0.790097
4	11.33254	0.026007	0.138478	36	12.80861	0.079425	0.422914
5	11.35959	0.029412	0.156613	37	10.41894	-0.27086	-1.44227
6	11.41328	0.051305	0.273183	38	10.49007	-0.2785	-1.48294
7	11.43985	0.058864	0.313435	39	10.57766	-0.21647	-1.15266
8	11.45557	0.122737	0.653539	40	10.60579	-0.14488	-0.77142
9	11.49702	0.117042	0.623215	41	10.6399	-0.1241	-0.66081
10	10.91352	-0.21931	-1.16776	42	10.68107	-0.18261	-0.97235
11	10.96039	-0.22301	-1.18746	43	10.71222	-0.19827	-1.05571
12	10.99092	-0.11903	-0.63381	44	10.729	-0.1914	-1.01917
13	11.00391	-0.02088	-0.1112	45	10.76364	-0.20855	-1.11048
14	11.04298	0.070516	0.375476	46	11.44959	-0.09736	-0.51841
15	11.10019	0.145107	0.772655	47	11.5317	-0.01071	-0.05702
16	11.12603	0.232918	1.240224	48	11.61934	0.152944	0.814383
17	11.13655	0.185744	0.989035	49	11.67591	0.00078	0.004155
18	11.15408	0.147553	0.785676	50	11.75009	0.148805	0.792344
19	10.05405	0.141197	0.751835	51	11.81466	0.272044	1.448555
20	10.09953	0.142582	0.759209	52	11.84957	0.197373	1.050953
21	10.14547	0.212025	1.12897	53	11.86107	0.089806	0.478192
22	10.1382	0.269305	1.433975	54	11.87875	0.030044	0.159973
23	10.16404	0.345324	1.838752	55	13.10453	-0.26757	-1.42476
24	10.18546	0.369825	1.969213	56	13.07732	-0.15659	-0.83381
25	10.19294	0.343497	1.829023	57	13.17256	-0.13177	-0.70163
26	10.18693	0.382904	2.038857	58	13.2053	-0.085	-0.45263
27	10.20808	0.400704	2.133635	59	13.31774	-0.07701	-0.41007
28	12.21528	-0.02511	-0.13369	60	13.41789	-0.0693	-0.36899
29	12.29556	-0.00442	-0.02351	61	13.48801	-0.14193	-0.75573
30	12.39304	0.156371	0.832632	62	13.53351	-0.18441	-0.98192
31	12.45835	-0.01114	-0.05931	63	13.58891	-0.2447	-1.30294
32	12.54975	0.095084	0.506296	64	11.9266	-0.02656	-0.1414
				65	12.03817	-0.00238	-0.01268

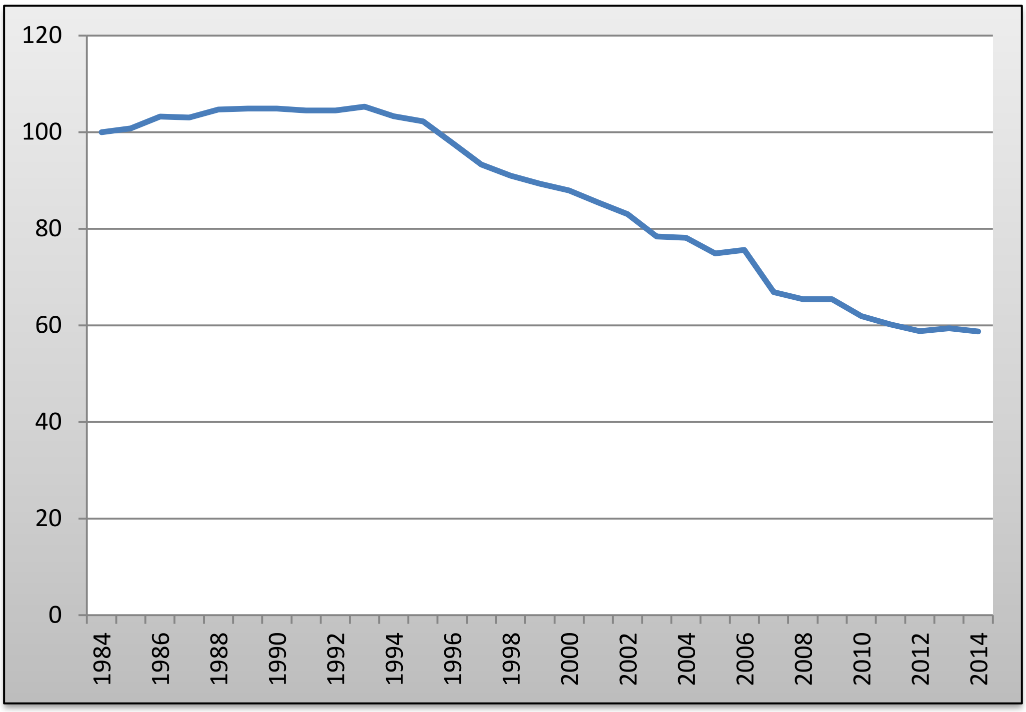
Obs	Predicted output	residue	Standard residue
66	12.12971	0.026004	0.138466
67	12.1918	-0.03958	-0.21077
68	12.25968	0.061896	0.329577
69	12.35327	0.104752	0.557775
70	12.40416	0.08595	0.45766
71	12.45233	0.011772	0.06268
72	12.50686	-0.0169	-0.08999
73	9.659817	-0.44811	-2.38604
74	9.724503	-0.37831	-2.01441
75	9.781888	-0.41923	-2.23228
76	9.810162	-0.37997	-2.02324
77	9.859979	0.002488	0.01325
78	9.930201	0.032225	0.171591
79	9.963709	-0.01558	-0.08295
80	9.991341	-0.02447	-0.13027
81	10.04694	0.036851	0.196223

4. Firm TFP and the EPE in 2010-2014



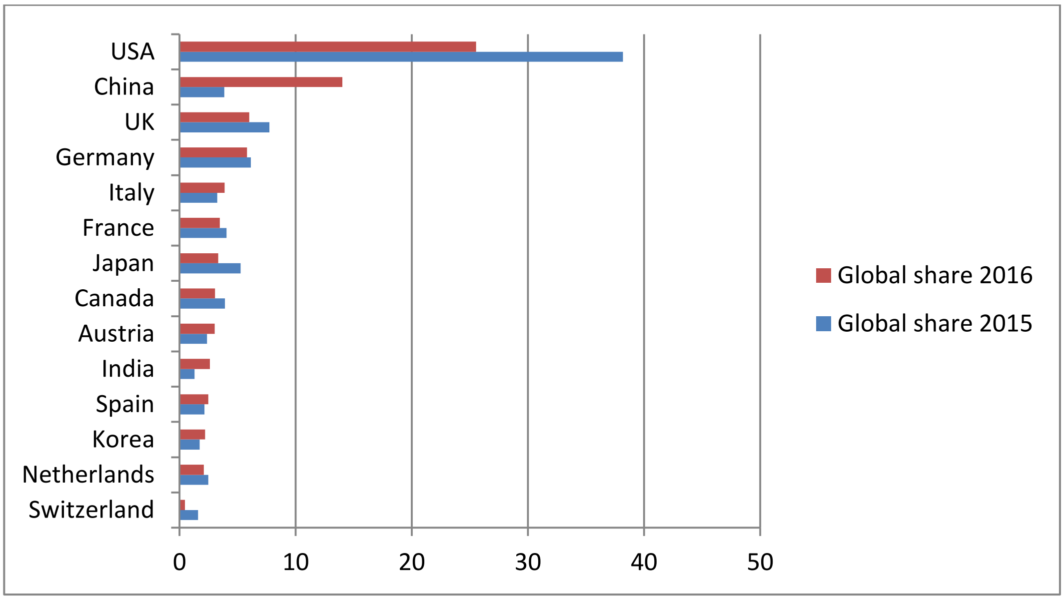
5. Producer Price Index by Industry: Semiconductor and Other Electronic Component Manufacturing

(unit: Index Dec 1984=100)



(**Source:** Federal Reserve Bank of St.Louis, US Bureau of Labour Statistics)

6. A Percentage of the world's top 10% most-cited publications (unit: %)



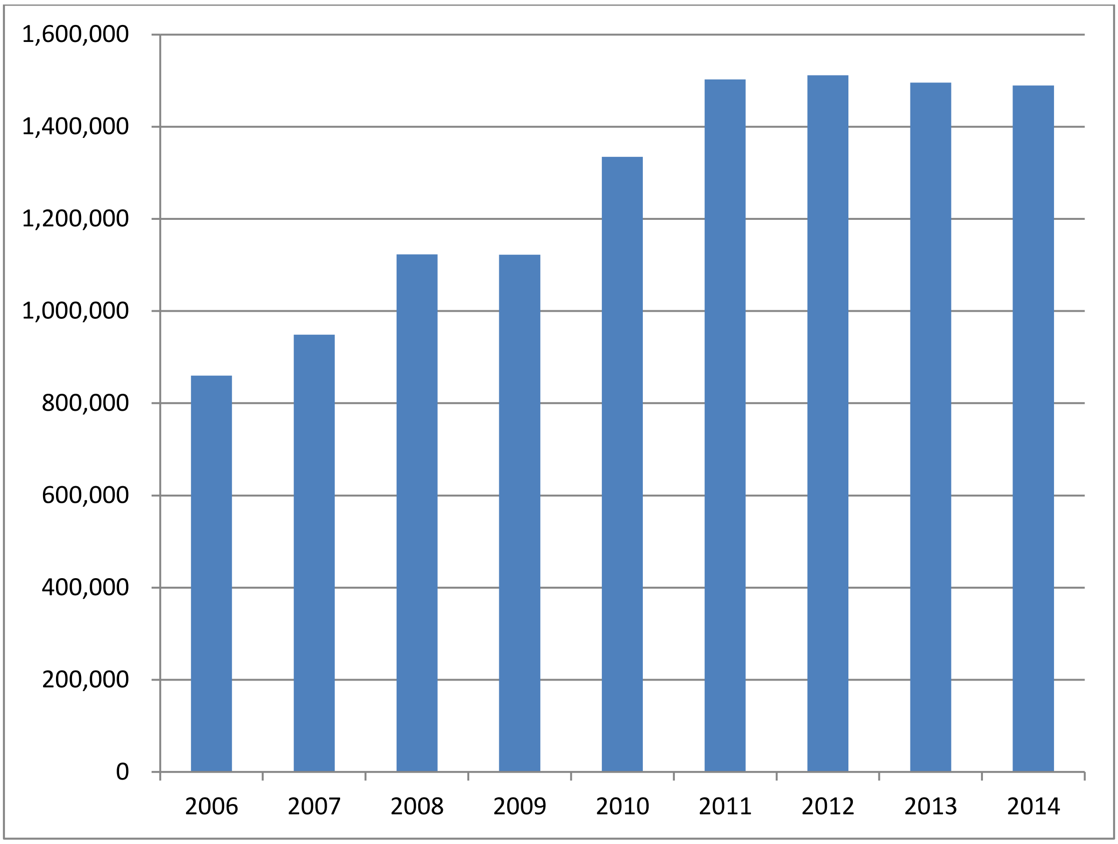
Global Share (%)	USA	China	UK	Germany	Italy	France	Japan
2015	38.19	3.86	7.73	6.15	3.25	4.05	5.26
2016	25.53	14.01	6	5.81	3.88	3.46	3.32

Global Share (%)	Canada	Austria	India	Spain	Korea	Netherlands	Switzerland
2015	3.92	2.36	1.29	2.14	1.72	2.49	1.59
2016	3.06	3.02	2.61	2.48	2.21	2.08	0.47

(Source: the OECD, Scimago Joural Rank indicator)

" 『Top-cited publications』 are the 10% most-cited papers normalised by scientific field and type of document (articles, reviews and conference proceedings). The Scimago Journal Rank indicator is used to rank documents with identifical numbers of citations within each class. This measure is a proxy indicator of research excellence. Estimates are based on fractional counts of documents by authors affiliated to institutions in each economy." (the OECD)

7. Manufacturing Output in 2006-2014 (unit: KW billion)



	2006	2007	2008	2009	2010	2011	2012	2013	2014
output (KW 100 billion)	8596	9486	11229	11219	13348	15023	15114	14957	14892
growth rate		0.10	0.18	-0.0009	0.18	0.12	0.006	-0.01	-0.004

8. Source of Data

8.1. Chapter II

Variable	Source
Industry-level Total factor productivity (TFP) - Capital stock - Labour	The Bank of Korea Ministry of Labour
General R&D, Environmental R&D	Ministry of Science and ICT
Environmental protection expenditure (EPE)	The OECD, Ministry of Environment
Firm-level TFP (labour, sales, tangible assets)	Korea Institute for Industrial Economics & Trade National Information Credit Evaluation service cooperation (NICE)

8.2. Chapter III

Variable	Source
Korean Export	Korea International Trade Association
Korean outward FDI	The Export-Import Bank of Korea
Environmental Policy Stringency (EPS)	The OECD
GDP, Population, tariff, wage	World Bank, Korean Customs Service, KOSIS
Human Development Index	UN
Distance	CEPII
Regional trade agreement	WTO

8.3. Chapter IV

Variable	Source
Trade	Korea International Trade Association
Environmental protection expenditure	Ministry of Environment
Real effective exchange rate - Trade between Korea and other countries - Nominal exchange rate	The Bank of Korea, the OECD, Korea International Trade Association
Tariff	Korean Customs Service
Size	Ministry of Labour Ministry of Trade, Industry and Energy
Physical and Human capital	The Bank of Korea Ministry of Labour

9. Classification in Manufacturing sector

SITC	Industrial Environmental Protection Expenditure	MIT code
Food Products Beverages Tobacco Products	Food products and beverages	Meat and dairy products, Processed seafood products Polished grains, flour and milled cereals, sugar and starches Bakery and confectionery products, noodles, Seasonings and fats and oils, Canned or cured fruits and vegetables and misc. food preparations Beverages, prepared livestock feeds, tobacco products
Textiles, except Apparel Wearing apparel, Clothing Accessories and Fur Articles Dressing of Leather, Luggage and Footwear	Textiles	Fibre yarn, Fibre fabrics, Wearing apparels and apparel accessories Other fabricated textile products, leather and fur products
Pulp, Paper and Paper Products Printing	Pulp, paper, paper products, printing and publishing	Pulp and paper, printing, Publishing and reproduction of recorded media
Coke, hard-coal and lignite fuel briquettes and Refined Petroleum Products	Coke, refined petroleum products Chemicals and chemical products	Coal products, Petroleum refinery products
Chemicals and chemical products except pharmaceuticals and medicinal chemicals Pharmaceuticals, Medicinal Chemicals and Botanical Products Rubber and Plastic Products		Organic basic chemical products, Inorganic basic chemical products Synthetic resins and synthetic rubber; chemical fibres Fertilisers and agricultural chemicals; Drugs, cosmetics, and soap; Other chemical products Plastic products Rubber products
Other Non-metallic Mineral Products	Other non-metallic mineral products	Glass products, pottery and clay products Cement and concrete products Other non-metallic mineral products
Iron and steel Non-ferrous metals	Basic metal products Fabricated metal products, except for machinery and furniture	Steel products Non-ferrous metal ingots and primary non-ferrous metal products Fabricated metal products
Fabricated Metal Products, Except Machinery and Furniture		Structural metal products, tanks, reservoirs and steam generators; Weapons and ammunition; Cutlery; Hand tools and general Hardware

Machinery and equipment n.e.c.	and computing machinery Electrical machinery and apparatus, n.e.c. Radio, television and communication equipment Medical, precision and optical instruments Other Machinery and equipment Office, accounting	Engines and turbines, Other pumps, compressors, taps and valves, bearings, gears, gearing and driving elements; Ovens, furnaces and furnace burners
Office, accounting and computing machinery		Electronic components and boards, Computers and peripheral equipment, Print equipment, Typewriters
Electrical machinery and apparatus, nec		Electric lighting equipment, Electric motors, generators, transformers and Electricity distribution, Batteries and accumulators
Radio, television and communication equipment		Flat display, Wire Telephone, Telegraph, Cable electrical transmission; Mics and headphones
Medical, precision and optical instruments		Measuring, testing, navigating and control equipment; Watches and clocks
Motor vehicles, trailers and semi-trailers	Motor vehicles, trailers and semi-trailers Other transport equipment	Motor vehicles, Bodies (coachwork) for motor vehicles
Building and repairing of ships and boats Aircraft and spacecraft Railroad equipment and transport equipment n.e.c.		Ship building and repairing Airplanes, Helicopters, Motorcycles, Other transportation equipment
Other industries	Other industries	Other industries

10. The researched countries among the OECD & the BRIICS countries in Chapter III

1	Australia
2	Austria
3	Belgium
4	Canada
5	Czech
6	Denmark
7	Finland
8	France
9	Germany
10	Greece
11	Hungary
12	Ireland
13	Italy
14	Japan
15	Netherland
16	Norway
17	Poland
18	Portugal
19	Slovak
20	Slovenia
21	Spain
22	Sweden
23	Swiss
24	Turkey
25	UK
26	USA
27	Brazil
28	China
29	India
30	Indonesia
31	Russia
32	South Africa

11. The Theoretical Gravity model for Export in Chapter III

We used the empirical gravity model on the basis of the theoretical equation of Anderson and van Wincoop (2003). They manipulated the CES expenditure system to derive a practical gravity model. They found three components of trade resistance: (1) the bilateral trade barrier between two trade partners (countries i and j), (2) the resistance of country i to trade with all countries, and (3) the resistance of country j to trade with all countries. They assumed that all goods are differentiated by their place of origin and each country is concentrated on only one good along with the CES demand function.

Let country i export its goods to country j. Consumers in country j maximise

$$\left(\sum_i \beta_i^{(1-\sigma)/\sigma} C_{ij}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)} \qquad \text{(A11.1)}$$ [114]

subject to the budget constraint

$$\sum_i p_{ij} C_{ij} = y_j \qquad \text{(A11.2)}$$

where C_{ij} is consumption by country j's consumers of goods from country i, σ is the elasticity of substitution between all the goods, β_i is a positive distribution parameter, y_j is the nominal income of country j's residents, and p_{ij} is the price of country i's goods for country j's consumers.

p_{ij} can be translated to

$$p_{ij} = p_i t_{ij} \qquad \text{(A11.3)}$$

where p_i is the exporter's supply price and t_{ij} is the bilateral trade costs.

Under the utility maximisation, the nominal demand for country i's goods by country j's consumers is

[114] I borrowed symbols and characters used by Anderson and van Wincoop (2003). in order to help understand derivation of model along with the paper of Anderson and van Wincoop (2003).

$$x_{ij} = s_{ij}\, y_j \qquad \text{(A11.4)}$$

where $s_{ij} = (\frac{\beta_i p_i t_{ij}}{P_j})^{(1-\sigma)}$ represents the expenditure share and is dependent on the relative prices, and P_j is the consumer price index of country j:

$$P_j = [\sum_i (\beta_i p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)} \qquad \text{(A11.5)}$$

Using the general equilibrium condition of market clearance:

$$y_i = \sum_j x_{ij} = \sum_j (\frac{\beta_i p_i t_{ij}}{P_j})^{(1-\sigma)}\, y_j = (\beta_i p_i)^{1-\sigma} \sum_j (t_{ij}/P_j)^{1-\sigma}\, y_j\,, \ \forall i.$$

(A11.6)

Solving for $\beta_i p_i$ and substituting them in equation (A11.4), we get

$$x_{ij} = \frac{y_i y_j}{\Pi_i} (\frac{t_{ij}}{P_j})^{1-\sigma} \qquad \text{(A11.7)}$$

where $\Pi_i \equiv (\sum_j (\frac{t_{ij}}{P_j})^{1-\sigma} y_j)$.

Equation (A11.7) has a very important implication for establishing the gravity model for the estimations. Anderson and van Wincoop (2003) consider P_j and Π_i as multilateral resistance, i.e. average trade barriers that country i or j face with their trading partners. Then, they come up with the important conclusion that bilateral trade between countries i and j is dependent on the bilateral trade barrier relative to multilateral resistance. That is, they believe that for a fixed bilateral trade barrier between countries i and j, the increase in the barriers between j and its trading countries, except for country i, will lead to the reduction of the relative prices of the goods imported from country I, which will consequently lead to an increase in the import of those goods.

Through applying logarithms to both sides of equation (A11.7), we obtain

$$ln\, x_{ij} = k + ln\, y_i + ln\, y_j + (1-\sigma) ln\, t_{ij} - ln\, \Pi_i - (1-\sigma) ln\, P_j$$

(A11.8)

where k is a constant.

12. The Theoretical Gravity model for FDI in Chapter III

12.1. First model

We derive a theoretical gravity equation on the basis of Kleinert and Toubal (2010). The assumption is that there are two sectors in the economy: one is agriculture producing homogeneous goods, while the other is the manufacturing sector producing a bundle M of differentiated goods. The utility function of the representative consumer from country J takes the Cobb-Douglas form.

$$U_j = X_{Aj}^{\mu} X_{Mj}^{1-\mu} \qquad \text{(A12.1)}$$ [115]

where o<μ<1. X_{Mj} is the subutility function of the CES type:

$$X_{Mj} = \left[\int_j \int_k X_{kij}^{(\sigma-1)/\sigma} \, dk \, di\right]^{\sigma/(\sigma-1)} \qquad \text{(A12.2)}$$

where X_{kji} is country j's consumption of a single variety produced by firm k from country I, and σ is the elasticity of substitution, which is >0 and constant across any pair of product. The assumption of monopolistic competition with symmetric manufacturers and varieties simplifies equation (A12.2) to $X_{Mj} = n_i x_{ij}^{(\sigma-1)/\sigma}$, where n_i is the number of firms in the equilibrium. The price index for manufacturing sector, P_{Mj}, is a CES subutility function:

$$P_{Mj} = [\int_i n_i p_{ij}^{1-\sigma}]^{1/(1-\sigma)} \qquad \text{(A12.3)}$$

[115] I borrowed symbols and characters used by Kleinert and Toubal (2010). in order to help understand derivation of model along with the paper of Kleinert and Toubal (2010).

From here, this paper focuses on the manufacturing sector. Therefore, the subscript M is dropped. The sales of each firm in country j, i.e. x_{ij}, are dependent on the good price in country j, p_{ij}, the price index in j, P_j, and the market size, Y_j.

$$x_{ij} = p_{ij}^{-\sigma}(1-\mu)Y_j P_j^{\sigma-1} \quad \text{(A12.4)}$$

Firms export to or invest in country j. They will produce abroad if doing so is more profitable than exporting:

$$\pi_i^{MNE} - \pi_i^{Ex} > 0 \Leftrightarrow (1-\sigma)\left[p_{ij}^{MNE} x_{ij}^{MNE} - p_{ij}^{Ex} x_{ij}^{Ex}\right] > \delta f_j \quad \text{(A12.5)}$$

where $\rho = \sigma/(\sigma\text{-}1)$ and f_j represents the fixed costs of setting up an additional plant in country j. δ stands for the fixed costs depreciation factor. Note that all n_i is produced in a foreign country or for export. We assume that exports provoke distance costs of the iceberg type. This leads to

$$p_{ij}^{Ex} = p_{ii}\tau_{ij} \quad \text{(A12.6)}$$

where τ_{ij} is the distance cost between i and j.

This paper assumes that MNE's production depends on intermediate goods imported from the home country. The technology of a MNE in country j follows the variable cost function:

$$C_j = \left(\frac{w_j}{\varepsilon}\right)^{\varepsilon}\left(\frac{q_{ij}}{1-\varepsilon}\right)^{1-\varepsilon} \quad \text{(A12.7)}$$

where ε stands for the cost share for labour and 1-ε for the intermediate inputs. w_j is the wage in j and q_{ij} is price for the intermediate good utilised in the MNE. The price is raised by the distance costs, which are of an iceberg type. This leads to $q_{ij} = q_{ii}\tau_{ij}$. Considering that the optimal price is a fixed markup over the marginal costs ($p_{ij} = \frac{c_{ij}}{\rho}$)

and that the marginal costs are increased by the distance costs, then the good price of the MNE is also increased by the distance costs. However, MNEs would then make higher profits than by exporting.

Combining equation (A12.4) with (A12.6) results in

$$p_{ij}^{Ex}x_{ij}^{Ex} = p_{ii}^{1-\sigma}\tau_{ij}^{(1-\sigma)(1-\varepsilon)}(1-\mu)Y_jP_j^{\sigma-1} \qquad \text{(A12.8)}$$

Now, let's insert equation (A12.8) into (A12.5). In this case, the foreign country investment condition is achieved.

$$n_ip_{ij}x_{ij} - \frac{n_i\delta f_{ij}}{1-\rho} = n_ip_{ii}^{1-\sigma}\tau_{ij}^{(1-\sigma)(1-\varepsilon)}(1-\mu)Y_jP_j^{\sigma-1} \qquad \text{(A12.9)}$$

Following Kleinert and Toubal (2010) and Redding and Venables (2003), we define $n_ip_{ii}^{1-\sigma}$ as s_i (home country supply capacity), $(1-\mu)Y_jP_j^{\sigma-1}$ as m_j (host country market capacity), $n_ip_{ij}x_{ij}$ as AS_{ij}(foreign affiliate sales in country j), and $\frac{n_i\delta f_{ij}}{1-\rho}$ as G_{ij} (Greenfield investment in country j). Under the assumption that τ_{ij} has the property of increasing the geographical distance function, $\tau_{ij} = \tau D_{ij}^{\eta_1}$ (η_1 >1), eventually, equation (A12.9) can be transformed to

$$AS_{ij} - \delta G_{ij} = s_i\,(\tau D_{ij}^{\eta_1})^{(1-\sigma)(1-\varepsilon)}m_j \qquad \text{(A12.10)}$$

Introducing time (t), gives

$$AS_{ijt} - \delta_tG_{ijt} = s_{it}\,(\tau D_{ij}^{\eta_1})^{(1-\sigma)(1-\varepsilon)}m_{jt} \qquad \text{(A12.11)}$$

In the short term, when t = 0 ($\delta_t = -\delta_0$) and AS_{ijt}= 0,

$$G_{ij} = s_i\,(\tau D_{ij}^{\eta_1})^{(1-\sigma)(1-\varepsilon)}m_j/\delta_0 \qquad \text{(A12.12)}$$

This means that the initial investment of Greenfield FDI, as foreign affiliate sales, relies on the home and host supply capacities and distance. That is, a gravity model can explain the FDI.

Applying logarithm function for equation (A12.12) shows the following.

$$\ln\left(FDI_{ij}\right) = \alpha_1 + \zeta_1 \ln(s_i) + \beta_1 \ln\left(\mathrm{D_{ij}}\right) + \xi_1 \ln\left(\mathrm{m_j}\right) \quad \text{(A12.13)}$$

where $\alpha_1 = (1-\sigma)(1-\varepsilon)\ln(\tau) - \ln(\delta_0)\ and\ \beta_1 = (\sigma-1)(1-\varepsilon)\eta_1$.

And: $\zeta_1 = \xi_1 = 1$, because of the gravity equation structure.

Now, this study tries to expand the assumption of $\tau_{ij} = \tau D_{ij}^{\eta_1} (\eta_1 > 1)$. That is, it introduces various investment frictions, including the environmental regulation index in distance costs, as well as geographic distance.

Anderson and van Wincoop (2003) showed the concept of two multilateral resistances (outward and inward) in their theoretical gravity model for trade. It is apparent that trade flow between two countries depends on the trade condition between the one country and its counterparts. The ideas of Anderson and van Wincoop (2003) are widely applied in the literature studies employing the gravity equation because of both the theoretical basis and empirical intuition. That is, nowadays, the gravity model with two multilateral resistances is common. Paniagua (2011) argued that FDI between country i and j is also influenced by two multilateral resistances because the investment environment of other countries has an effect on FDI between the two countries directly involved. Our study follows the thinking of Paniagua (2011) and introduces two multilateral resistances into equation (A12.13).

12.2. Second model

The second model follows Waglé's theoretical gravity model. The model tries to consider both country and firm selection biases. The merit of Waglé's model is that it can include firm heterogeneity without employing firm-level data.

Consumption

Let's assume, a representative consumer with a preference for variety wants to maximise his CES utility function ($U = [\int_{\Omega} x(\upsilon)^{\rho}\, d\upsilon]^{1/\rho}$) [116]subject to the aggregate expenditure ($E = \int_{\Omega} p(\upsilon)x(\upsilon)d\upsilon$) where Ω is the mass of available goods. The demand elasticity ($\sigma = \frac{1}{1-\rho} > 0$) of all the various goods is constant. In consideration of the CES price index (P), the Marshallian demand for a variety is

$$x(\upsilon) = [\frac{p(\upsilon)}{P}]^{-\sigma}\ \frac{E}{P} \qquad \text{(A12.14)}$$

Production

Here, it's assumed that a firm in country i tries to minimise its production input costs ($c_i a$), where c_i represents the cost of the bundle of the country's inputs per unit of output, which is uniform across country i and a denotes the firm-specific productivity and estimates the number of the bundle. Monopolistic competition with increasing returns means a decreasing average cost [∫(x)=f+cx]. Each firm does not do any strategic interaction. The profit-maximisation condition is the following.

$$\pi_i = p_i x_i - c_i a x_i - c_i f_i \qquad \text{(A12.15)}$$

$$\frac{\delta \pi_i}{\delta p_i} = x_i + (p_i - c_i a)\frac{\delta x_i}{\delta p_i} = 0 \qquad \text{(A12.16)}$$

[116] I borrowed symbols and characters used by Waglé (2010). in order to help understand derivation of model along with the paper of Waglé (2010).

$$p_i = c_i a - \frac{x_i}{\frac{\delta x_i}{\delta p_i}} \quad \text{(A12.17)}$$

Substituting $\frac{\delta x_i}{\delta p_i} = -\sigma(p)^{-\sigma-1}EP^{\sigma-1}$ in equation (A12.17) leads to

$$p_i = \frac{c_i a}{\rho} \quad \text{(A12.18)}$$

which is the optimal price is a constant mark-up over the marginal cost.

Investment costs across borders

MNEs in country j face non-trivial coordination and transaction costs, τ_{ij}, in addition to the fixed cost for establishing a new or additional plant in country j.

$$p_j = \tau_{ij} p_i = \tau_{ij} c_j a \left[\frac{\sigma}{\sigma-1}\right] = \frac{\tau_{ij} c_j a}{\rho} \quad \text{(A12.19)}$$

Take $E_j = Y_{j,}$

$$\pi_{ij} = (1-\rho)\left[\frac{\tau_{ij} c_j a}{\rho P_j}\right]^{1-\sigma} Y_j - c_j f_{ij} \quad \text{(A12.20)}$$

MNE activities in country j are profitable when $\pi_{ij} > 0$. Such a condition suggests cut-off productivity, implying that only when MNE has productivity higher than the cut-off point, will it achieve profits in terms of FDI (Waglé 2010). The cut-off productivity is

$$a_{ij} = \left[\frac{Y_j(1-\rho)}{c_j f_{ij} \rho P_j}\right]^{\frac{1}{\sigma-1}} \frac{\rho P_j}{\tau_{ij} c_j} \quad \text{(A12.21)}$$

The above cut-off equation shows the extensive margin of FDI. That is, it explains the change in the number of firms investing in the host country. An increasing GDP of the host country but a drop of fixed and variable costs leads to rising FDI. The total value of FDI from home country i to host country j is the sum of all the firms investing in the host country (Waglé 2010):

$$FDI_{ij} = \int_{a_L}^{a_{ij}} p_j x_j N_i \, dG(a) \qquad (A12.22)$$

where $G(a_{ij})$ is the firms that have a positive intention to operate a plant in the host country and N(i) is the number of firms.

Let's name $V_{ij} = \int_{a_L}^{a_{ij}} a^{1-\sigma} \, dG(a)$ for $((a_{ij} > a_L)$, the following is obtained.

$$FDI_{ij} = [\frac{\tau_{ij} c_j}{\rho P_j}]^{1-\sigma} Y_j N_i V_{ij} \qquad (A12.23)$$

General equilibrium

Waglé (2010) assumes that in the home country(i) the total income is equal to the aggregate sales by firms from country i at home and in other countries.

$$Y_i = \sum_{j=1}^{C} [\frac{\tau_{ij} c_j}{\rho P_j}]^{1-\sigma} Y_j N_i V_{ij} \qquad (A12.24)$$

$$N_i [\frac{c_j}{\rho}]^{1-\sigma} = \frac{Y_i}{\sum_{j=1}^{C} [\frac{\tau_{ij}}{P_j}]^{1-\sigma} Y_j V_{ij}} \qquad (A12.25)$$

Considering the outward multi-lateral resistance (indicated as $[\prod_i]^{1-\sigma} = \sum_{j=1}^{C} [\frac{\tau_{ij}}{P_j}]^{1-\sigma} \frac{Y_j V_{ij}}{Y}$ where Y is the total world income), the augmented gravity equation for FDI is the following.

$$FDI_{ij} = \frac{Y_i Y_j}{Y} [\frac{\tau_{ij}}{\prod_i P_j}]^{1-\sigma} V_{ij} \qquad (A12.26)$$

13. The Theoretical model of Chapter IV

I established the estimation models on the basis of the theoretical equation of Levinson and Taylor (2008). Their equation takes into account two countries: the home country and the foreign country (denoted by *). To derive their theoretical model, they made the assumption that factor price and environmental regulations (i.e. in effect, the pollution taxes) are exogenous. Likewise, they assumed that each industry sector comprises various firms that differ only in their pollution intensity, and are indexed by $\eta \in [0,1]$[117]. A value closer to 1 means a higher pollution intensity. Then, for simplicity, they assumed that consumers allocate a constant fraction of their income on the products from each industry.

Outputs

When a firm (η) produces pollution as a by-product, and uses a fraction (θ) of the production factors or resources to abate said pollution, the output ($x(\eta)$) of the firm (the production function is CRS) can then be written as

$$x(\eta) = [1 - \theta(\eta)]\ F(K(\eta), L(\eta)) \qquad \text{(A13.1)}$$

where K is the capital and L is the labour. Levinson and Taylor believe that θ(η) is a share of the pollution abatement costs in the value added in the firm η. In terms of the by-product, a pollution emission ($Z(\eta)$) function can be expressed as

$$Z(\eta) = \phi(\theta(\eta))\ F(K(\eta), L(\eta)) \qquad \text{(A13.2)}$$

where ϕ is a diminishing function of θ. Levinson and Taylor assume that $\phi(\theta) = (1-\theta)^{1/\alpha}$, where $0<\alpha<1$. They believe that firms faced with a pollution tax (τ) per unit of

[117] I borrowed symbols and characters used by Levinson and Taylor (2008) in order to help understand derivation of model along with the paper of Levinson and Taylor (2008)

pollution emission, and given also the prices incurred for the labour and capital employed in abatement of the pollution emissions, select θ to minimise the costs. If θ > 0, and considering equation (A13.2), then equation (A13.1) can be transformed into

$$x(\eta) = Z(\eta)^{\alpha(\eta)}\left[F\left(K(\eta), L(\eta)\right)\right]^{1-\alpha(\eta)} \qquad \text{(A13.3)}$$

This resembles a Cobb-Douglas function of pollution emissions and production factors.

Trade flows from the difference in costs

From equation (A13.3), the unit production cost ($c(\eta)$) in a firm η in the home country is

$$c(\eta) = k(\eta)\tau^{\alpha(\eta)}(c^F)^{1-\alpha(\eta)} \qquad \text{(A13.4)}$$

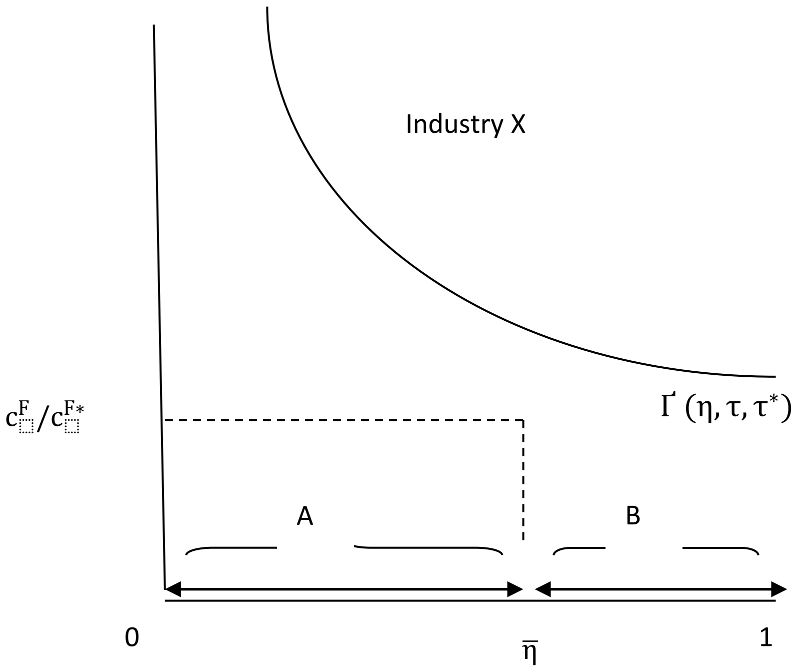
where k(η) is a constant, τ is the pollution tax per unit of z (pollution emission) and $c^F = c^F(w, r)$ is the unit cost of producing one unit while employing labour and capital with factor prices (w, r). As mentioned before, a foreign country's unit cost is denoted by c(η)*. In this case, the trade pattern is considered as follows:

According to Levinson and Taylor, if c(η) ≤ c(η)*, all firms η in their home country are involved in production and exporting, but foreign firms produce the remainder. By using equation (A13.4), this condition can be arranged into the following equation.

$$\left(\frac{c^F}{c^{F*}}\right) \leq \left(\frac{\tau^*}{\tau}\right)^{\frac{\alpha(\eta)}{1-\alpha(\eta)}} \equiv \Gamma(\eta, \tau, \tau^*) \qquad \text{(A13.5)}$$

Levinson and Taylor also suggest that the equal value of equation (A13.5) defines 'an interior threshold firm $\bar{\eta} \equiv g(c^F, c^{F*}, \tau, \tau^*)$'.

Figure A13.1: Threshold determining Activity and the Exports of firms in the Home country



Industry "X" faces the factor cost c^F at home and c^{F*} in the foreign country, and pollution taxes τ and τ*. In A – part (0 to $\bar{\eta}$), because c(η) < c(η)*, firms in this area are active at home and also export their products to foreign countries. On the contrary, in B – part (at the right-hand side of $\bar{\eta}$), c(η) > c(η)* leads firms to produce their goods in foreign countries and then to export their goods to the home market.

The theoretical estimation equations

By using the income spending on goods of sector i, Levinson and Taylor proposed a net import function as

$$\text{Net import}_i = b_i I\,[1-\overline{\eta_i}] - b_i^* I^* \overline{\eta_i} \qquad \text{(A13.6)}$$

where bi and bi* are the fractions of income used for industry i goods in the home and foreign countries. I and I* denote national income. Therefore, $b_i I\,[1-\overline{\eta_i}]$ is the value of home imports from foreign countries in industry I, while $b_i^* I^* \overline{\eta_i}$ is the value of foreign imports from the home country in industry i.

Levinson and Taylor divided equation (A13.6) by domestic production $((b_i I + b_i^* I^*)\overline{\eta_i})$, because the industry sectors differ significantly in size, in order to prevent excluded variables linked with industry size from affecting the error term (Leamer and Levinshon, 1996). In this case, equation (A13.6) is transformed into

$$N_i = -[1 - \frac{s_i}{\overline{\eta}_i}] \qquad \text{(A13.7)}$$

where N_i is net imports and s_i is the ratio of home expenditure to world spending $(\frac{b_i I}{b_i I + b_i^* I^*})$. If $s_i > \overline{\eta}_i$, net imports are positive. Considering the components of $\overline{\eta}_i$, Levinson and Taylor made equation (A13.7) close to a linear function, as given by the following

$$N_{it} = \alpha_0 + \alpha_1 s_{it} + \alpha_2 C_{it}^F + \alpha_3 C_{it}^{F*} + \alpha_4 \tau_{it} + \alpha_5 \tau_{it}^* + \varepsilon_{it} \qquad \text{(A13.8)}$$

where N_{it} is the net imports scaled by production, C_{it}^F is the typical production costs (labour and capital), C_{it}^{F*} is the foreign production cost, τ_{it} *and* τ_{it}^* are the pollution tax at home and in the foreign country, and ε_{it} is both an approximation error and a standard measurement error from the data collection.

14. Goldberg's approach

Goldberg suggested three methods for determining the industrial real exchange rate in terms of a weighting method.

Export-weighted

$$xer_t^i = \sum_c w_t^{ic} * rer_t^c \text{, } where\ w_t^{ic} = \frac{x_t^{ic}}{\sum_c x_t^{ic}} \qquad \text{(A14.1)}$$

Import-weighted

$$mer_t^i = \sum_c w_t^{ic} * rer_t^c \text{, } where\ w_t^{ic} = \frac{M_t^{ic}}{\sum_c M_t^{ic}} \qquad \text{(A14.2)}$$

Trade-weighted

$$ter_t^i = \sum_c [(0.5 \frac{x_t^{ic}}{\sum_c x_t^{ic}} + 0.5 \frac{M_t^{ic}}{\sum_c M_t^{ic}}) * rer_t^c] \qquad \text{(A14.3)}$$

where x_t^{ic} is the export of sector i to trading counterpart c at time t, M_t^{ic} is the imports of sector i from c at time t and rer_t^c is the bilateral real exchange rate of each Korean trading partner c.

15. Merits and Drawbacks of various methods of measuring stringency of environmental regulations

	Multi-dimensionality (and Sampling)	Identification	Enforcement (De jure vs De facto)	Data Issues
Single policy change event	*Depending on the research question. Powerful in looking at direct effects at a micro-level where other variables can be controlled for or ignored. *Utilisation as proxy of overall country stance on environmental regulation relies on assumptions that selected policy events can represent the general legislative setting.	*In principal policies are well identified, though the weighting and aggregation structure imposes assumptions on the interactions among environmental policies that may not be valid. Empirical applications may face problems of different time lags in reactions to policies.	*Practically fully de jure	*Depending of the event chosen. For instance, the data of signing international agreements (i.e. Kyoto) is easier to collect than implementation data of national legislations. Being often dummy variables, they can be used in international comparison only if the same policy is introduced (i.e. Kyoto, EU Directives, etc)

Composite indicators of policies	*Linked to the process of scoring, aggregation and weighting of diverse instruments which is challenging. The underlying assumption is that a sufficient set of “representative” instruments is informative on the overall policy stance.			*Theoretically, they give potential for recreating historical time series. Data gathering may be particularly cumbersome for some developing countries. Once data are gathered, comparing and quantifying policies may not be straightforward.
Surveys of perception	*Implicit-different dimensions are implicitly weighted via the surveyed sample. *Sample self-selection is a major issue.	*Distinguishing effect of overall environmental policies or individual environmental policies from the effects of other polices (labour, competition, financial market) and of other factors (economic developments, available technologies, market structure, trade etc.) is tricky. *May focus on direct effects, rather than total effects, i.e. outsourcing.	*De facto	*Few surveys are conducted consistently across countries.
Firm/Plant level environment-related expenditures	*Focusing on consequences circumvents the part of multi-dimensionality due to different instruments and their design. In this sense, they also include policies that are normally difficult to score or obtain information on i.e. soft policies,		*De facto	*Several datasets, even if sometime discontinuous, are available (i.e. US-PACE, EU-EPER, etc.) but not easily comparable internationally. Measurement and definitional issues.
Shadow prices				*Environmental performance data are available for most OECD countries on a

Environmental Performance/outcomes	voluntary approaches (VAs). *Environmental multi-dimensionality remains a major issue. *Sample self-selection is a major issue.			restricted set of media/pollutants (mainly GHG). Shadow prices prone to assumptions on the production function.

(Source : Botta, E. and T. Koźluk, 2014)