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An Analysis of the Effect of Environmental Regulations on Industrial Competitiveness

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Summary

Economic activities are closely related to real-world environmental issues. Currently, more attention is paid to the association between environmental regulations and industrial competitiveness because of the pressures on economic development and environmental protection. Usually, the public holds the point of view that environment regulations inevitably have a negative impact on competitiveness because of the presumed increase in costs. This opinion is also shared by many academics. In the 1990s, another hypothesis was developed which is represented by Porter. The researchers argue that the innovative aspects of environmental regulations can have a positive impact on industrial competitiveness. To this day, there is no consensus.

This study aims to identify and explain the association between environmental regulations and industrial competitiveness within an appropriate theoretical framework. It makes use of data from China, as there has been little research in this field in that country; and China, the biggest developing country, has the unavoidable responsibility to protect the environment and promote world economic development.

This study is conducted on two levels. First, the association between regulations and the competitiveness of different industries in the secondary sector in China is studied on the national level. Then it studies the association from the perspective of the whole secondary sector of 30 provinces on the provincial level. The modelling method is used in that part. Finally, the study applies the General Equilibrium Theory to build a theoretical framework to analyse the mechanism behind the association and use the mechanism to interpret the results of the modelling.

Several important findings are summarised. First, the impact of environmental regulations on industrial competitiveness is not a simple linear one but a U-relationship, meaning that the traditional hypothesis works first and Porter's Hypothesis fits later. Second, the traditional hypothesis and Porter's Hypothesis are not contradictory but can be integrated within the General Equilibrium framework. Third, the crucial point to activate the U-relationship or Porter's Hypothesis is the innovation, which, among others, can be triggered by stringent regulations, well-designed policies and better education. Last, moving back to the case of China, China on the whole enjoys a positive association between environmental regulations and industrial competitiveness. However, conditions vary from province to province. The impact of environmental regulations on industrial competitiveness varies. The eastern provinces are experiencing a positive impact, while other provinces are in the dilemma where there is a trade-off between the regulations and competitiveness.

This study proposes some suggestions to activate the positive impact at last, including the following points: use market-based instruments; adopt stringent rather than lax regulations; set different policies for different provinces and strengthen the interaction; continue to improve the level of education.

Key words: Environmental regulations; Industrial Competitiveness; Porter's Hypothesis; Traditional Hypothesis; China

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Lists of Abbreviations

EDU	The rate of people with higher education
GAQSIQ	General Administration of Quality Supervision, Inspection and Quarantine
GDP_PC	Gross Domestic Product per capita
GMM	Generalized method of moments
IC	Industrial Competitiveness
IV	Instrumental Variables
IMD	International Institute for Management Development
INF	Infrastructure
LISA	Local Indicators of Spatial Association
LM	Lagrange Multiplier
LR	Likelihood Ratio
MEP	Ministry of Environmental Protection
MT	Ministry of Technology
NBS	National Bureau of Statistics
NDRC	National Development and Reform Commission
PI	Pollution Intensity
POP	Population
PPF	Production Possibility Frontier
R&D	Research and Development
SAR	Spatial Auto Regression Model
SDM	Spatial Durbin Model
SEM	Spatial Error Model
SEPA	State Environmental Protection Administration
SER	Stringency of Environmental Regulation
SI	The Scale of Industry
WEF	World Economic Forum

Chapter 1: Introduction

1.1 Background

Economic activities are closely linked to real-world environmental issues. The occurrence of economic activities may improve or damage environmental quality, whereas the quality of the environment may meanwhile facilitate or impede economical operation.

Since the Industrial Revolution about 200 years ago, many countries have experienced a phase of fast economic growth coupled with rapid deterioration of the environment. Severe environmental problems have already harmed human health and restricted long-term economic growth. In 1972, the United Nations Conference on the Human Environment held in Stockholm brought attention of the world to environmental protection. The conference contributed to the advent of the Action Plan for Human Environment and led to the establishment of United Nations Environment Programme. In 1992, the United Nations World Commission on Environment and Development proposed sustainable development, urging more people to realize that how to protect and improve the environment lie at the heart of the world's most urgent and pressing challenges. At present, environmental protection and sustainable development have permeated every aspect of human social and economic activities.

Environmental problems usually root in negative externalities of economic activities, which mean that the actors of economic activities add external costs to the society by pollution without paying the corresponding social costs. The phenomenon can also be described in light of "tragedy of the common" (Hardin, 1968), where environment is the unregulated "commons" that is free access. In absence of regulation, each individual will tend to over-exploit the commons/environment to her or his own advantage. Therefore, environmental problems cannot be solved only by market mechanism. To maximize social welfare and sustainable development, most countries implement environmental regulations. Especially in developed countries, strengthening environmental protection and reinforcing environmental regulations have become major issues (Vogel, 2009).

Developing countries, whose economic development level and technological level are relatively low, are facing a dilemma. On the one hand, because of the significant role of industrialization in promoting economic growth, these countries urgently need to develop secondary industry. As they are limited by their technological level, capital strength and human capital, “pollution intensive” industries are their first choice. On the other hand, they have to face huge costs to the environment since they are in the low-level development phase. When facing the choice between economic development and environmental protection, they will always give preference to economic development. This is because of the “common view” that firms have already made the optimum choice in real economic activity, and that implementation of environmental regulations will only increase the cost of production, which consequently will impede international competitiveness and further economic development (Denison, 1979;Gollop & Roberts, 1983). If the stringency of environmental regulations is improved, developing countries think these "pollution intensive" industries will be affected since their technology cannot handle the more stringent regulations.

In consequence, environmental regulations in developed countries is always more stringent than that in developing countries. It is the very difference in the stringency of environmental regulations within different countries that leads the public to consider the potential negative effect of environmental regulations on international trade and industrial competitiveness. Whether to adopt stringent environmental regulations or not, and whether environmental regulations will be a hindrance to industrial competitiveness, and further be a hindrance to national competitiveness has received significant attention from many countries and academics. The association between environmental policy and industrial competitiveness has entered the public view (Wallace, 1995).

As for China, it has achieved remarkable economic progress during the past 30 years. Many factors contribute to the success, especially industrialization. Even so, China is still in the late middle period of industrialization and has a long way to complete industrialization (Li, 2009;Cai, 2009;Li, 2009;Zhang, 2012). Also, the former development of China was extensive and consumed a huge amount of resources with low efficiency and high pollution levels. The government’s pursuit of speed in economic development unilaterally led to deterioration of the environment. According to the OECD report *Environmental Performance Review (2007)*, the air pollution in some Chinese cities is among the worst in the world; almost one third of the rivers are severely polluted. *Chinese Green National Economy Accounting Study Report* issued by SEPA and NBS shows that the economic loss caused by environmental pollution is 511.8 billion yuan (around 62.5 billion dollar) accounting for 3.05% of GDP that year. The Chinese environmental situation is hardly optimistic.

Fortunately, the Chinese central government has realized the dilemma and already started to correct its actions. It has proposed many plans to solve the current environmental problems, including building an environment friendly society, adhering to a sustainable development strategy, etc. But concerns over the negative effect of environmental regulations on economic development never disappear. Such concerns even influence the formulation and implementation of environmental regulations, especially by the local governments who often fall in their tasks to protect the environment. (Li, 2012).

China, as an important member in the world community, has the unavoidable responsibility to protect the environment as well as promote world economic development. Based on the above background, the topic of the research is to study the association between environmental regulations and industrial competitiveness in China. The results may enrich the relative research achievements and contribute to the formulation of economic and environmental policies in China.

1.2 Problem Statement

Currently, there are three major views regarding the effect of environmental regulations on industrial competitiveness. Some regard them as rewarding to the competitiveness, some believe they can trigger innovation and improve competitiveness, while others think environmental regulations do not have a significant impact on industrial competitiveness, or have a joint influence with other factors.

Academics, who support the Pollution Haven Hypothesis, which is a major hypothesis of disadvantageous view, argue that environmental regulations would increase the industrial costs and thus have adverse effects on products’ market performance. The different degrees of stringency in environmental regulations practiced in different countries would negatively affect those firms that participate in the international market, making them prefer to relocate to less stringent jurisdictions. The countries with relatively less stringent environmental regulations compared with their trade partner countries will possess the comparative advantages in hosting polluting industries. It destroys fair competition in international trading (Copeland & Taylor, 1994). However, Porter's Hypothesis (1991), which is in favour of environmental regulations, considers losses in competitiveness caused by environmental regulations to be of short-term duration. Proper environmental regulations will promote enterprises’ production efficiency and competitiveness by technical innovations in the long run. As for the third opinion that the impact is non-significant or jointly significant, academics have also done an amount of researches which will be reviewed in Chapter 2 in detail (Jaffe et al., 1995;Sinclair-Desgagné, 1999; Xepapadeas & de Zeeuw, 1999).

All of these theories have provoked a large number of empirical studies to that either support or reject them. But no consensus has been reached in the literature. Many factors contribute to the different conclusions of those empirical studies. The diversity of indices, which are used to measure the stringency of environmental regulations and the performance of industrial competitiveness, are important (Clark & Guy, 1998). Because there is no consensus on indices and it is comparatively difficult to obtain environmental data and certain industrial data, many academics would subjectively use some proxy variables. Another difficulty may be the different national conditions. One theory suited for a country may not be appropriate for another one. China, with its special culture and large population, needs to be studied as a unique phenomenon (Jin, 2009). Additionally, endogeneity of environmental variables can influence results of theoretical and empirical researches (Levinson & Taylor, 2008), because that previous studies always treat environmental variables as exogenous. Other factors also lead to such a situation. Therefore, this research is dedicated to find an appropriate theoretical framework to explore and explain the effect of environmental regulations on industrial competitiveness in China.

1.3 Research Objective

This research aims to identify and explain the association between environmental regulations and industrial competitiveness, based on an appropriate theoretical framework.

First, reasonable indices were adopted to measure the stringency of environmental regulations and industrial competitiveness. Then these indicators were applied to build an appropriate model to explore and identify the effect of environmental regulations on industrial competitiveness in China. To describe the impacts more comprehensively and deeply, and find the difference between different research angles, the study was conducted on two levels. On the national level, the performance of different industries in the secondary sector was studied. On the provincial level, the industries in the secondary sector from each province were treated as a whole, and the research focused on the performance of different provinces considering the spatial effect. Based on the results of the econometric model, the research plans to use an economic model and theories to explain the mechanism. Finally, this research hopes to provide some policy suggestions on environmental regulations and industrial competitiveness. Therefore, the specific objectives are as follows:

- Find the appropriate indices that can measure the stringency of environmental regulations and industry competitiveness;
- Explore the impact of environmental regulations on industrial competitiveness;
- Explore the mechanism behind the impact and association;
- Provide some suggestions based on the results.

1.4 Provisional Research Questions

According to the objective, the main research question is:

> *What is the influence of environmental regulations on industrial competitiveness in China?*

The research question can be subdivided into following sub-questions:

1. Which factors can measure the level of industrial competitiveness and the stringency of environmental regulations?
2. On the national level, what is the impact of environmental regulations on industrial competitiveness?
3. On the provincial level, what is the impact of environmental regulations on industrial competitiveness?
4. What is the mechanism behind the influence?
5. Based on the results, how can we improve the effect of environmental regulations while reducing the negative effect on industrial competitiveness and economic development at the same time?

1.5 Significance of the Study

With the continuous development of economic globalization, national competitiveness has become a hot issue worldwide. According to Porter's Theory (Porter, 1990), the competitive advantage of nations mainly lies in their industries' competitive performance on international markets according to Porter's Theory. Therefore, the study of industrial competitiveness has been an important concern in this field. Meanwhile, the pressure to preserve the environment has become overwhelming. As previously stated, the association between environmental protection and industrial competitiveness, together with the potential negative and positive impacts has obtained more attention from academics, officials and the public.

China as a developing country is currently at a critical stage of industrialization, while at the same time facing a huge pressure for environmental protection. Given its development, and as a member of the Global Village, China has the enhanced and unavoidable responsibility to accelerate the world economic development and preserve the environment. Therefore, the effect of environmental regulations on industrial competitiveness is not only crucial to Chinese policy-makers and policy-performers, but also to the world's economic development and environmental protection. Presently, only a few empirical studies in this field have been conducted in China. This research may enrich the body of knowledge in the related theories.

1.6 Scope and Limitations

1.6.1 Area Scope of the Research

As mentioned above, this research was focused only on China and conducted on two levels as mentioned above. First, on the national level, the research studied the association between environmental regulations and industrial competitiveness from the perspective of 36 industries of the secondary sector in China (see Appendix 1 for the names of the 36 industries). Then, on the provincial level, it studied the association from the perspective of the whole secondary sector of 30 provinces except Tibet, Taiwan, Hong Kong and Macao (see Appendix 2 for the names of the 30 provinces).

1.6.2 Time Scope of the Research

Both the data on national level and provincial level ranged from 2001 to 2010, because some statistical methods and content in the yearbook have been changed since 2010 and the industry category was changed in 2000.

1.6.3 Limitations of the Research

There were several limitations to this research. First, there was a lack of qualitative research. This research only used the econometric and economic models to explore and explain the phenomenon. Second, because the field of spatial econometrics is still in its infancy, that's why many tests for the model were not complete in this research. Third, due to the accessibility of data, some variables used the proxy variables and four regions were not included on the provincial level. Fourth, land data were not considered because of the unavailability of data in this research. Last, all data of the research were obtained from the statistical yearbook and was a secondary data.

Chapter 2 Theory Review

2.1 State of the Art of the Theories

This chapter reviews some of the concepts and theories in the fields of environmental regulation and industrial competitiveness, together with some famous hypotheses and theories on the association between environmental regulation and industrial competitiveness.

2.1.1 Environmental regulations

In nature, environmental problems derive from market failure (Pigou, 1920; Coase, 1960). Environment possesses the attributes of public goods, thus the existence of externality is inevitable. Because of the negative externalities, the natural resources are overused and environmental problems are increasing. There is a grave deviation between the optimal outputs determined by the maximization of individual profit and the separate maximization of social welfare. The costs caused by environmental pollution are not always added to the polluters' economic costs wholly on account of their implicit equity, which forces other stakeholders in the society to share those costs. That's why the private costs of the polluters are much lower than the costs to society. Therefore, it is necessary that the governments take actions to correct the market failure, constrain environmental externalities and clarify the environmental equity. This is the reason for the need of environmental regulations (Stewart, 1991).

Currently, there is no uniform, specific and authoritative definition of environmental regulations. But according to regulation economics, regulations have usually been clearly defined as follows:

> *"Regulations are general rules or specific actions imposed by administrative agencies that interfere directly with the market allocation mechanism or indirectly by altering consumer and firm demand and supply decisions"*
>
> (Spulber, 1989, p37)

Hence, this research defines environmental regulations referring to regulation economics: Environmental regulations are the general rules or specific actions enforced by administrative agencies to control pollution and manage natural resources with the purpose of protecting the environment and internalising externalities, including direct and indirect intervention.

In the 1990s, the conceptual boundaries of environmental regulations were extended. In addition to the environmental regulations imposed by administrative agencies, voluntary regulations made by firms and industrial associations are also included in environmental regulations (Zhao et al., 2009). However, this research attempts to discuss the authoritative environmental regulations enforced by administrative agencies.

2.1.2 Instruments of Environmental Regulation and Theoretical Basis

At present, environmental regulations mainly have three policy instruments, or a hybrid of these three basic instruments. They are 1) Conduct instruments, 2) Price instruments and 3) Quantity instruments (Wiener, 1999). This research groups them into two categories: Command-and-Control Instruments and Market-Based Instruments.

2.1.2.1 Command-and-Control Instruments

Command-and-Control instrument is a conduct-oriented regulation. Administrative agencies can mandate practices and technologies to protect the environment (Wiener, 1999). Usually, it is a series of standards designed by regulators to be followed by polluters or to require a certain industry to adopt a certain technology in accordance with rules and regulations. Administrative agencies can impose sanctions on violators and reward compliers. For example, the category and quantity of discharged pollutants and way of discharging have been set clearly by administrative agencies in the coking chemical industry in China[1]. In the coal industry, administrative agencies have required firms to adopt a certain technology to control the emission of SO_2[2]. Moreover, administrative agencies have even set output ceiling to control the negative externalities generated by producers, like the Chinese paper-making industry whose output ceiling is 116 million tons in 2015[3].

A Command-and-Control instrument is also simple and direct. Standards and rules set by the administrative agencies usually reflect the willingness of society to control and reduce pollution. It is the most widely adopted approach now (Wiener, 1999). Due to the different levels of economic development and technology, the stringency of these environmental regulations differs. Generally, developed countries adopt stringent regulations, while developing countries often implement lax regulations (Copeland & Taylor, 1994).

However, in light of the existence of previous government failure, the formulation and implementation of these environmental standards may not achieve the optimal result in reality. Additionally, the whole process would increase the government’s financial burden and increase social cost further. But currently the main instruments of regulations are still the command-and-control (Zhao et al., 2009; Wang, 2012; Li, 2013)

2.1.2.2 Market-Based Instrument

Market-based instrument uses market signals and economic means to control

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[1] Referring to the Chinese national standard, *Emission standard of pollutants for coking chemical industry (GB16171-2012)* issued by MEP and GAQSIQ of China.

[2] In 2002, MEP and MT of China promulgated a policy, *named Pollution Control Technology Policy of Sulphur Dioxide Emissions in Coal Industry*, which mandated certain technologies to control Sulphur Dioxide Emissions.

[3] Referring to *China's twelfth five-year plan for paper-making industry* issued by NDRC in 2011. It is a supporting plan of *the Twelfth Five-year Plan of National Economy and Social Development*.

pollution and internalise externalities, mainly including price and quantity instruments. For the price instrument, Emission Tax/Pigouvian tax is a representative application. For the quantity instrument, Emission Permit Trading is a specific instrument that is widely used. In addition, the instrument among others also includes the subsidy system, deposit refund system and voluntary environmental agreements (Stavins, 2000;Segerson & Miceli, 1998).

2.1.2.2.1 Price Instruments

Price instruments always force polluters to pay for the social costs of their activities to internalize their environmental costs. These instruments can be imposed ex post or ex ante. Ex post instruments are based on the strict liability for the sources of pollution that have actually damage the environment. With respect to ex ante instruments, administrative agencies impose tax on polluters for the estimated external costs of their emissions beforehand. (Wiener, 1999).

Pigouvian tax is the theoretical base of price instruments. In *the economics of welfare*, Pigou (1920) proposes to grant a subsidy to activities that have positive externalities, which is the basis of Pigouvian tax. The tax is levied on the amount of pollutant emissions or environmental damages caused by economic activities, and it is a specific duty. The amount of Pigouvian tax should be the difference between marginal private cost and marginal social cost. The tax rate will achieve an optimal point, when marginal social costs equal marginal benefit. After imposing Pigouvian tax, the private costs of economic activities will be equal to social costs, and the marginal costs of abatement of polluters will start to exceed the tax imposed, which mean that externalities are internalised (Pigou, 1920).

Ideally, Pigouvian tax can make the efficiency of resource allocation achieve Pareto Optimality. But its premise is that the government should fully cognise the externalities, which is very hard to meet. If the government fails to know the correct level to levy tax or is unwilling to spend time and budget in a repeated “trial and error” process to find the correct level, an emission charge such as Pigouvian tax could generate a negative effect on economic activities or even leads to worsening the situation (Tietenberg, 1990).

2.1.2.2.2 Quantity Instruments

Quantity instruments first set the upper limit on the amount of resource use and pollution discharge. Administrative agencies then partition this quantity to different parties by granting licenses or permits. These licenses and permits can be traded in the market through negotiation between different participants.

One specific instrument is emission permit trading, which is a typical application of the Coase theorem and formally proposed by John Dales in 1968. Coase (1960) argues that if there is a clear demarcation of property rights and zero transaction costs, externalities would not cause the misallocation of resources, and the market could realise the efficient use of resources. Emission permit trading derived from the Coase theorem just introduces market mechanism into the allocation of environmental resources, and bases the transactions on the clear delineation of environment property rights. Then if transaction costs are low, the market can achieve Pareto Optimality of the allocation of environmental resources through negotiation between polluters.

As long as difference exists between marginal pollution treatments costs of different polluters, emission permit trading can benefit both sides. By emission permit trading, the pollution-control activities will happen through the source which has the lowest marginal pollution treatment cost (Tietenberg, 1985). Currently, emission permit trading has been something of a global standard in environmental regulations and a radical innovation (Voß, 2007).

However, fulfilling the trading also has many premises. First, environmental capacity and value must be calculated correctly. Correct identification of environmental capacity and value is the basis of the whole trading. Second, transaction costs should be as low as possible. Zero-transaction-cost is the assumption of the whole system, which is almost impossible in reality. Therefore, it is necessary that the government develops institutions to reduce the transaction costs. Third, the initial allocation of emission permits or licenses should be decided reasonably. Currently, there are two main kinds of allocation modes, the free mode and the non-gratuitous mode, or a combination of the two. The free mode is performed according to certain public standards, and the parties obtain permits freely. The non-gratuitous mode is realised by auction, which generates a market price of permits and can achieve Pareto Optimality. Fourth, the conversion rate of trading in different space and time must be set scientifically by the government. Since different pollutants emitted in different space and time could have diverse effects on the environment, the conversion rate must be set scientifically to guarantee equal trading (Zheng, 2005).

Compared with price instruments, quantity instruments use trading between polluters to internalise the externalities and implement regulations, which eases the financial burden on the government and reduces the total social cost. However, its defects are also obvious. With the total amount of pollutant unchanged, the pollutant may concentrate on one area. Moreover, the premise of emission permit trading is sometimes hard to achieve completely, especially the zero-transaction-cost assumption. Even so, it is still an innovation in governance and indeed has positive effects on environmental protection. (Wiener, 1999;Zheng, 2005)

2.1.3 Industrial Competitiveness

Competition is one of the basic issues in economics, and is the premise of market economy and efficient resource allocation. Currently, academics and organizations cast many debates on national competitiveness. In fact, industrial competitiveness is closely linked to national competitiveness and enterprise competitiveness, like on a meso-level. The improvement of industrial competitiveness is based on the improvement of enterprise competitiveness within the industry. With several industries raising the competitiveness, the national competitiveness will be enhanced as a consequence (Porter, 1990).

As for the definition of industrial competitiveness, much debate and no consensus exist on a common definition. WEF and IMD are the first organizations to research the international competitiveness. In 1985, WEF first put forward the concept of international competitiveness, which is the ability that firms in one country could provide products and services with better quality and lower costs compared with domestic and foreign competitors. In 1991, IMD and WEF defined international competitiveness jointly as follows: International competitiveness is the ability that firms in one country could design, produce and sell products and services on a global scale, with more attractive price characteristics and non-price characteristics as compared with its competitors (WEF & IMD, 1991). In 1994, WEF and IMD redefined the international competitiveness, that it is the ability of a nation or a firm to produce more wealth compared with competitors on the global market in a balanced way (WEF & IMD, 1994). The earlier studies of WEF and IMD on international competitiveness of firms and nations can be used for reference in defining industrial competitiveness. After that, these two organizations mainly focused on the national competitiveness (Ochel & Röhn, 2006).

Michael E. Porter (1990), one of the first academics to engage in industrial competitiveness study, argues that a mere explanation of competitiveness on the national level is insignificant. He stresses to focus on specific industries and industry segments and then try to explain national competitiveness. A new theory must explain why a nation is a able to be the home base for internationally competitive companies. (Porter, 1990). He defines industrial competitiveness as follows: competitiveness at the industry level is superior productivity, either in terms of lower costs than competitors or the ability to offer superior-value products that justify a premium price (Porter & Van de Linde, 1995). Jin (1996), a famous economist in China, uses a similar definition to Porter, i.e. that industrial competitiveness is the productivity reflected in sales performance on international markets. It measures the market share and profitability of one product.

In this research, industrial competitiveness is also defined as superior productivity to occupy the market and gain profits, as well as the capacity reflected on the international market to achieve the product’s value, meet the consumers' demands and realise sustainable development.

2.1.4 Theories of Industrial Competitiveness

During the history of economy, different economic schools have had different explanations of the source of industrial competitiveness.

2.1.4.1 The Theory of Comparative Advantage

The Theory of Comparative Advantage was originally developed in the 19^{th} century. Different economic schools developed the theory of comparative advantage to explain the competitiveness based on the different features of their eras.

2.1.4.1.1 Classical Comparative Advantage

David Ricardo (1821), proposes the theory of comparative advantage in his book *On* *the Principles of Political Economy and Taxation*, which is also called comparative cost theory and is the development of the theory of absolute advantage. He argues that the basis of international trading is a comparative advantage instead of absolute advantage in production. Every country should focus on producing some particular goods and providing certain services, which are at a lower marginal and opportunity cost than the others, namely, more efficiently than other countries (Ricardo, 1821). He maintains that even if the nation does not have any absolute advantage, it could use its comparative advantage to exchange against some high-cost products and services to improve the welfare of society.

2.1.4.1.2 Neo-classical Comparative Advantage

Ricardo's model only considers the labour costs in production and is based on the assumption of labour homogeneity. Eli Heckscher (1919) and his student Bertil Ohlin (1933), instead, propose the H-O model based on comparative advantage, which begins to pay attention to factor endowments of a region. This model no longer insists that labour is the only production factor but also considers the capital factor. This model predicts that a region will gain comparative advantage in one product, if such a product is produced by using its relatively abundant and cheap factors.

However, the H-O model neglects the influence of technical progress. Posner, M.V. (1961) covers the shortcoming of the H-O theory. He remarks that technical progress is different in different countries; comparative cost differences caused by technical changes may lead to trade in particular goods; a country rich in technology endowment can obtain and maintain competitiveness in the industry until the rest of the world successfully imitated its innovation. Vernon. R. (1966) develops the Product-Cycle Theory that also covers the shortcoming of H-O the model. He stresses that all products have a life cycle that is composed of five stages: introduction, growth, maturity, saturation and decline. Because of the different levels of technology, all countries, whether developed countries or developing countries can obtain comparative advantages in different stages. The Product-Cycle Theory is a dynamic theory of comparative advantage.

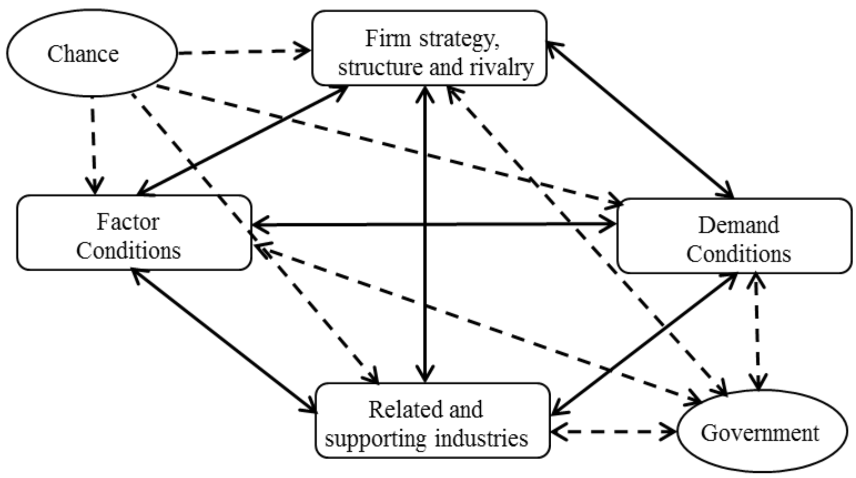
2.1.4.1.3 Modern Comparative Advantage

With the development of international trading and division of labour, the New Trade Theory in 1970s further developed the theory of comparative advantage. Krugman, P., a representative of the New Trade Theory, deems that the neo-classical theory can only explain the trading happening in different industries between countries and regions; the comparative advantage in trading within the same industry is dependent on two factors: the scale economies and the difference in the products. When an industry has scale economies, both internal (scale economies of a firm) and external (scale economies of an industry), it can sell its products at a competitive price. When the income of a region reaches a relatively high level, there is room for differences in products (Helpman & Krugman, 1989). His theory could also be grouped into the dynamic theory of comparative advantage.

2.1.4.2 The Theory of Competitive Advantage

Porter (1990) does not think that the theory of comparative advantage could explain the source of industrial competitiveness. He remarks that the classical theory, which explains competitiveness based on the factor-based comparative advantage, has been overshadowed in advanced industries and economies in the trend of international competition and by the power of technology (Porter, 1990). Therefore, he proposes the theory of competitive advantage to explain the source of competitiveness. Compared with comparative advantage, competitive advantage is obtained by outperformance. That is to say, the performance of an industry of a country or region that exceeds the same industry, instead of a different one, belonging to another country or region in the same global competitive environment (Porter, 1990).

Based on a number of case studies, Porter (1990) develops a diamond model and summarises six broad factors that will determine the performance of an industry in a country (see Figure 1). They are 1) factor conditions, 2) demand conditions, 3) related and supporting industries, 4) firm strategy, structure and rivalry, 5) government and 6) chance. Among the six factors, the first four factors are the determinants of industrial competitiveness, which influence each other mutually and create the national environment in which firms are born and making progress. Governments can have an impact on these four determinants, while chance is outside of anyone's control (Porter, 1990).

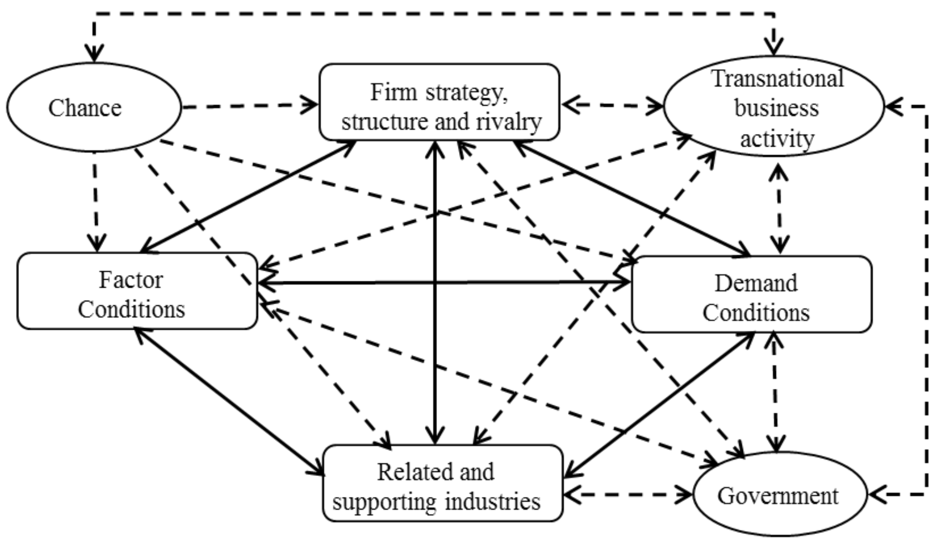


(Source: Porter, 1990)

Figure 1 Porter Diamond Model

Subsequently, Dunning (1993) remarks that the Diamond Model fails to consider multinational activities. He argues that foreign inward and outward investment would affect the model. Therefore, he proposes to bring transnational business activities into the original model to extend the Diamond Model into the International Diamond Model. Since then, multinational activities are formally included and work more than a simple exogenous variable.

Rugman and D’Cruz (1993) also deem that the traditional diamond model is seriously flawed when used to explain the competitiveness of a small, open and trading economy. They criticise that Porter only defines outward foreign direct investment (FDI) as being valuable to create competitiveness. However, there is a major conceptual problem which would lead to an erroneous valuation of competitiveness of small, open and trading economy. They analyse the case of Canada and claim that because of Free Trade Agreement and comparative small market in Canada, the border between Canada and U.S. is becoming less and less important in the development of policies of Canadian industries. Therefore, in order to survive in the rivalry with leading U.S. firms, policy-makers in Canada need to link the Canadian Diamond Model with the U.S. Diamond Model rather than focus solely on the home country diamond. Such a model is useful to these small economies that share a border with large foreign markets.



(Source: Rugman and D’Cruz, 1993)

Figure 2 Double Porter Diamond Model

Of course, many other academics also developed the Diamond Model based on their own researches, like the Multiple Linked “Diamond” by Cartwright, the nine-factor model by Dong-Sung Cho, etc. Regardless of the kind Diamond Model, they all have a huge influence on the studies of competitiveness and on have built up a new framework of competitiveness research.

2.1.4.3 The Theory of Innovation

The School of Technology Innovation Theory represented by Schumpeter, J.A. (1912) reckons that technology and organizational innovation are the driving forces of economic development. He defines innovation as new production functions and new combinations of production factors. These could be new goods, new modes of production, expansion of markets, conquests of new sources of supply of raw materials or semi-finished goods, or a new organization of one industry (Schumpeter, 1934). Schumpeter (1912) in his book *The Theory of Economic Development* argues that innovation activities will result in entrepreneurial profit and can be regarded as a productive factor. The entrepreneur's pursuit of innovation is the source of competitiveness.

In the 1970s, the School of Institutional Economics represented by North, D.C. considers that competitiveness can be obtained through institutional innovation, by creating an environment to promote the scientific and technological progress which benefits for releasing the economic potential. Institutional innovation is not only profitable to entrepreneurs but is a major source of productivity growth and economic development in one nation (North & Tomas, 1970). The reason why institutional innovation has such an influence is that highly-efficient institutions can reduce transaction costs, narrow the difference between the benefits of individuals and society, and inspire individuals and organizations to produce.

Evolutionary economics pays attention to the intrinsic mechanism of innovation. It stresses that innovative activities by firms face an amount of uncertainty. Due to imperfect information and limited rationality, firms cannot find optimal decisions. They subject innovative activity to past experience, which is called path dependence. Therefore, innovation relies on individual skills of innovators, accumulated experience of innovation of firms, tacit knowledge and etc. All these internal variables constitute innovation routine which determines the innovation activity (Nelson & Winter, 1982).

No matter which innovation theories, they all emphasize the importance of innovation and the factors behind the innovation. Backed up by a huge amount of empirical studies conducted by many academics, it is obvious that innovation indeed has a positive influence on competitiveness at every level (Clark & Guy, 1998)

2.1.4.4 Competitiveness Equation

Since the 1980s, WEF and IMD have conducted an amount of theoretical researches and empirical studies of international competitiveness; they summarise the general rule of determinant factors of competitiveness, namely the competitiveness equation, to measure the international competitiveness. They argue that competitiveness is decided by the competitive asset and competitive process. The Competitiveness Equation is as follows:

$$\textit{International Competitiveness} = \textit{Competitiveness Asset} \times \textit{Competitive Process} \quad \text{(Formula 1)}$$

Asset here includes both inherent assets like natural resources and created assets like infrastructure. Process is the ability to translate economic results generated by the assets into competitiveness by international market[4]. Therefore, in order to build competitiveness, asset and process are both indispensable. Although such a theory is

[4] Quote from a secondary source: Wang,Y., 2000. The International Competitiveness of Chinese Economy. Nanchang: Jiangxi People's Publishing House. pp 43.

first used to study the competitiveness of nations, many academics think that it could also be applied to industrial competitiveness and other kinds of competitiveness.

2.1.5 The Association between Environmental Regulations and Industrial Competitiveness

Now, this research moves on to the core issue of this research, namely, the association between environmental regulations and industrial competitiveness. There are already several kinds of theories to explain the association.

2.1.5.1 Traditional Hypothesis

The traditional hypothesis maintains that the implementation of environmental regulations will have a negative effect on industrial competitiveness, because of the increasing costs, decreasing profits and losses in productivity. Two representative hypotheses are “Race-to-the-Bottom Hypothesis” and “Pollution Haven Hypothesis”.

2.1.5.1.1 Environmental Race-to-the bottom Hypothesis

Environmental Race-to-the-bottom Hypothesis is a socio-economic phenomenon that emerged in the United States between the late 19^{th} and early 20^{th} centuries. It stresses that environmental regulations will increase the cost of some industries. The assumption of this hypothesis is that every country will anticipate that other countries would adopt less stringent environmental standards to avoid increasing costs resulting from relatively high environmental standards. Therefore, all the countries will race to lower the standards, so as to make themselves more attractive to outside financial investment (Schram, 2000), which would lead to the tendency of relaxing regulations globally and finally to the deterioration of the global environment. It is the contradiction between individual and collective rationality.

Although this hypothesis is derived from the real case of the United States, it now contradicts reality. From the global perspective, environmental regulations have the tendency towards more stringent. Even the financial crisis cannot change this trend.

2.1.5.1.2 Pollution Haven Hypothesis

Pollution Haven hypothesis may be one of the most controversial predictions in international economy. It can be explained by the H-O theory that is mentioned above. Environmental factors are now regarded as new inputs for production. The countries that are abundant in environmental factors have a comparative advantage. Usually, the costs of environmental factors are determined by the stringency of environmental regulations. Therefore, the countries with less stringent regulations have comparative advantages in environmental factors. On account of free trading, the industries, especially the pollution-intensive ones, would then relocate to these countries which have comparative advantage in environmental factors. These countries are always developing countries, because developed countries usually adopt strict regulations. The pollution haven is then formed unintentionally because of the agglomeration of these pollution-intensive firms and industries (Siebert, 1977;McGuire, 1982). Further, many policy-makers and academics think that more stringent environmental regulations will hollow out the industry, leading to a decline in export and increase in import. Reduction of the competitiveness of these industries is inevitable in these nations (Jaffe et al., 1995).

Since the advent of the hypothesis, academics have conducted many empirical studies to support it or oppose it. However, what we should keep in mind is that the Pollution Haven Hypothesis is built on the assumption that environmental regulations affect different industries in different ways (Taylor, 2005). They would have much more influence on dirty goods than other goods. Additionally, besides environmental regulations, other factors can also influence the dirty goods industry jointly. Therefore, all analyses depend on the situation.

Some empirical studies supporting the traditional hypothesis are reviewed here. Gray and Shadbegian (1995) adopt the data from paper, oil and steel industries ranging from 1979 to 1990 to test the hypothesis. They find that abatement cost has a significant negative relationship with total factor productivity. Specifically, \$1 spent in abatement will cost the equivalent of \$1.74 productivity loss in the paper industry, \$1.35 in the oil industry and \$3.28 in the steel industry. But other measures of environmental regulations such as control of emissions, enforcement and compliance do not show an obvious association with total factor productivity. Picazo-Tadeo, A. J. et al. (2005) use the directional distance function to test the influence of environmental regulations on the Spanish ceramic pavements industry. Their results show that firms with potential to improve their desirable output will be significantly affected when faced with the environmental rules preventing disposals of waste. If disposal of water is free, the desirable products will grow by 7%. Conversely, when the disposal of waste water is charged separately, the potential increase of desirable goods will fall to 2.2%. It illustrates that environmental regulations are at the cost of decreased growth.

2.1.5.2 Revisionist Hypothesis

Compared with the Race-to-the-Bottom Hypothesis and the Pollution Haven Hypothesis, revisionist hypothesis argues that environmental regulations can generate a win-win situation, where environment improves and industrial competitiveness enhances at the same time. Such a view is represented by the Porter Hypothesis coupled with the Pollution Halo Hypothesis and the Race-to-the-top Hypothesis.

2.1.5.2.1 The Porter's Hypothesis

Porter's Hypothesis was formulated in 1995 in the article *Toward a New Conception of the Environment-competitiveness Association* with Van der Linder. For their part, innovation can be triggered by properly designed environmental standards, by which the competitiveness of one industry can be enhanced in the long run. The benefits can be gained from two aspects: 1) innovation offset and 2) early-move advantage. Innovation can offset the costs of obeying regulations partially even more than fully. And more stringent regulations can generate greater innovation. This is called innovation offset. Besides innovation offset, the firms can also attain competitiveness from early-mover advantages on the international market, once the environmental standards set by the domestic government are consistent with international tendencies of environmental protection (Porter & Van de Linde, 1995). The Porter Hypothesis provides a win-win situation between the environmental regulations and industrial competitiveness instead of a trade-off.

Porter and Van der Linder set three principles for the formulation of good regulations. Many academics believe they are hard to achieve in reality. Other academics criticize that the hypothesis is supported by an amount of case studies while lacking a cost-benefit analysis. But Porter's Hypothesis at least provides the possibility that environmental regulations could have a positive effect on competitiveness, and that could serve to indirectly reduce the negative effect of regulation.

2.1.5.2.2 The Pollution Halo Hypothesis

Zarsky (1999) proposes the Pollution Halo Hypothesis which asserts FDI can help diffuse cleaner technologies, better environmental-management systems and best practise throughout the world since multinational companies have the same internal environmental standards and procedures no matter of the country in which they operate. FDI has the ability of transferring superior technologies from developed to developing economies.

Although this hypothesis concerns on the impact of FDI on environment, FDI is closely related with competitiveness (Dunning, 1992) as mentioned above. It indicates that with the increase of competitiveness, the stringency of environmental regulations increase at the time. They have the positive association.

2.1.5.2.3 The Environmental Race-to-the-top Hypothesis

The Race-to-the-top Hypothesis is based on the famous "California effect" proposed by David Vogel (1997).In maintains that stringent environmental regulations can push regulatory standards upward. From 1970 to the 1990s, California always enacted stricter emission standards in automobile industry than other states. Instead of states with lax regulations undermining the automobile industry of California, California helped to push the whole country's mobile emission standards upward. The effect even spills over to European countries, because the manufacturers have to comply with the stricter regulations to ensure the market access and avoid the huge expenditure of complying with different standards. Based on the example of automobile industry in California, Vogel concludes that market competition caused by trade liberalisation can facilitate the spillover of environmental standards from greener nations to less greener ones (Vogel, 1997). Since the degree of liberalisation and openness of trade is the very important factor to improve competitiveness and can be reflected by FDI, it can also conclude that environmental regulations have a positive association with competitiveness.

Here are some related studies to support the Revisionist Hypothesis. Some literatures adopt the econometric model to make up the defect of Porter's Hypothesis, which is lacking in quantitative analysis. For instance, Hamamoto (2006) applies an econometric model to Japanese manufacturing industries and finds the evidence to support Porter's Hypothesis. He uses pollution control expenditure to measure environmental regulations and concludes that environmental regulations have a positive effect on R&D activity. Further, R&D investment will have a significant positive influence on the growth rate of total factor productivity and stimulate a high rate of return. Boyd et al. (2002) use the Malmquist-Leunberger Index which provides a linkage between the rate of diffusion of technology and productivity growth, and the directional distance function to test the association between environmental regulations (measured by emission of NO_x) and the productivity of the glass container industry with data ranging from 1987 to 1990. They conclude that the potential output of a win-win situation exceeds output loss caused by environmental regulations in all the years except 1988, and the change of technology contributed to productivity growth and environment protection. These conclusions support Porter's Hypothesis.

Bommer, R. supported the Revisionist Hypothesis from the opposite perspective. He builds a political-support maximum model based on the assumption that the information between regulator and the regulated is asymmetry. The result shows that an entrepreneur may rearrange his capital and relocate his production for purely strategic reasons instead of reduced competitiveness. Relocation is a way of indirect rent-seeking, to convince the regulator to believe the inability of enterprises to accept a further tightening of environmental regulations (Bommer, 1999). Bommer's research denies the traditional hypothesis. Dong et al. (2012) study the association between FDI and environmental standards, and apply a North-South market model based on the assumption that pollution is trans-boundary. They find that if the market sizes of two countries are small, FDI can trigger "race-to-the-top" in emission standard; but if the market sizes are large enough, FDI will not change the environmental standards. The research denies the traditional hypothesis to some extent, although it cannot prove the "race-to-the-top" under the circumstances of large-size market.

2.1.5.3 Comprehensive "Theory"

It is natural that the debates between promoters of the traditional hypothesis and revisionist hypothesis are vigorous, which impels some researchers to re-exam the association between them. Some people think that environmental regulations alone cannot influence industrial competitiveness, but that they have a combined effect with other factors. Some regard environmental regulations as not having a decisive impact on competitiveness. Although there has been no formulated theory at this point, many academics have built economic models or done empirical researches to support their views (Jaffe et al., 1995; Sartzetakis & Constantatos, 1995;Sinclair-Desgagné, 1999;Xepapadeas & de Zeeuw, 1999).

For example, Sinclair-Desgagné (1999) summarizes innovation into three types, namely: 1) incremental innovation, 2) risk reducing innovation and 3) radical innovation. He remarks that the Porter Hypothesis is partially acceptable. How to generate a win-win situation depends on the kind of innovation firms pursued-incremental, risk reducing or radical, and on the measures taken by the regulators to facilitate the innovation. Another study by Sartzetakis, E. S. and Constantatos, C. points out that the effect of environmental regulations is related to the instruments government choose. In the Cournot-Nash equilibrium, regulations implemented by emission permit trading can contribute to the efficient allocation of an abatement effect and the increase of total market share of firms, while the command and control instruments may fail to achieve (Sartzetakis & Constantatos, 1995).

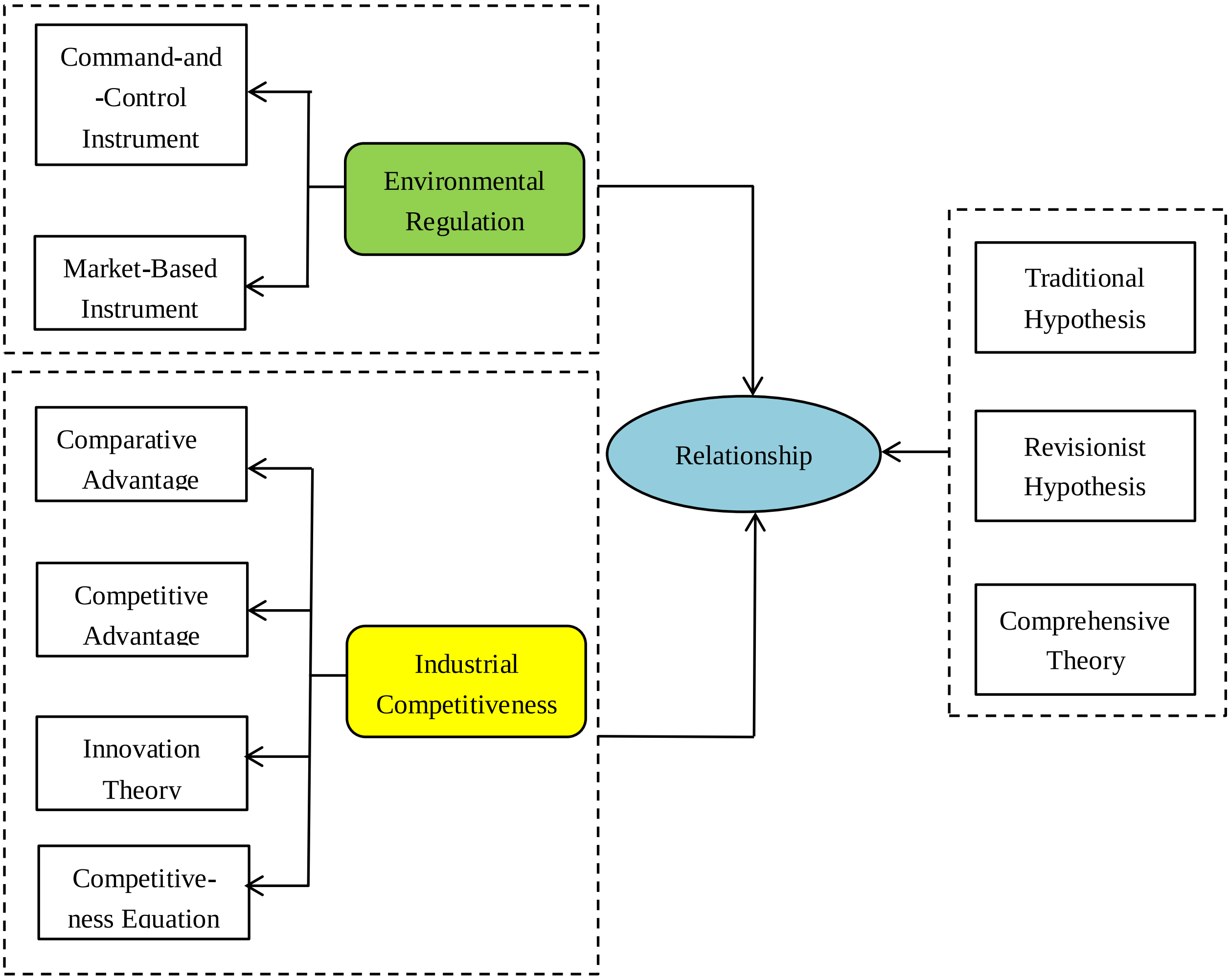
The research conducted by Xepapadeas, A.and de Zeeuw, A. (1999) is also important. The authors develop a mathematical model in which firms invest in machines at different ages, where younger machines have high productivity and are cleaner, but are also more expensive compared with the older ones. They find that more stringent environmental regulations have two effects subject: 1) productivity effect and 2) profit-emission effect. The former one means that with downsizing of the capital stock and modernization of the machines arising from strict regulations, the average productivity will increase. However, the profit-emission effect implies that profit and emissions will decline at the same time. Although the decreasing speed of profit will be lowered by the modernization of machines, profit decline is inevitable. The authors do not evaluate the effect of environmental regulations on industrial competitiveness directly, but focus on productivity and profit, which are two very important aspects of competitiveness. However their performance related to environmental regulations differs.

Jaffe et al. (1995) conclude that sometimes the effect of environmental regulations on industrial competitiveness may be so small that it is hard to detect. They find some reasons as follows: there is a limited ability of the existing data to measure the degree of stringency; it is a small proportion of compliance cost to the total cost of production; there are small gaps between environmental requirements in some nations; firms are unwilling to relocate to less than state-of-the-art nations and more-than-expected pollution controls in some industries in developing countries. Based on the review of empirical studies, they conclude that little consistent empirical evidence can be found to support either the traditional hypothesis or the revisionist hypothesis. Therefore, Jaffe et al (1999) considers that the truth should lie in between the two extreme situations.

2.2Conceptual Framework

The first section of Chapter 2 made a review of related concepts and theories, which lead up to the following conceptual framework. First, it summarised the categories of instruments of environmental regulations and the theories behind them. The two main categories are Command-and-Control instruments and Market-Based instruments. Command-and-Control instruments are passive and mandatory which are still the main instruments used in China. Market-Based instruments are guided by economics theories like Pigouvian tax and Coase theorem which is becoming popular in more countries. After that, the section focused on the industrial competitiveness and reviewed many important theories which can be used to explain the competitiveness, including comparative advantage theory, competitive advantage theory, innovation theory and competitiveness equation. These theories all develop with the times.

These two parts forms the two crucial concepts of this research - environmental regulations and industrial competitiveness. After that, the previous section reviewed three main theories/hypotheses today that can explain the association between the two concepts. They are: 1) the traditional hypothesis including Environmental Race-to-the-bottom Hypothesis and Pollution Haven Hypothesis; 2) the revisionist hypothesis including Porter's Hypothesis, Pollution Halo Hypothesis and Environmental Race-to-the-top Hypothesis among which Porter's Hypothesis is the representative; and 3) the comprehensive "theory" which is not a formulated theory currently but impels many researchers to re-exam the association between environmental regulations and industrial competitiveness. According to the previous section, the conceptual framework is as follows (see Figure 3):



(Source: Author, based on the literature review)

Figure 3 Conceptual Framework

The conceptual framework consists of three parts. The first part is related to environmental regulations. Indicators will be generated to measure the stringent degree of environmental regulations in the next part by studying the concepts and theories in this part. The second part relates to industrial competitiveness. Four theories are listed to explain the source of industrial competitiveness. In the next chapter, this research will develop indicators to measure the industrial competitiveness based on these four theories. The third part concerns the influence of environmental regulations on industrial competitiveness. It enumerates the main existing hypotheses or theories. In the following chapters, an econometric model and an economic model will be used to test and describe which theory is suitable for China.

Chapter 3 Research Design and Method

3.1 Revised Research Questions

Overall research questions:

"What is the influence of environmental regulations on industrial competitiveness in China?"

Specific research sub-questions:

1. Which factor can measure the level of industrial competitiveness and the stringency of environmental regulations?
2. On the national level, what is the impact of environmental regulations on industrial competitiveness?
3. On the provincial level, what is the impact of environmental regulations on industrial competitiveness?
4. What is the mechanism behind the influence?
5. Based on the results, how can we improve the effect of environmental regulations while reducing the negative effect on industrial competitiveness and economic development at the same time?

3.2 Operationalization: Variables and Indicators

The purpose of this research is to study the impact of environmental regulations on industrial competitiveness, namely, the influences of different stringent environmental regulations on industrial competitiveness and the mechanism behind them. Therefore, the stringency of environmental regulations is the dependent variable and industrial competitiveness is the independent variable. The research was conducted on two levels, the national level and the provincial level as mentioned in Chapter 1. On the national level, panel data of 36 industries belonging to the secondary sector in China were collected and analysed. Due to the availability of the data, different industries in the secondary sector were treated as a whole industry on the provincial level. Panel data of the whole secondary sector of each province were collected and analysed. To reveal the impact and association more accurately and convincingly, the quantitative approach was applied.

3.2.1 Operationalization of SER and IC

Since there is no direct official statistical data about stringency of environmental regulations and industrial competitiveness, this research defined and quantified these two variables based on specific evaluation systems that were established on the reviewed theories. The research used SER and IC to represent the two important concepts.

3.2.1.1 Operationalization of SER

For SER, referring to theories reviewed in Chapter 2, there are many different kinds of instruments currently in use. In China, the government mixes all kinds of instruments, and the proportion of different instruments changes with time (Jiang, 2010). Hence, it is hard to measure SER from the instruments themselves. This research used the achievements and effectiveness of environmental regulatory instruments to define and measure the stringency. Many academics have adopted a similar method. For example, Olsthoorn et al (2001) once use SO_2 emissions, NO_X emissions and COD emissions to operationalize the environmental performance. In this research, considering the diversity of industries, different kinds of pollution, including waste water, SO_2 (representing waste gas) and solid waste, were used to measure the achievement and effectiveness of environmental regulations. Notably, SO_2 data were used to represent waste gas, because it is the typical coal-smoke pollution that is consistent with the current Chinese energy structure.

3.2.1.2 Operationalization of IC

For IC, this research used the superior productivity to define the industrial competitiveness according to the definition proposed by Porter reviewed in the previous chapter, meaning that high productivity leads to high competitiveness.

In microeconomics, the traditional production function is determined by labour, capital, land and entrepreneurship. Later, Cobb and Douglas improve the production function by adding the technology factor (Cobb & Douglas, 1928), which is consistent with the theories reviewed above. Therefore, this research also measured the superior productivity according to the above aspects. Considering the availability of data and drawing on the previous experience of related research, this article did not include the land data and used the innovation factor to represent the entrepreneurship and technology factors. Thus, the productivity function is as follows.

$$Productivity = f(Labour, Captial, Innovation) \qquad \text{(Formula 2)}$$

Additionally, according to the competitiveness theory proposed by WEF and IMD (see Formula 1), these factors of production, namely labour, capital and innovation only reflect competitive assets. The ability to integrate these factors is of importance too, which indicates the competitive process and entrepreneurship to some extent.

Thus, the evaluation of industrial competitiveness was conducted from four aspects: labour, capital, innovation and integrative ability based on the above analysis. Hence, the formula of industrial competitiveness function is as follows:

$$Industrial\ Competitiveness = g(Labour, Captial, Innovation, Ability) \qquad \text{(Formula 3)}$$

This Formula measures industrial competitiveness from the perspective of production. It is the very built-in mechanism that can improve the productivity and further improve the competitiveness. Many academics have done related researches to prove the association between these factors and competitiveness. For example, Preibisch (2007) argues that labour is the core factor influencing competitiveness, especially foreign labour can secure a flexible workforce and is one of the planks of the global competitiveness; Corden (1994) stresses that an increase in capital flow leads to the appreciation of external competitiveness; Schumpeter (1934) and many academics stress the importance of innovation in competitiveness as mentioned in Chpater 2; Wang (2012) use the resouce allocation capability to measure industrial competitiveness.

Therefore, this evaluation system is rational, reliable and valid.Industrial competitiveness can be measured by labour, captial, innovation and ability.

3.2.2 Operationalization of Other Control Variables

The association between environment and competitiveness has been researched for a long time, but no conclusive results have been achieved. Many reasons contribute to it. One of them is that former research did not account for important moderating factors or control variables for the association between them (Wagner, 2001). To study the association between SER and IC, other exogenous variables that may influence the association between them should be meanwhile controlled. Wagner (2002) proposes that the scale of firms, different characteristics of countries, different operating processes and varying industrial market structures all have significant influence on the association based on reviews of former research. Besides those factors, Li (2013) argues that the pollution intensity is also important and may influence the association.

Considering the scope and aims of this research and the availability of data, on the national level, the scale of industry, pollution intensity and numbers of firms within the industry were added into the model with no location factor being involved, because these industries were in the same context, i.e. in China. In detail, the scale of industry could determine the ability of the industry to comply with environmental regulations and to control pollution, and can also reflect the different operating processes to some extent. The pollution intensity of an industry could show the difference in processes and techniques of production and difficulties of industries to control pollution. The number of firms within the industry can reflect the industry market structure to some extent- an industry with more firms in it tends to have lower degree of monopoly and vice versa.

On the provincial level, the characteristics of different provinces, namely the location factors, were considered to reflect other exogenous variables besides the variables mentioned on the national level. These location variables can depict the basic characteristics of each province which will influence the association between the SER and IC (Wagner, 2001). Variables include population that indicate the size of local labour market, GDP per capita that reflect the level economic development, infrastructure level, education level and FDI that reflect the openness of economy. These variables are adopted in many empirical researches about region competitiveness, including the Global Competitiveness Report issued by WEF, Hungary competitiveness report written by Lengyel (2004) and so on, meaning that they are good at depicting characteristics of a region.

Details are shown in the table below.

3.2.3 Operationalization Table

Table 1 : Details of Variable

Category	Variable	Sub-variabl	Indicator	Units
Y	Industrial Competitiveness(IC)	Labour	Labour Productivity (Output per employment)	10K yuan per capita
			Growth of Employment	%
		Capital	Capital Productivity (Output per capital)	N/A
			Growth of Fixed Asset	%
		Innovation	Ratio of New Products to Revenue from Principal business	%
			Numbers of Patent Per Unit of Firms	N/A
		Ability	Ratio of Profits to Cost	%
			Product Sale Rate	%
X (Both for National Level and Provincial Level)	Stringency of Environmental Regulation(SER)		Treatment rate of Waste Water	%
			Treatment rate of SO_2	%
			Treatment rate of Solid Waste	%
	Pollution Intensity (PI)		Emission of Waste Water per unit of Output	ton/10K yuan
			Emission of SO_2 per unit of Output	ton/10K yuan
			Emission of Solid Waste per unit of Output	ton/10K yuan
	Scale of Industry (SI)		Output of Industry	10K yuan
	Market Structure (MS)		Numbers of Firms within the Industry	N/A
X (Location Factors on Provincial Level)	Population (POP)		Population of the Province	10k
	Economic development situation (GDP_PC)		GDP per capita of the Province	10K yuan per capita
	Infrastructure (INF)		Density of Road Network	km/km^2
			Density of Railway	km/km^2
			Density of Post Road	km/km^2
	Education Level (EDU)		Proportion of Residents with Higher Education	%
	Foreign Capital (FDI)		Foreign Direct Investment	100M yuan

3.3 Research Strategy and Methodology

This research used the econometric model to conduct descriptive research to explore and describe the characteristics of the association between environmental regulations and industrial competitiveness. Then it applied economic theories and models to conduct explanatory research to find the mechanism behind the association.

According to the objectives and characteristics of this research, secondary macro-data were collected and quantitative analysis was applied to this research.

3.4 Data Collection Methods

The sources of the data were the statistical yearbook related to environment, science and technology, industrial economy, the yearbook of China and each province, and the China Economy Information Net Statistics Database, which were all issued by national and provincial governments.

It is worth noting that SO_2 data were used to represent waste gas. In the yearbook of environment, three items, SO_2, NO_x and industrial dust, are included in the waste gas. To simplify the calculation, SO_2 was selected as representative because it was the typical coal-smoke pollution that is consistent with the current Chinese energy structure.

3.4 Validity and Reliability

Validity concerns on what the variable measures and how well they do so (Anastasi & Urbina, 1997). The used variables and indicators were proven to be valid, because these variables and indicators were either consistent with theories reviewed in Chapter 2 or operated in former related research.

Reliability refers to dependable and trustworthy data measured by an assessment tool (Anastasi & Urbina, 1997). The data were also reliability for several reasons. 1) The data source is official. All statistical books are issued by NBS and other national ministries. And China Economy Information Net Statistics Database is a state-owned company which has a strong think-tank. Its data-source is also official. 2) The statistical methods of variables are consistent during the studying period. 3) Cross checks were conducted for the same variable from different sources. Some data were checked with news.

3.5 Data Analysis Techniques and Methods

3.5.1 Research on the Impact of Environmental Regulations on Industrial Competitiveness

This part applied modelling to find the impact based on the variables listed above. The modelling was conducted on the national level and the provincial level. The steps and techniques are the following.

3.5.1.1 Pre-processing of Data

Before analysis and modelling, some data and variables were pre-processed. Since they are the panel data, the data related to price and output including SI, GDP _PC and FDI were divided by the inflation rate, and then the price data were on the price level of the base year, 2000. Additionally, because FDI were reported in U.S. dollars, the FDI number was translated into China Yuan according to the average exchange rate in that year to maintain data consistency.

3.5.1.2 Calculation of Composite Variables

As table 1 shows, SER, PI, IC and INF were composite variables that need to be calculated in this research. No direct official data exist. To simplify the calculation, all the sub-variables were given the same weight. Within each sub-variable, the indicators also had the same weight. Before summing up the different indicators of SER, IC and PI, the indicators were standardized from 0 to 1 to eliminate the effect of index dimension and quantity of data. The Min-Max method was applied as the following formula 3 shows:

$$I_{kt} = \frac{V_{kt} - Min\ (V_k)}{Max\ (V_k) - Min\ (V_k)} \qquad \text{(Formula 3)}$$

Where, I_{kt} is the normalized value of indicator k in time t. V_{kt} is the original value of indicator k in time t. $Min\ (V_k)$ and $Max\ (V_k)$ are the respective minimum and maximum values of indicator k during the studied period.

After that, all the indicators were aggregated into SER, PI, IC and INF index respectively according to the weights.

3.5.1.2 Stationary Test and Co-integration Test

After the steps above, all the data were tested by a stationary test to avoid spurious regression, because they all had time series properties. If all the variables were stationary, the research would model directly. If not, but variables were uniformly integrated, co-integration tests were needed. If variables were co-integrated, it indicated that a long-term stable equilibrium relationship exists. Then the research could also model directly. If they were not co-integrated, other techniques such as finite difference were to be used to construct co-integrating relationship or generate stationary series. All the tests were done by Stata 11.

3.5.1.3 Modelling

3.5.1.3.1 Modelling on the National Level

On the national level, the research was conducted from the perspective of 36 industries ranging from 2001 to 2010 as mentioned before. Therefore, the dataset was panel data. One of the pooled regression model, the fixed effect regression model or the random effect regression model would be selected to reflect the association, in accordance with the results of the F-test and the Hausman test.

In the environmental fields, there is a famous curve named the Environmental

Kuznets Curve, which describes the U-relationship between economic development level and environmental quality. It demonstrates that environmental degradation worsens as economy develops until the average income reaches a certain threshold (Shafik, 1994). The theory could also be compared to the association between environmental regulations and industrial competitiveness to some extent. The industrial competitiveness could worsen as environmental regulations are strengthened, until the stringency of environmental regulations reaches the turning point. In case of the non-linear association between IC and SER like the Environmental Kuznets Curve, the square term of SER was included in the model, and the cubic term of SER was also tried during the modelling.

The following formulas are potential models.

$IC_{it} = \alpha + \beta_1 SER_{it} + \beta_2 {SER_{it}}^2 + \boldsymbol{X}\beta_3 + \varepsilon_{it}$ (Formula 4)
$IC_{it} = \alpha + \alpha_i + \beta_1 SER_{it} + \beta_2 {SER_{it}}^2 + \boldsymbol{X}\beta_3 + \varepsilon_{it}$ (Formula 5)
$IC_{it} = \alpha + \gamma_t + \beta_1 SER_{it} + \beta_2 {SER_{it}}^2 + \boldsymbol{X}\beta_3 + \varepsilon_{it}$ (Formula 6)
$IC_{it} = \alpha + \alpha_i + \gamma_t + \beta_1 SER_{it} + \beta_2 {SER_{it}}^2 + \boldsymbol{X}\beta_3 + \varepsilon_{it}$ (Formula 7)

Where $\boldsymbol{X}$ is the vector of other independent variables in the national level except SER; β_1, β_2 and β_3 are the coefficients; α is the common intercept; the variable α_i captures all unobserved, individual effects that affect IC_{it}; the variable γ_t captures all unobserved, time effects; ε_{it} is the error.

Formula 4 is the pooled regression model. Formula 5 to 7 are the effect model. Thereinto formula 5 is the individual effect model; formula 6 is the time effect model and formula 7 is the individual and time effect model. When α_i and γ_t are treated as a random variable and are unrelated to each explanatory variable, it is called random effect. If they are treated as a parameter to be estimated and are correlated with one or more explanatory variable, it is the fixed effect. The selection of the model was made according to the estimation results, statistical tests and economic sense.

3.5.1.3.2 Modelling on the Provincial Level

On the provincial level, the research studied the association from the perspective of 30 provinces. To reflect the spatial association between neighbouring provinces, the spatial regression model was applied. The panel data of the whole secondary industry of different provinces was modelled by either the spatial auto regression model (SAR), the spatial error model (SEM) or the spatial Durbin model (SDM). Before modelling, Moran's I index was calculated to test the existence and properties of spatial association, and the spatial weight matrix was set according to geographic situation.

The following formulas are potential models.

$IC = \alpha + \alpha_i + \gamma_t + \boldsymbol{\rho W IC} + \boldsymbol{X\beta} + \boldsymbol{\varepsilon} \quad \boldsymbol{\varepsilon \sim NID}(\boldsymbol{0}, \boldsymbol{\sigma^2 I})$ (Formula 8)
$IC = \alpha + \alpha_i + \gamma_t + \boldsymbol{X}\beta + \boldsymbol{\varepsilon}, \boldsymbol{\varepsilon} = \lambda \boldsymbol{W}\varepsilon + \mu \quad \mu \sim NID(0, \boldsymbol{\sigma^2 I})$ (Formula 9)
$IC = \alpha + \alpha_i + \gamma_t + \rho \boldsymbol{W}IC + \boldsymbol{X}\beta + \boldsymbol{WX}\theta + \varepsilon \quad \varepsilon \sim NID(0, \boldsymbol{\sigma^2 I})$ (Formula 10)

Where $\boldsymbol{X}$ is the vector of control variables; ρ and λ are the auto-regression coefficients; $\boldsymbol{W}$ is the spatial weight matrix; ε is the error terms; α is the common intercept; α_i is individual effect and γ_t is time effect like in Formula 7. The selection of the model was based on a series of statistical tests, including LM tests and its robust tests, LR tests and Wald tests. And like the model in ordinary panel data, α_i and γ_t would be chosen on the basis of the Hausman test and economic sense. Naturally, the square term of SER was included and the cubic term of SER was tried.

All the modelling process were conducted on Stata 11, supplement with Matlab R2009b.

3.5.2 Research on the Mechanism behind the Association between Environmental Regulations and Industrial Competitiveness

In this part, the research used the general equilibrium theory and the bounded rationality theory to explain the mechanism. First the Edgeworth Box diagram was used to show the interaction between environmental regulations and industrial competitiveness based on a series of assumptions. Then the production possibility frontier, combined with the bounded rationality assumption was applied to interpret the hypotheses reviewed in Chapter 2. Finally, the mechanism was applied to interpret the results of models.

Chapter 4 Research Findings

4.1 Analysis on the National Level

As mentioned before, on the national level, the research focuses on the performance of different industries in the secondary sector. The data is aggregated by the data of firms in the industry. Stata 11.0 is used to conduct the research. The table of descriptive statistics of variables is in Appendix 4.

4.1.1 Modelling

4.1.1.1 Stationary test/ unit root test

Because the dataset is the panel data and the time span is 10 years, a stationary test is necessary to avoid spurious regression.

For panel data, there are five commonly used methods, namely, LLC test (Levin et al., 2002), IPS test (Im et al., 2003), Breintung test (Breitung, 2000), Hadri test (Hadri, 2000) and PP-Fisher test (Phillips & Perron, 1988). This research adopts two methods to do the test, the LLC test that tests the common unit root of panel data, and the IPS test that tests the individual root of panel data.

For the LLC test, the null Hypothesis is that a common unit root process exists. For the IPS test, the null hypothesis is that an individual unit root process exists. The results of the unit root test are shown in the Table 2.

Table 2 Results of Unit Root Test

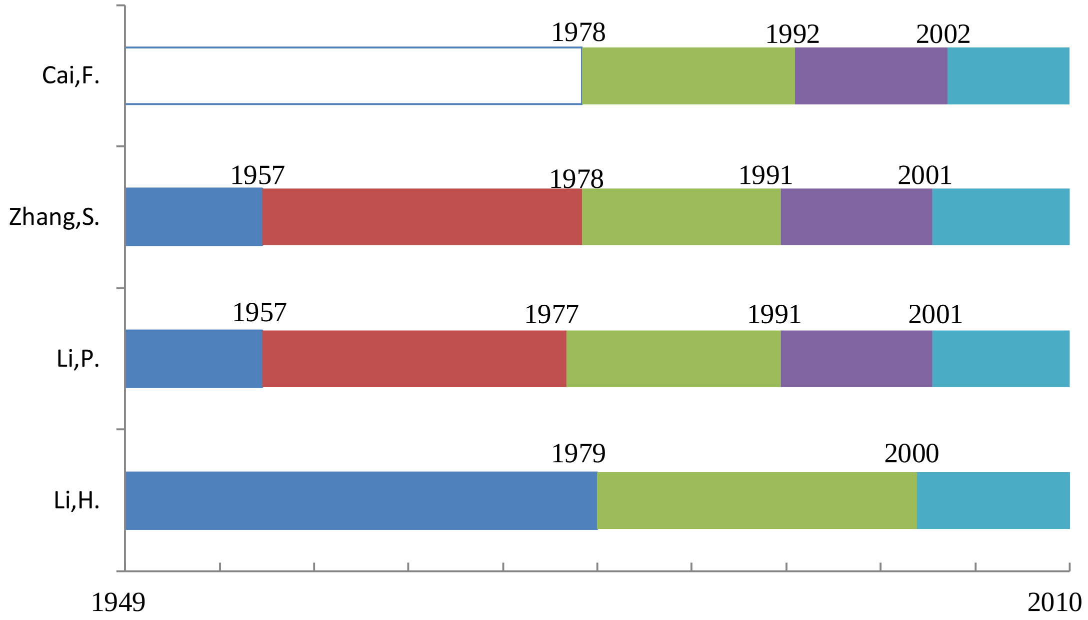
Variable	Test	Statistic	Prob	Test Form	Conclusion
IC	LLC	-8.9410	0.0000	(C,K,T)	Stationary
	IPS	-7.2604	0.0000		
SER	LLC	-14.3256	0.0000	(C,K,T)	Stationary
	IPS	-5.1184	0.0000		
SER^2	LLC	-20.4905	0.0000	(C,K,T)	Stationary
	IPS	-4.9241	0.0000		
PI	LLC	-20.6015	0.0000	(C,K,T)	Stationary
	IPS	-1.7697	0.0384		
SI	LLC	0.0368	0.5147	(C,K,T)	Non-stationary
	IPS	4.4093	1.0000		
d(SI)	LLC	-10.7431	0.0000	(C,K,T)	Stationary
	IPS	-6.6922	0.0000		
MS	LLC	-8.1689	0.0000	(C,K,T)	Stationary
	IPS	-5.2279	0.0000		

(Source: Author, calculated by Stata 11)

The results show that IC, SER, SER^2,PI and MS are stationary, but SI is not stationary. However, the first order difference of SI, d(SI), is stationary. Therefore, the research uses IC, SER, PI, d(SI) and MS to model and can avoid spurious regression. The correlation table is in Appendix 5.

4.1.1.2Model specification

4.1.1.2.1Time Effects vs. Individual Effects



(Source: Author, graphed according to related literature)

Figure 4 Division of Chinese Industry History

Panel data models usually have three forms, the pooled regression model, the fixed effect model and the random effect model as mentioned in Chapter 3.

The fixed effect model and random effect model are called the effect model. No matter which effect model is selected, there are two effects for panel data, time effects and individual effects. Whether to select one of them or both of both of them is based on the industrial economic realities combined with statistic tests.

First the time effects are examined. Reviewing the history of Chinese industrial economy after 1949[5], different academics have had many attitudes on the division of history, which are largely identical but with minor differences (See the Figure 4). Zhang (2012) divides the Chinese industrial economic history into two periods, before and after the policy of reform and open. He then sub-divides the two main phases into five phases. He argues that China is in the stage of new industrialization and going global since the end of 2001, the year when China accessed to the WTO. Li, P. (2009) almost makes the same point, i.e. that 2001 is a critical year because of the accession to WTO. His division of the development stage of Chinese industrial history is almost the same as Zhang's. He remarks that Chinese industrial economy is in the new industrialization stage since the beginning of 2002. Li, H. (2009), however divides the history into three stages. He stresses that from 1949 to 1979, China is in the industrialization stage under the planned economy; from 1980 to 2000, Chinese industrialization was market-oriented; since 2001, the Chinese industrialization process is guided by the sustainable development and scientific development. Cai

[5] The foundation year of the People's Republic of China

(2009), who studied the economy after 1979, almost proposes the same perspective, that since the end of 2002, Chinese industrial economy has already turned into the "three pillar" structure of state-owned capital, private capital and foreign capital.

To sum up, Chinese industrial economy has not experienced a structural transformation since 2001. As the units of the whole Chinese industry, different industries could also be assumed to be in the same stage since 2001. Therefore, from the perspective of a specific industry, variables do not change structurally with time. Time effects do not exist during the studying period.

Then individual effects are examined. Individual effects focus on different cross sections, namely on different industries. From the perspective of a specific cross section, different industries could react differently to environmental regulations, because of the diverse production modes, products, pollution intensity, investment in production elements, etc. Additionally, different industries are guided by different policies. For example, the electrolytic aluminium industry is restricted, while hydraulic electro-generating industry is encouraged[6]. In conclusion, individual effects may exist and need to be further examined by statistical tests.

4.1.1.2.2 Test for Squared-term of SER

In order to choose the appropriate model, some necessary tests should be conducted, which are based on the estimation results of these three models. For the fixed effect model and the random effect model, the research only considers the individual effect based on the analysis above.

Considering the potential U-relationship between IC and SER, three models with SER and the squared-term of SER are first listed below.

Table 3 Results of Estimation with squared-term SER

Estimation Method	**OLS (pooled regression model)**	**Fixed Effect Model**	**Random Effect model**
IC	Coefficient (Standard Error)	Coefficient (Standard Error)	Coefficient (Standard Error)
SER	-0.2471 (0.2284)	-0.0917 (0.1624)	-0.1135 (0.1611)
SER^2	0.3493* (0.1982)	0.2122* (0.1397)	0.2359* (0.1386)
PI	-0.3761*** (0.0534)	-0.1861*** (0.0580)	-0.2111*** (0.0548)
d(SI)	1.6×10^{-5}*** (2.17×10^{-6})	9.01×10^{-6}*** (1.78×10^{-6})	9.73×10^{-6}*** (1.73×10^{-6})

[6] see *A Guidance Catalogue for Industrial Structure Adjustment version 2013* issued by National Development

Estimation Method	OLS (pooled regression model)	Fixed Effect Model	Random Effect model
MS	-8.94×10^{-7}*	1.99×10^{-6}***	1.42×10^{-6}***
	(4.61×10^{-7})	(5.85×10^{-7})	(5.33×10^{-7})
Constant	0.3246***	0.2596***	0.2689***
	(0.0656)	(0.0480)	(0.0481)
Coefficient Joint test	41.59***(F-test)	42.78***(F-test)	225.24***(Wald-test)
R-squared	0.3954	0.8288[7]	0.3311
Adjusted R-squared	0.3859	0.8046	-[8]
Rho	-	0.7356	0.6962

(Source: Author, calculated by Stata 11)

Note: (a)***denote significant at 1% level; ** denote significant at 5% level; * denote significant at 10% level.

(b) Intercept in the fixed effect for each section are omitted.

(c) The numbers in the bracket are the t-statistic value.

According to Table 3, the coefficients of SER are not significant in any of the three models, while the coefficients of SER^2 are significant in all the models. To avoid the redundancy of independent variables and to find the most appropriate relationship, other estimations of three models without SER are listed below.

Table 4 Results of Estimation without squared-term SER

Estimation Method	OLS (pooled regression model)	Fixed Effect Model	Random Effect model
IC	Coefficient (Standard Error)	Coefficient (Standard Error)	Coefficient (Standard Error)
SER^2	0.1373***	0.1346***	0.1398***
	(0.0299)	(0.0245)	(0.02389)
PI	-0.3579***	-0.1763***	-0.2001***
	(0.0507)	(0.0553)	(0.0523)
d(SI)	1.6×10^{-5}***	9.05×10^{-6}***	9.80×10^{-6}***
	(2.17×10^{-6})	(1.77×10^{-6})	(1.73×10^{-6})

[7] In Stata .xtreg-fe command report an incorrect R-squared statistic for fixed effect model due to the larger degrees of freedom and its standard errors. However, .areg command report correct R-squared and adjusted R-squared. (Source: https://kb.iu.edu/d/auur)

[8] Adjusted R-squared for random effects model cannot be obtained in .xtreg-re command.

Estimation Method	OLS (pooled regression model)	Fixed Effect Model	Random Effect model
MS	-9.9×10^{-7}** (4.53×10^{-7})	1.97×10^{-6}*** (5.83×10^{-7})	1.38×10^{-6}*** (5.31×10^{-7})
Constant	0.2548*** (0.0118)	0.2330*** (0.0096)	0.2362*** (0.0122)
Coefficient Joint test	51.66***(F-test)	53.52***(F-test)	224.81***(Wald-test)
R-squared	0.3931	0.8286	0.3290
Adjusted R-square	0.3855	0.8051	-
Rho	-	0.7370	0.6906

(Source: Author, calculated by Stata 11)

Note: (a)***denote significant at 1% level; ** denote significant at 5% level; * denote significant at 10% level.

In the models without SER, all the independent variables are significant. Especially for the SER^2, the coefficients are much more significant than the models with SER.

This could lead to the preliminary conclusion that the variable SER may be the redundant one. To check it scientifically, this research uses the F-test combined with the t-test for coefficient as shown in the table above, to do the redundancy test for the variable SER. The principle behind the F-test is to check that whether the addition of a "new" variable (SER) will reduce the sum of squared residuals significantly, or increase the R-squared significantly. The formula is as follows

$$F = \frac{(R^2_{new} - R^2_{old})/n}{(1 - R^2_{new})/df} \sim F(n, df) \qquad \text{(Formula 11)}$$

Where, R^2_{new} is the R-squared of the model with additional variables; R^2_{old} is the R-squared of the initial model; n is the number of additional variables; df is the degree of freedom of the model with additional variables.

In this model, n equals 1 and df equals 318 for the "new" pooled model and 283 for the "new" fixed effect and random effect model. This research compares the "old" models with the "new" model one-to-one. For the pooled model, the F equals 1.2097, which is smaller than the critical value $F_{0.1}(1{,}318)$=2.721. For the fixed effect model, the F statistic value is 0.33, which is much smaller than $F_{0.1}(1{,}283)$=2.723. For the random effect model, the F statistical value is 0.8885 that is also smaller than $F_{0.1}(1{,}318)$.

As the t-tests for the coefficient of SER have already shown that the SER is not significant. Therefore, it can be concluded that SER is a redundant variable and it will thus be omitted in the final model.

The research also tries the cubic-term of SER, but the estimation is not as good as the model with only the squared-term of SER and the coefficient is not significant. Due to lack of space, the estimations with the cubic-term of SER are not listed here.

4.1.1.2.3 OLS vs. Fixed effects

The F-Test of the joint significant of the fixed effects intercepts can be applied to test the necessity of fixed effects. It means that in Formula 12, individual effects α_i are zero jointly if no fixed effects exist. The null hypothesis of the test is H_0: $\alpha_1 = \alpha_2 = \cdots = \alpha_{N-1} = 0$. F statistics are calculated according to formula 12.

$$F = \frac{(SSE_r - SSE_u)/(N-1)}{SSE_u/(NT-N-1)} \sim F(N-1, NT-N-K) \qquad \text{(Formula 12)}$$

Where SSE_r is the sum squared residuals of the pooled regression model; SSE_u is the sum squared residuals of the fixed effect model; N means the numbers of cross-sections; T is the time periods.

Here, the F equals 20.47 and is larger than the critical value that is $F_{0.05}(35,283)=1.4647$. It rejects the null hypothesis, and it can be concluded that the fixed effect model is better than the OLS model.

4.1.1.2.4 OLS vs. Random Effect Model

Breusch and Pagan (1980) propose a LM test for random effects. The null hypothesis is that the variance across entities is zero which means that there is no significant difference across the units. The null hypothesis is that H_0: $\sigma_u^2 = 0$.The LM statistics follows chi-square distribution with the one degree of freedom. The LM statistics are calculated according to Formula 13.

$$LM_u = \frac{nT}{2(T-1)}\left[\frac{T^2\overline{e'}\bar{e}}{e'e} - 1\right]^2 \sim \chi^2(1) \qquad \text{(Formula 13)}$$

Where $e'e$ is the sum squared residual of pooled OLS regression; $\bar{e}$ bar is the n×1 vector of the group specific means of pooled regression residuals.

Here, $LM_u = 523.44 > \chi^2_{0.05}(1) = 3.841$. Therefore, compared with random effect model, pooled OLS is also rejected.

4.1.1.2.5 Fixed Effect Model vs. Random Effect Model

Usually, the Hausman test can compare the coefficients of fixed effects with random effects. The null hypothesis is that the preferred model is random effects. The formula is as follows:

$$H = (\beta_{RE} - \beta_{FE})'(V_{RE} - V_{FE})^{-1}(\beta_{RE} - \beta_{FE}) \sim \chi^2(m) \qquad \text{(Formula 14)}$$

Where β_{RE} is the coefficient vector of the random effect model; β_{FE} is the coefficient vector of the fixed effect model; V_{RE} is the covariance matrix of the random effects estimator; V_{FE} is the covariance matrix of the fixed effects estimator. m is the rank of the difference in the variance matrices.

Here, H=4.58, which almost equal to $\chi^2_{0.1}(2)$. Such a result does not give us a clear option. Thus, a further test is needed.

Then the Sargan-Hansen test is suitable. This test is intended to test over-identifying restrictions. However, a test for random vs. fixed effect can also be treated as over-identifying. "The fixed effects estimator uses the orthogonality conditions that the regressors are uncorrelated with the idiosyncratic error. The random effects estimator uses the additional orthogonality conditions that the regressors are uncorrelated with the group-specific error. These additional orthogonality conditions are overidentifying restrictions."[9]. For fixed vs. random effects, the null hypothesis of this test is that the random effect model is preferable.

In this dataset, the Sargan-Hansen statistic is 9.409, distributed as $\chi^2(4)$. The p-value is 0.0517. Although it cannot reject the random effect model at 5% level, it can reject it at 10% level. Tracing back to the definition of random effects and fixed effects in Chapter 3, the key point to determine that whether fixed effect model or random effect model is used is whether unobserved effects $\alpha_i$is uncorrelated with all independent variables. In this panel data, the research cannot treat the sample as a random sample from a large population because it covers all the industries in the secondary sector. Then it makes sense to treat each α_i as a separate intercept to estimate for each cross-sectional unit (Wooldridge, 2002). Hence, combined with the results of the tests, the fixed effect model is preferable.

4.1.1.3 Diagnostics of Model

After testing the model specification, the individual fixed effect model is selected. However, for a panel data using a fixed effect model, some other diagnostics need to be conducted in order to get a robust, consistent, unbiased and effective estimation, because the fixed effect model is based on the following three assumptions: cross-sectional independence, between group homoscedasticity and serial un-correlation.

First, cross-sectional dependence is tested. Pesaran cross-sectional dependence test is able to handle a balanced panel following the method proposed by Pesaran(2004). It follows a standard normal distribution. The null hypothesis is that residuals are not correlated. In this dataset, Pesaran cross-sectional dependence test= 30.478, p-value=0.000. Therefore, the panel dataset has cross-sectional dependence.

Second, heteroskedasticity is tested. A modified Wald statistics for groupwise heteroskedasticity proposed by Greene (2000) is workable for test heteroskedasticity of the fixed effect model. The null hypothesis is that homoskedasticity exists, namely, $\sigma_i^2 == \sigma^2$. The test statistic is distributed as Chi-squared (N). In this dataset, the chi(36)=228.61 and the p-value is 0.000, rejecting the null hypothesis. Therefore the dataset has groupwise heteroskedasticity.

Third, serial correlation is tested. For serial correlation in panel data, Wooldridge (2002) presents a Wald test for idiosyncratic errors, which follows F distribution. He argues that if there is no serial correlation, the autocorrelation coefficient of the residuals from the regression of the first-difference variable is -0.5. The null hypothesis of the test is that there is no serial correlation in this specification. In this

[9] refer to the Stata 11 command :help .xtoverid

model, the F(1,35) statistics equal 2.103 and the p-value is 0.1559. So there is no serial correlation in the model.

4.1.2.4Model revision

Concluded from the above diagnosis, the original fixed effect model has the problem of cross-sectional dependence and heteroskedasticity.

To deal with the heteroskedasticity, the research adopts robust estimation to get the robust standard error. As for cross-sectional dependence, new results will be estimated with standard error clustered at industry level, namely doing cluster adjustment, to overcome the heteroskedasticity. Table 5 shows the estimation results after revision.

Table 5 Final Estimation Results of the Dataset

IC	Coefficient	Robust Standard Error	t	P-value
SER^2	0.1346	0.04452	3.02	0.005***
PI	-0.1763	0.08026	-2.20	0.035**
D(SI)	9.05×10^{-6}	1.73×10^{-6}	5.22	0.000***
MS	1.97×10^{-6}	5.42×10^{-7}	3.63	0.001***
Constant	0.2330	0.01483	15.70	0.000***
R-square	0.8274	R-square adjusted	0.8286	
Rho		0.7370		

(Source: Author, calculated by Stata 11)

Note: (a)***denote significant at 1% level; ** denote significant at 5% level; * denote significant at 10% level.

4.1.2Findings

Table 5 shows a robust unbiased estimation of the model. Some findings can be obtained from the above results.

(1) On the national level, the increase of SER will lead to the increase of IC. Environmental regulations have a positive impact on industrial competitiveness. It is worth noting that the association is not a simple linear one, but IC is positively related to the squared-term of SER, and the turning point is 0. It means that after controlling other variables, SER has a positive impact on IC from the beginning and IC grows faster with the increasing of SER, although the growth rate is low. Porter's Hypothesis fits the situation.

(2) Pollution intensity (PI) has a negative impact on IC, while the increment of industry scale (d(SI)) and the number of firms (MS) have a positive influence on IC. It means that the increase of pollution intensity will impede industrial competitiveness while the increase of the increment of industry's scale and number of firms in this industry will have a positive influence on competitiveness. The results are obvious

and logical. Higher pollution intensity would impair the health of workers and make the industry less attractive. That the scale of the industry becomes larger can lead to the scale effect which makes the whole industry more competitive. The growing number of firms could increase competition within the industry, whereas healthy competition can improve the competitiveness of the whole industry to some extent. The signs of these variables all conform to the expected signs.

4.2 Analysis on the Provincial Level

The above analysis is conducted from the industrial perspective and the data of each industry are the sum of each firm belonging to this industry nationwide. However, on the provincial level, due to the availability of the data, the different industries in the second sector will be considered wholly. Therefore, the provincial-level dataset consist of the data from the secondary sector of each province. The table of descriptive statistics of variables is in Appendix 6.

Tobler (1979) proposes the First Law of Geography which argues that attribute values on a geographic surface are related to each other, and closer ones are more strongly related than distant ones. Therefore, the spatial association is un-ignorable when considering the problem in the space. Economic activities, capital, labour, commodities, information etc. flow frequently between regions, particularly between neighbouring regions.

4.2.1 Modelling

4.2.2.1 Specification of Spatial Weight Matrix

The spatial weight matrix $\boldsymbol{W}$ is the key of spatial analysis because it expresses the spatial association between units. How to set an appropriate spatial weight matrix is controversial and difficult (Bavaud, 1998). Usually, $\boldsymbol{W}$ is set by dichotomy based on the Rook criterion of contiguity. The rule defines $w_{ij} = 1$ for regions that share a common side with the region of interest; $w_{ij} = 0$ for non-neighbouring regions and elements of the principal diagonal. $\boldsymbol{W}$ is called as geographic spatial weight matrix. The general form of matrix $\boldsymbol{W}$ is as follows:

$$\boldsymbol{W} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1N} \\ w_{21} & w_{22} & \cdots & w_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1} & w_{N2} & \cdots & w_{NN} \end{bmatrix} \quad \text{(Formula 15)}$$

Table 6 Neighbouring Information of Each Provinces

Code	Name of Provinces	Neighbouring Provinces	Code	Name of Provinces	Neighbouring Provinces
1	Beijing	2,3	16	Henan	3,4,12,15,17,26
2	Tianjin	1,3,15	17	Hubei	12,14,16,18,22,26
3	Hebei	1,2,4,5,6,15,16	18	Hunan	14,17,19,20,22,24
4	Shanxi	3,5,16,26	19	Guangdong	13,14,18,20,21

Code	Name of Provinces	Neighbouring Provinces	Code	Name of Provinces	Neighbouring Provinces
5	Inner Mongolia	3,4,6,7,8,26,27,29	20	Guangxi	18,19,24,25
6	Liaoning	3,5,7	21	Hainan	19
7	Jilin	5,6,8	22	Chongqing	17,18,23,24,26
8	Heilongjiang	5,7	23	Sichuan	22,24,25,26,27,28
9	Shanghai	10,11	24	Guizhou	18,20,22,23,25
10	Jiangsu	9,11,12,15	25	Yunnan	20,23,24,
11	Zhejiang	9,10,12,13,14	26	Shaanxi	4,5,16,17,22,23,27,29
12	Anhui	10,11,14,15,16,17	27	Gansu	5,23,26,28,29,30
13	Fujian	11,14,19	28	Qinghai	23,27,30
14	Jiangxi	11,12,13,17,18,19	29	Ningxia	5,26,27
15	Shandong	2,3,10,12,16	30	Xinjiang	27,28

(Source: *Map of People's Republic of China* issued by SinoMaps Press in 2013)

Table 6 shows information about the neighbouring provinces of each province, except for Tibet, Taiwan, Hong Kong and Macao due to the lack of data. It is worth noting that Hainan province is an island located to the south of Guangdong Province. It was once a part of Guangdong in the history. Therefore, the research set Guangdong as the neighbouring province of Hainan.

Such a spatial weight matrix based on the Rook criterion is reasonable in this research. For regional characteristics variables, neighbouring provinces often has more association with each other than non-neighbouring provinces in economy and culture. As for environmental regulations, the weight is also rational. Here is the deduction. Assume that industrial competitiveness IC_{it} is a function of pollutants (P_{it}) and other characteristic variables ($\boldsymbol{Z_{it}}$), the competitiveness is as follows:

$$IC_{it} = f(P_{it}, \boldsymbol{Z_{it}}) \qquad \text{(Formula 16)}$$

Then, assume pollutants can spill over to other provinces through wind and water flow, biologic chain, etc. and can only have significant impacts on neighbouring provinces because of the distance limitation. Another important assumption is that emission of pollutants is decided by the degree of stringency of environmental regulations (SER_{it}). Therefore, the amount of pollutants in a province is as follows:

$$P_{it} = g(SER_{it}, \textstyle\sum_{j \neq i} SER_{it}) \qquad \text{(Formula 17)}$$

where SER_{it} represents pollutants produced by the local province; $\sum_{j \neq i} SER_{it}$ represents pollutants from neighbouring provinces which indicates the spillover effect of pollutants. Combined Formula 16 with Formula 17, the SER in the local provinces together with the SER in the neighbouring provinces can have an influence on the local industrial competitiveness as follows:

$$IC_{it} = h(SER_{it}, \textstyle\sum_{j \neq i} SER_{it}, \boldsymbol{Z_{it}}) \qquad \text{(Formula 18)}$$

Therefore, the spatial weight matrix based on the Rook criterion is also reasonable to interpret the functions of neighbouring environmental regulations.

Before using the spatial weight matrix $\boldsymbol{W}$, $\boldsymbol{W}$ should be normalized in the row, namely every matrix element w_{ij} is divided by the sum of elements of each row element, which uses Formula 19. The purpose of normalization is to make the sum of spatial effects of neighbouring units on each unit equal to 1 and to eliminate the external influence of the inter-region. After that, $\boldsymbol{W}$ is set.

$$w_{ij}^{*} = \frac{w_{ij}}{\sum_{j=1}^{N} w_{ij}} \qquad \text{(Formula 19)}$$

$$\boldsymbol{W_E} = \begin{bmatrix} w_{11}^{*} & w_{12}^{*} & \cdots & w_{1N}^{*} \\ w_{21}^{*} & w_{22}^{*} & \cdots & w_{2N}^{*} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1}^{*} & w_{N2}^{*} & \cdots & w_{NN}^{*} \end{bmatrix} \qquad \text{(Formula 20)}$$

4.2.2.2 Test for Spatial Association

Before modelling, the spatial association should be tested to decide whether to adopt the spatial model or not. Moran (1950) proposes Moran's I test to detect the global spatial association. The null hypothesis is that a spatial association does not exist. The formula is as follows:

$$I = \frac{n}{\sum_i^n \sum_j^n w_{ij}} \times \frac{\sum_i^n \sum_j^n w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_i^n (y_i - \bar{y})^2} \qquad \text{(Formula 21)}$$

Where w_{ij} is the spatial weighted matrix, y_{ij} and $\bar{y}$ are the variable in the i^{th} location and the mean of the variable, n is the number of observations.

The statistic value of Moran's I ranges from -1 to 1. If the value is significantly larger than 0, the spatial units that have similar attributes agglomerate. If it is significantly smaller than 0, the spatial units are negative related which means that units with different attributes are clustered. If the value equals 0 approximately, spatial effects do not exist. Moreover, the Z-test will be used to test the significance of Moran's I. The formula is as follows:

$$Z = \frac{I - E(I)}{\sqrt{Var(I)}} \qquad \text{(Formula 22)}$$

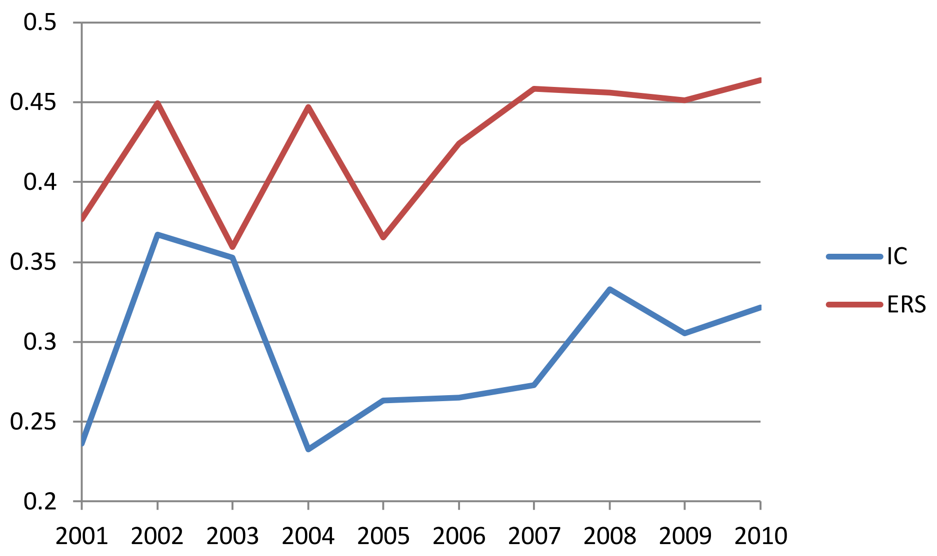
Where *E(I)* is the expect value of Moran I, *Var(I)* is the variance of Moran I and their calculation are based on the random distribution assumption. Under the null hypothesis, the Z statist follows asymptotic normal distribution.

Usually, only the dependent variable is tested by the Moran test to demonstrate the spatial association. To study the main variables' spatial characteristics, this research also calculates the Moran's I for SER. The table below shows the Moran's I test of IC and SER from 2001 to 2010, and the line chart displays the trend of Moran's I.

Table 7 Moran's I of IC and SER (2001-2010)

Year	IC		SER	
	Moran's I	p-value	Moran's I	p-value
2001	0.2362	0.014**	0.3768	0.003***
2002	0.3674	0.015**	0.4492	0.002***
2003	0.3530	0.001***	0.3595	0.002***
2004	0.2393	0.017**	0.4470	0.002***
2005	0.2633	0.014**	0.3651	0.004***
2006	0.2650	0.015**	0.4244	0.001***
2007	0.2728	0.011**	0.4584	0.001***
2008	0.3329	0.004***	0.4562	0.001***
2009	0.3051	0.006***	0.4514	0.002***
2010	0.3215	0.003***	0.4638	0.001***

(Source: Author, calculated by OpenGeoda 1.2.0)



(Source: Author, graphed according to Moran's I)

Figure 5 Line Chart of Moran's I of IC and SER (2001-2010)

As is shown in Table 7, it is apparent that the Moran's I of IC and SER are all positive and significant at least on 5% level from 2001 to 2010, which means spatial units agglomerate positively in term of environmental regulations and industrial competitiveness in China and the distribution is not random. The degree of agglomeration fluctuates before 2005 and then experiences a growing trend. It means that the agglomeration phenomenon is becoming more and more obvious. Therefore, IC and SER are polarizing. The spatial association cannot be ignored.

4.2.2.3 Model Specification

Since the spatial association has been detected, the spatial model is the better choice. For spatial dependence, Anselin (1988) summarises two reasons to explain the situation. The first is the by-product of measurement errors for observation in neighbouring spatial units. In practise, data is obtained at an aggregate level. So, there may be no correspondence between the spatial scope of the phenomenon under the research and the delineation of the spatial units of observations. Therefore, measurement error is likely to exist. And it tends to spill over across the boundaries, which means that measurement errors for observation i are likely to be related to neighbouring spatial units. The second reason is spatial interaction and diffuse process leading to the dependence between phenomena at different locations that means observation at one unit is determined partially by what happens elsewhere in the system. Therefore, two basic models in spatial econometrics are the Spatial Auto regressive Model (SAR) and the Spatial Error Model (SEM). In 2009, LeSage and Pace proposed a more general model, the Spatial Durbin Model, which nests both spatial lagged dependent variables and independent variables and is more general. When $\theta=0$, it is the SAR; when $\theta+\rho\beta=0$, it is the SEM model (See Formula 10 in Chapter 3).

4.2.2.3.1 Rules of Elhorst

Elhorst (2010) proposes a series of test procedures to find out which model is the most appropriate model to explain the data.

First, the OLS model is estimated and the LM-test and robust LM-test are used to test whether the SAR or SEM model is more appropriate to describe the data. If the OLS model is rejected, then the SDM model should be estimated by maximum likelihood. Subsequently, the LR test could be used to test the hypotheses H_0:$\theta=0$ and $H_{0:}\theta+\rho\beta=0$. If the hypotheses are rejected at the same time, the SDM model is the most appropriate. However, if H_0:$\theta=0$ cannot be rejected and (robust) LM test is also in favour of SAR, SAR model can describe the data. If $H_{0:}\theta+\rho\beta=0$ cannot be rejected and the (robust) LM test also points to the SEM model, the SER model describes the data best. If one of these conditions is not satisfied, i.e. the (robust) LM test and the LR test point to different model, then the SDM model is still the best because this model generalizes the SAR and SEM models.

The (Robust) LM test mentioned above is developed by Anselin (1988). These tests are based on the results of OLS estimation. Two types of LM tests are applied, one-directional tests and robust tests. The LM test statistic is distributed as $\chi 2$ (chi-square) with one degree of freedom (The formula is in Appendix 3).

4.2.2.3.2 Stationary Test/ Unit root test

For the spatial panel data still has the time trend. Before modelling, a unit root test is necessary. The LLC and IPS tests are adopted here as they are used above.

From the results of unit root test, it can be concluded that except scale of the industry (SI), GDP per capita (GDP_PC), population (POP) and foreign direct investment (FDI), other variables are stationary. But the first-order difference of SI GDP_PC

POP and FDI is stationary. Therefore, the research uses IC, SER, SER^2,PI, d(SI), MS, d(GDP_PC), d(POP), D(FDI), INF and EDU to estimate the model. The correlation table is in Appendix 6.

Table 8 Results of Unit Root Test

Variable	Test	Statistic	Prob	Test Form	Conclusion
IC	LLC	-5.2779	0.0000	(C,K,T)	Stationary
	IPS	-4.5043	0.0000		
SER	LLC	-11.5949	0.0000	(C,K,T)	Stationary
	IPS	-4.4909	0.0000		
SER^2	LLC	-13.776	0.0000	(C,K,T)	Stationary
	IPS	-3.8511	0.0001		
PI	LLC	-8.8591	0.0000	(C,K,T)	Stationary
	IPS	-2.1694	0.0154		
SI	LLC	-1.6843	0.0461	(C,K,T)	Non-stationary
	IPS	5.7450	1.0000		
d(SI)	LLC	-6.9923	0.0000	(C,K,T)	Stationary
	IPS	-3.9853	0.0000		
MS	LLC	-6.1453	0.0000	(C,K,T)	Stationary
	IPS	-3.2599	0.0006		
GDP_PC	LLC	2.7579	0.9971	(C,K,T)	Non-stationary
	IPS	5.9312	1.0000		
d(GDP_PC)	LLC	-6.6950	0.0000	(C,K,T)	Stationary
	IPS	-4.9810	0.0000		
POP	LLC	-7.2799	0.0000	(C,K,T)	Non-stationary
	IPS	-0.0121	0.4952		
d(POP)	LLC	-8.3095	0.0000	(C,K,T)	Stationary
	IPS	-2.4381	0.0074		
FDI	LLC	-6.7829	0.0000	(C,K,T)	Non-stationary
	IPS	-1.0685	0.1426		
d(FDI)	LLC	-19.9146	0.0000	(C,K,T)	Stationary
	IPS	-4.7628	0.0000		
INF	LLC	-12.0450	0.0000	(C,K,T)	Stationary
	IPS	-2.9906	0.0014		
EDU	LLC	-7.9835	0.0000	(C,K,T)	Stationary
	IPS	-4.5888	0.0000		

(Source: Author, calculated by Stata11)

4.2.2.3.3 Estimation and Selection of Model

As is discussed above, first a pooled regression model is estimated without considering the spatial effects. Based on the estimations, the LM tests are conducted to do the first-round selection. The results of the LM tests are listed below. Due to lack of space, the estimation results of the pooled regression model are not listed.

Table 9 Results of Tests for Spatial Dependence

Statistics	Value	Prob
LM-error	77.931	0.000***
LM-lag	24.324	0.000***
Robust LM-error	55.176	0.000***
Robust LM-lag	1.569	0.210

(Source: Author, calculated by Stata11)

The Table 9 above shows that spatial effects indeed exist. And the OLS estimation is rejected. Then the research will estimate the SDM model according to the Elhorst's rules.

According to the analysis in 4.1, the spatial model also only considers the individual effect model and neglect time effect. The Hausman test which is shown in Table 10 rejects the random effect. Therefore the following estimations only consider the individual fixed effect.

This research uses Stata 11 for the analysis. As mentioned above, the estimation includes the squared-term of SER. The estimation results of SDM are the following:

Table 10 Estimation Results of SDM

Variable	Coefficient (Standard error)	Variable	Coefficient (Standard error)
SER	-0.2147** (0.0972)	W*SER	-0.3950** (0.1736)
SER^2	0.1447* (0.0774)	W*SER^2	0.2409* (0.1382)
PI	-0.1418*** (0.0428)	W*PI	-0.2007** (0.0763)
d(SI)	5.05×10^{-6}* (2.37×10^{-6})	W*d(SI)	3.76×10^{-6} (2.84×10^{-6})
MS	-9.34×10^{-8} (5.38×10^{-7})	W*MS	-6.29×10^{-7} (6.66×10^{-7})
d(GDP_PC)	0.0926** (0.0289)	W*d(GDP_PC)	-0.0180 (0.0448)
d(POP)	4.49×10^{-5} (3.61×10^{-5})	W*d(POP)	-1.127×10^{-4} (6.58×10^{-5})

Variable	Coefficient (Standard error)	Variable	Coefficient (Standard error)
d(FDI)	1.76×10^{-5} (3.37×10^{-5})	W*d(FDI)	4.56×10^{-5} (4.87×10^{-5})
INF	0.0375 (0.0733)	W*INF	0.0235 (0.1145)
EDU	0.0028* (0.0017)	W*EDU	0.0036 (0.0031)
Rho	0.2479** (0.07624)		
LR (H_0:θ=0)	16.24***	LR(H_0:θ + ρβ=0)	34.87***
Hausman-test	68.93***	R-squared	0.7621

(Source: Author, calculated by Stata11)

The two LR tests reject the null hypotheses. Therefore, SDM model is an appropriate model according the rules of Elhorst.

However, the coefficients above cannot explain the spill-over effect and marginal effect of variables as an ordinary model, because such point estimates of spatial regression models do not consider the complex interaction correctly and will lead to erroneous conclusions (LeSage & Pace, 2009). LeSage and Pace (2009) then propose a partial derivate method to interpret the impact from changes to the variables. They divide the impact into three effects, namely, the direct effect, indirect effect and total effect. The direct effect shows the effect from the change of an explanatory variable in a local unit; the indirect effect measures the impact on other dependent variables in other units; the total effect is the sum of direct effect and indirect effect. Three effects are listed below.

Table 11 Direct Effect, Indirect Effect and Total Effect of Explanatory Variables

Variable	Direct Effect	Indirect Effect	Total Effect
SER	-0.2434** (0.0812)	-0.5512** (0.2303)	-0.7946** (0.2521)
SER^2	0.1640** (0.0687)	0.3318* (0.1800)	0.4959** (0.1897)
PI	-0.1535*** (0.0468)	-0.3036*** (0.0811)	-0.4570*** (0.0968)

Variable	Direct Effect	Indirect Effect	Total Effect
d(SI)	5.32×10^{-6}**	5.5×10^{-6}	1.08×10^{-5}**
	(2.26×10^{-6})	(3.35×10^{-6})	(4.14×10^{-6})
MS	4.1×10^{-8}	4.1×10^{-7}	9.99×10^{-7}
	(5.45×10^{-7})	(7.35×10^{-7})	(9.42×10^{-7})
d(GDP_PC)	0.0980***	-0.0020	0.0959
	(0.0292)	(0.0592)	(0.0655)
d(POP)	3.87×10^{-5}	-1.31×10^{-4}	9.2×10^{-5}
	(3.77×10^{-5})	(8.4810^{-5})	(9.27×10^{-5})
d(FDI)	2.01×10^{-5}	7.31×10^{-5}	9.32×10^{-5}
	(3.42×10^{-5})	(5.81×10^{-5})	(7.41×10^{-5})
INF	0.0343	0.0490	0.0833
	(0.0655)	(0.1219)	(0.1269)
EDU	0.0030*	0.0056	0.0086**
	(0.0016)	(0.0037)	(0.0038)

(Source: Author, calculated by Stata11)

4.2.2 Findings

(1) On the provincial level, the IC and SER are still the U-relationship, which means that the traditional hypothesis fits first and Porter's Hypothesis works later. Additionally, IC is not only influenced by SER in the local unit but also influenced by SER in neighbouring units and even in non-neighbouring units.

(2) The turning point can be calculated according to Table 11. For the direct effect, the turning point is around 0.74 which means that SER has a negative impact on the local IC until it reaches 0.74. For the indirect effect, the turning point is around 0.83 which shows that SER has a positive influence on the IC of other units after reaching 0.83. The indirect impact is not only on the neighbouring unit but also on the non-neighbouring unit, because of the spatial interaction between neighbouring units and non-neighbouring units. For the total effect, the turning point is about 0.80. The Total effect shows the aggregated impact of SER of a local unit on the global scale. Therefore, after the SER of one unit arrives at 0.8, it can generate a positive influence as the whole, namely it has a positive impact on China.

(3) For other variables, the pollution intensity (PI), the increment of GDP per capita (d(GDP_PC)), the increment of industry scale (d(SI)) and the percentage of people with higher education(EDU) have impacts on the local IC. PI also influences other units. Globally, the PI, d(SI) and EDU on the whole influence the IC. Although the influences of d(SI) and EDU on other units are not significant, they generate indelible

impacts on the local IC and then globally produce the significant impacts. Moreover, the competitiveness in neighbouring units also has a positive impact on local industrial competitiveness.

(4) All the signs of the other significant variables conform to the theory and common sense. Pollution intensity has negative influences on three levels, because higher pollution would impel people and even capital to flee away. The increment of the scale of industry is positive because scale effect can be activated by the augment of the scale. GDP per capita is also positive, because it indicates the economic level of a province, and the development of economy and industry are always mutually promoted. EDU has good effects on IC both locally and globally, because higher education can transform human resources into human capital. More people receiving higher education can increase human capital and then raise labour productivity. As for the competitiveness of neighbouring units, the positive sign means positive agglomeration, which is consistent with the Moran's I test.

4.3 The Mechanism of Environmental Regulations on Industrial Competitiveness

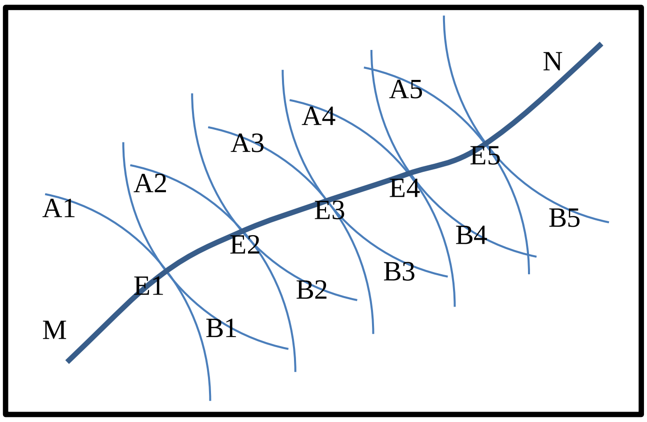
From the analysis above, it could be concluded that IC and SER have a U-relationship on both the national level and provincial level. The difference is the turning point. On the national level, or from the perspective of a specific industry, the turning point is 0. It means that increased stringency of environmental regulations can lead to the increase of industrial competitiveness almost at the beginning, which indicates that Porter's Hypothesis fits the reality. But on the provincial level, the turning point is 0.74 for local, 0.83 for other provinces and 0.8 for the whole country. It is obvious that SER first have a negative impact on the industry then have positive impact, which means that the traditional hypothesis fits the reality first and then Porter's Hypothesis works. What is the mechanism behind the U-relationship? Why does it show different U-relationship on different levels? The research uses the General Equilibrium Theory to explain the reality in China.

4.3.1 The General Equilibrium Analysis of Industrial competitiveness and Environmental Regulations

This research refers to the analysis conducted by Zhang (2012) and makes some improvements. Assume that there are only two sectors in the economic system, the firms and the government. The government that "produces" environmental regulations represents the public interest, while the firms that produce products seek the maximization of profit. Their production activity is simultaneous and both need the input of production factors. Another assumption is that there are only two production factors in the society, the capital and the labour, and technology does not change within a short time period. With the input of production factors increasing, the output of firms is growing and the stringency of environmental regulations is increasing too. However, the total supply amount of production factors is fixed and scarce. Thus how to arrange the scarce resources can then be explained by the Edgeworth Box (Figure 6).

Products (Firms)

Capital Input



Environmental Regulation (Government)

Labour Input

(Source: Zhang, 2005)

Figure 6 Edgeworth BOX

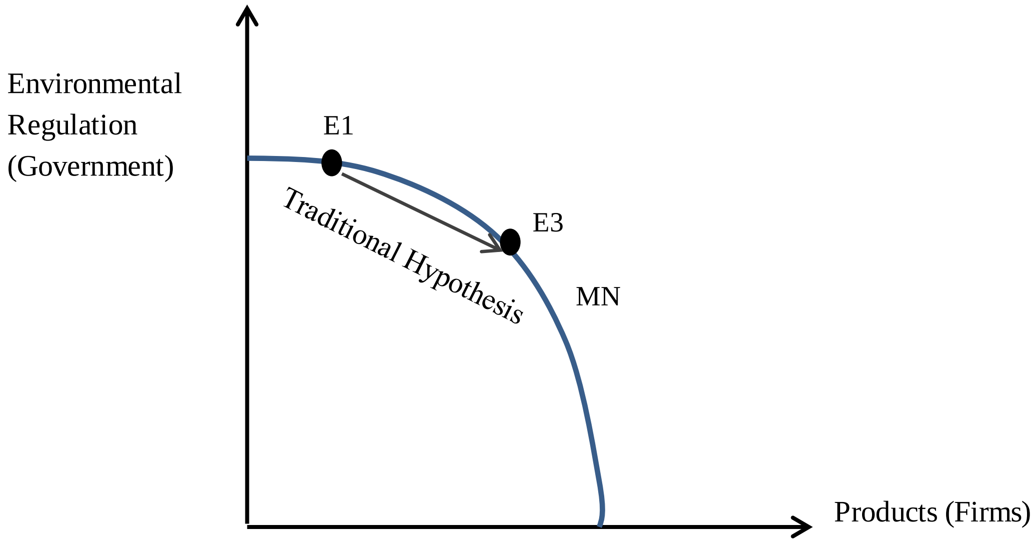
Figure 6 above shows the optimum allocation of two "outputs", environmental regulations and ordinary products. The top right corner is the output of firms and the lower left corner is the output of the government. The horizontal axis represents the amount of labour and the vertical axis shows the amount of capital. Here this research uses the amount of products to approximately represent competitiveness.

The curves A1 to A5 show the indifference curve of the stringency of environmental regulations. In a specific curve, the different portfolios of labour and capital lead to the same stringency of environmental regulations. With increased input, the stringency of environmental regulations increase too and the indifference curve moves to the top right corner, like from A1 to A3. It is same with the curve B1to B5, which are the indifference curves of firms. With input into producing increasing, the output goes up.

According to the General Equilibrium Theory, the line MN in Figure 6 that consist of the tangency points of two types of indifference curves like E1 to E5, conforms to Pareto Optimality of resource allocation, which is called the product contact curve.

Since the product contact curve has been obtained, the Production Possibility Frontier can be drawn. Figure 7 below shows the maximum and optimum output combination of environmental regulations and products in such circumstance where the total amount of labour and capital is fixed and the technology is fixed.

Point E3 and E1 in Figure 7 represent different combinations of environmental regulations and products. In E3, more resources are allocated to the government, where environmental regulations are stringent while the production of firms is low. In E1, the situation is the contrary; more resources are used to produce products and less input is made into environmental regulations. But the total quantity of production factors is the same because they are on the same production possibility frontier.



(Source: Zhang, 2005)

Figure 7 Production Possibility Frontier

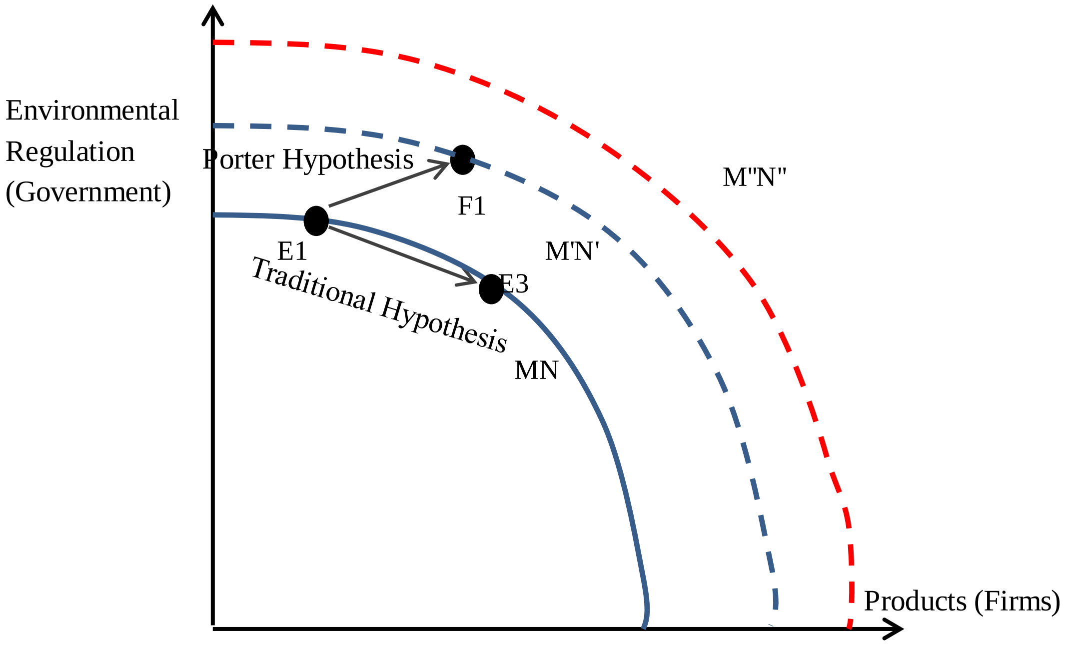
This is consistent with the traditional hypothesis that increase of environmental regulations inevitably leads to the decrease of output, namely industrial competitiveness, because fewer resources are allocated to production and more company resources are used to deal with the more stringent environmental regulations. It is a trade-off, as is shown from point E1 to E3.

However, such a situation is based on perfect rationality, perfect information and optimal allocation, which are hard to achieve in reality. Actually, due to the limitation of knowledge, technology, ability, information and the finite of the time, human are bounded rational (Simon, 1957). Decision-makers can only make decisions based on the things they have. Porter and Van der Linde (1995) are of the similar opinion that reality is full of highly incomplete information, organizational inertia and control problems. The resource allocation cannot achieve optimality, and discharges and pollutants signal the inefficiency of resource utilization. Therefore, the curve MN in Figure 7 is not the real production possibility frontier. This frontier is based on bounded rationality.

The true frontier is the dash curve M'N' (the dash blue line in Figure 8) that can never be achieved due to the bounded rationality, but can be approached with the development of rationality and technology.

And it is easy for smart firms and managers to find that the current situation is inside the boundary, which means that Pareto improvement is possible. So, their improved path could be from E1 to F1 instead of E5, where the products and environmental regulations increase at the same time through the resource-efficiency improvement, discharge decrease, etc. This is what Porter and Van de Linde called the innovation offset (Porter & Van de Linde, 1995).

Another impact brought by the increase of stringency of environmental regulations is the expansion of resources. With the improvement of environmental quality, more people will be attracted to this place, which will result in an increase in the labour force virtually. Although the impact of environmental regulations on capital is not clear, the increase of labour could make the production possibility frontier move outward, like the red dash line M"N".



(Source: Author)

Figure 8 "New" Production Possibility Frontier

4.3.2 The Integration of theTraditional Hypothesis and Porter's Hypothesis

Strictly speaking, the traditional hypothesis does not contradict Porter's Hypothesis in nature. They are two different situations fit for different firms. If the firm cannot activate the innovation offset but sticks to the production possibility frontier based on bounded rationality, namely sticks to their current limited knowledge and technology level, they have to face the trade-off between environmental regulations and competitiveness. However, if the firm can grasp the opportunity and information provided by the increasing stringency of environmental regulations and activate innovation offset successfully, they can enjoy the positive impact and the secondary positive effect brought by the environmental regulations. These firms are more competitive.

4.3.3 How to Activate Innovation

It is obvious that whether innovation can be activated is the key point. How to trigger innovation offset? This research lists some conditions as follows.

First, stringent regulations are better (Porter & Van de Linde, 1995). Compared with the lax regulations policy, stringent regulations can focus greater company attention on fundamental solutions rather than end-of-pipe or secondary treatment solutions.

The environmental regulations only have a positive influence once they passed the turning point, which means innovation offset is triggered successfully

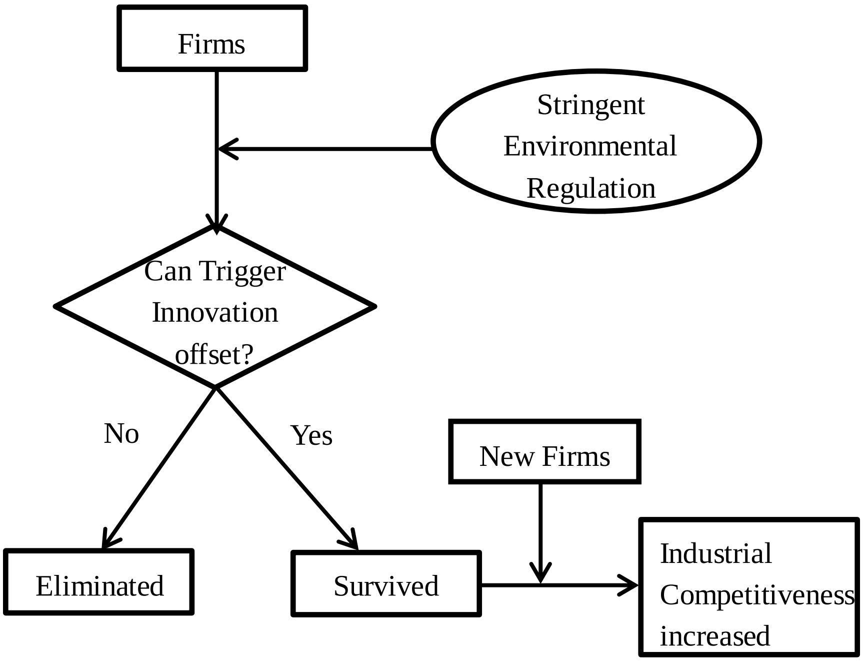
Second, a well-designed environmental policy is crucial (Porter & Van de Linde, 1995). Since the decisions-makers are all subject to bounded rationality, it is important to improve the rationality. One of the reasons for bounded rationality is imperfect information (Simon, 1957). A well-designed policy can provide useful additional information, which reduces the cost of information collection to some extent, and induces the firms to make a change towards the right target. Therefore such policies can lead the managers to realize and find the room for improvement. If the policy is not designed well, it may generate negative impacts.

Third, education is of importance too. Bounded rationality is partly because of cognitive limitations and inability to process and compute (Simon, 1957). Education, especially higher education and continuing education, can improve this. With more knowledge, the limitations of these aspects are reduced gradually.

4.3.4 How to Interpret the U-relationship

The U-relationship means that when environmental regulations are lax, there is a trade-off; when they are stringent, there is a positive impact. The explanation is as follows.

Assume all other things being equal. When the regulations are lax to some extent, most firms in the society cannot obtain innovation offset due to the reasons mentioned by Porter. The trade-off association works. This trade-off will continue until the stringency achieves the turning point and innovation is triggered. This is because PPF does not move outward and more factors used to deal with environmental regulations during that period. For fear of a continuous decrease of competitiveness, the government would usually give up enforcing more stringent regulations. It is a vicious circle.



(Source: Author)

Figure 9 Influences of Stringent Environmental Regulations

When regulations are stringent to some extent, they will trigger innovation for some firms, provided that other conditions are successfully being met. The whole process is like the procedure shown in Figure 9. When environmental regulations are strengthened to some extent, firms are divided into two categories gradually. Those firms which can move their bounded-rational frontier outward and trigger innovation offset will enjoy the increase of industrial competitiveness, while those that cannot will be eliminated because they fall behind the competition and cannot keep pace with the times. It needs some time to trigger innovation and eliminate the laggard firms, so there could be trade-off at first. But after that, the surviving firms will improve the industrial competitiveness of the whole society. Meanwhile, many new firms that conform to the time trend will join the competition, which can also improve the competitiveness. The positive impacts work.

In consideration of the above two points, the U-relationship is generated when the stringency of environmental regulations range from a low level to a high level.

4.3.5 Explanation of the Results

The main difference between two econometric results is the turning point. From the perspective of the industry, China is seemingly already at the stage where environmental regulations can trigger innovation offset. But on the provincial level, China is still in the transition stage. The answer lies in the fact that provinces in the east of China are already at the stage where environmental regulations can trigger innovation offset, while provinces in the West of China is still at the transition stage. Since most firms locate in the east of China, their positive association between environmental regulations and industrial competitiveness can somehow cover the negative performance of the firms in the same industry which are located in the relatively less-developed West China.

The research first looks at the agglomeration of environmental regulations. This research uses the LISA cluster map to analyse agglomeration. LISA proposed by Anselin (1995) is also called local Moran's I, which decomposes global Moran's I into each spatial unit in nature. The research uses OpenGeoDa 1.2.0 to calculate the LISA of SER of each province and map the cluster map based on z-test ($P \leq 0.05$) and 9999 permutations. Due to lack of space, only maps for 2001, 2005 and 2010 are listed below. In the following maps (Figure 9-11), the coloured provinces (except green) are all significant units which have a strong association with their neighbouring units. The red means the provinces are the core of the high-high club; it is the "hot spot". The blue indicates the units are the "cold spot" which is the core of low-low agglomeration. Pale red and pale blue represent the "pocket area" which has negative impacts on neighbouring provinces. Pale red means the core of the low-high agglomeration; pale blue means the core of high-low agglomeration.

According to the maps below, almost all the significant units are in positive spatial association with their neighbours. Units that deviate from the global trend, like Gansu in 2001, are limited and disappearing. There are two obvious stable agglomeration regions. The first one is the Yangtze River delta, where the provinces around Jiangsu and Zhejiang are always in the "high-high" club. Another region is the northwest of

China, where the provinces like Qinghai and Xinjiang are usually in the low-low club. According to the calculation, most of the stringency of environmental regulations in eastern provinces already exceeded the turning point in the 2004 (see Table 12). Many provinces in the West of China were still below the turning point in 2010 (see Table 13). With more stringent environmental regulations, the firms in the east of China have more advantages in triggering innovation offset.

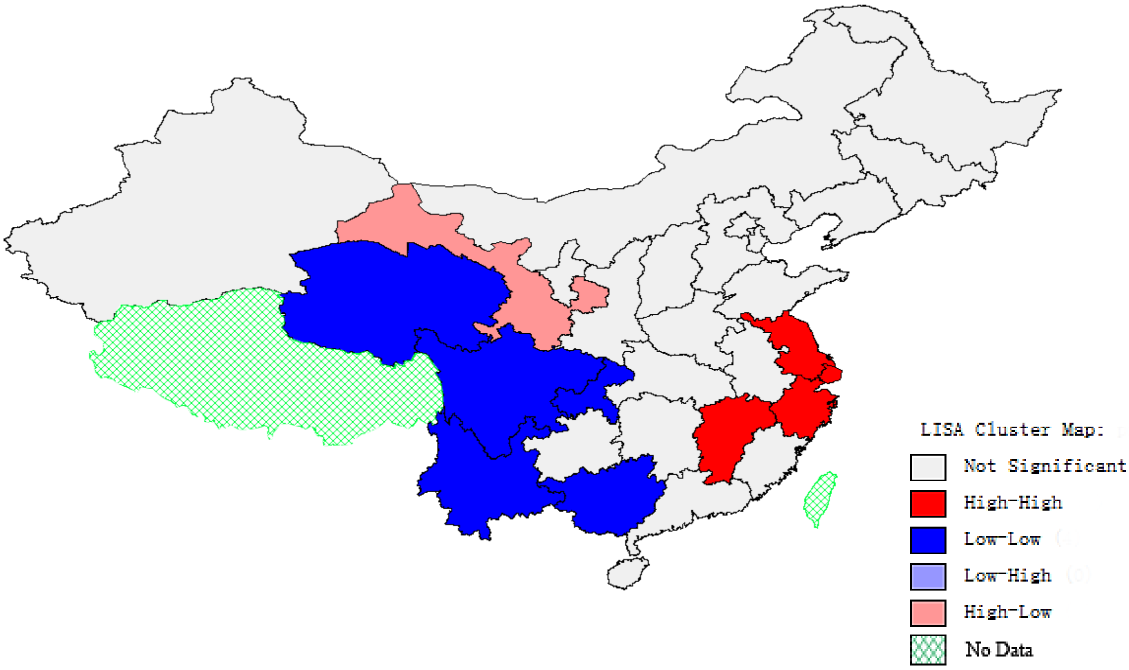


Figure 9 LISA Cluster Map of SER in 2001

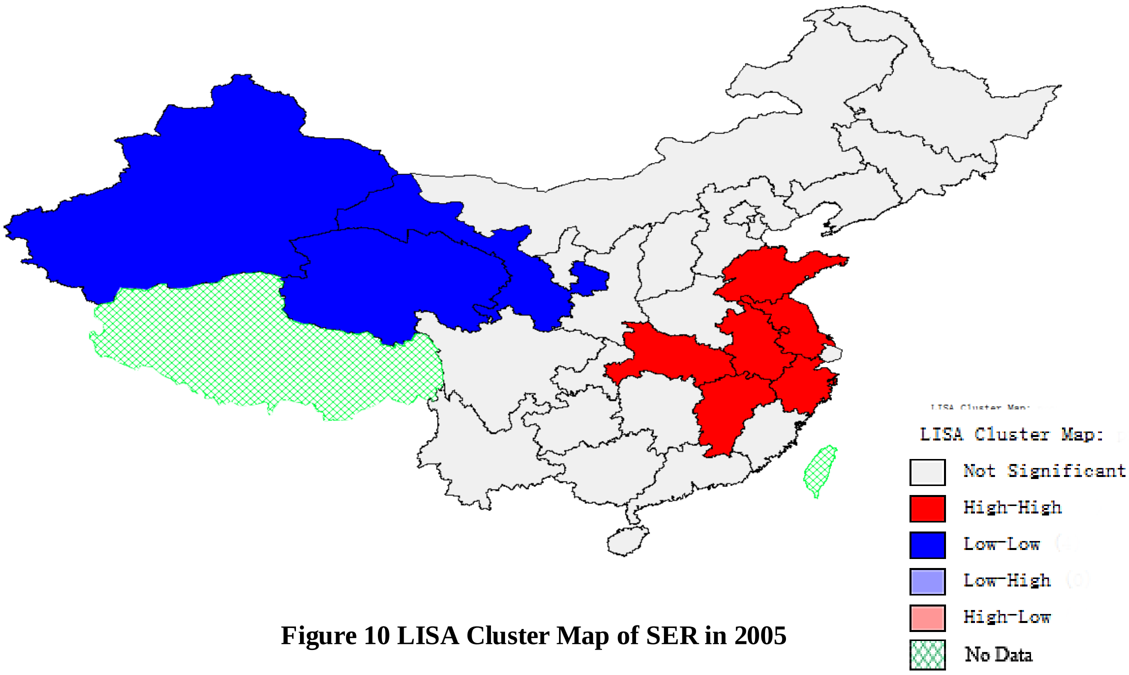


Figure 10 LISA Cluster Map of SER in 2005

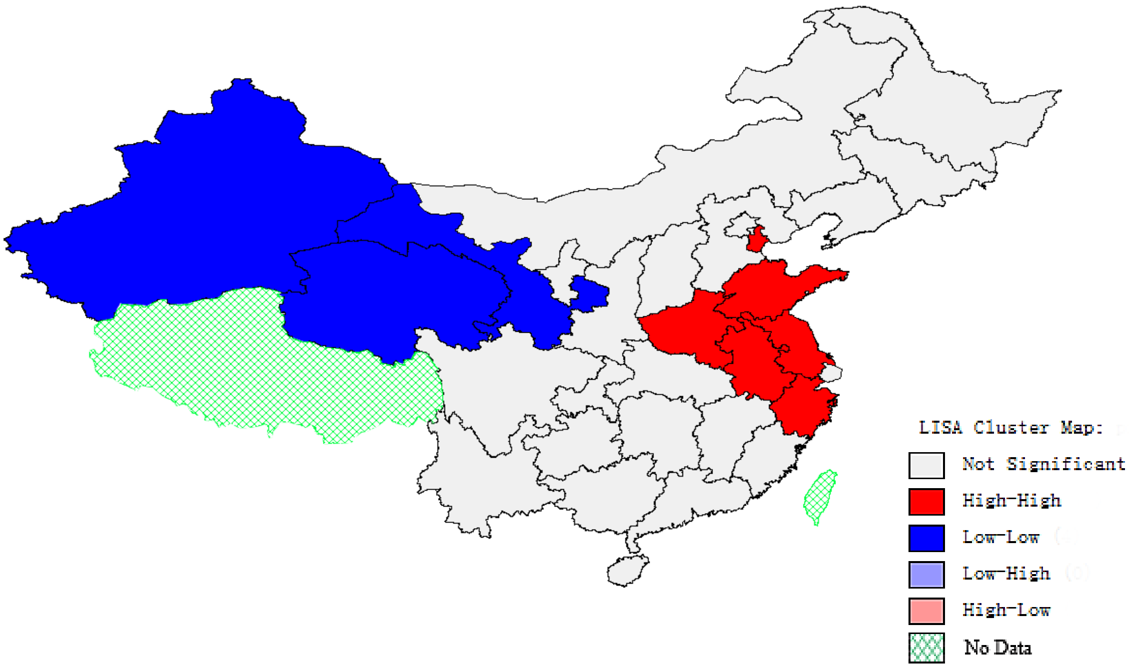


Figure 11 LISA Cluster Map of SER in 2010

(Figure10-12 source: Author, graphed according to LISA using OpenGeoDa 1.2.0)

Table 12 SER of Jiangsu and Zhejiang (Some Provinces in the East of China)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Jiangsu	0.65	0.69	0.69	0.76	0.79	0.83	0.86	0.89	0.90	0.91
Zhejiang	0.68	0.75	0.76	0.77	0.81	0.76	0.80	0.85	0.89	0.90

(Source: Author, calculated according to the data collected)

Table 13 SER of Qinghai and Xinjiang (Some Provinces in the West of China)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Qinghai	0.37	0.25	0.29	0.32	0.13	0.18	0.22	0.27	0.32	0.41
Xinjiang	0.20	0.42	0.38	0.40	0.32	0.34	0.35	0.36	0.37	0.37

(Source: Author, calculated according to the data collected)

Second, the east of China engaged with market economy much earlier compared with the other parts of China. Therefore, the institutional conditions are better. The environmental policies are always well-designed under better institutional circumstances, which can provide more information and better trigger innovation.

Third, look at the education. The eastern provinces usually have a much higher rate of higher education compared with other provinces. It demonstrates that labour there has more ability to deal with information, which is a better condition to trigger innovation offset.

Table 14 Higher Education Rate of Yunan and Guizhou (Some Provinces in the West and Middle of China)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Yunnan	2.23	1.99	1.83	3.84	3.37	3.10	4.02	3.51	3.06	5.78
Guizhou	2.16	3.52	5.29	4.47	3.32	2.72	3.22	3.50	3.31	5.29
Henan	2.88	4.30	3.20	4.42	4.22	4.14	4.04	4.72	5.16	6.40
Jiangxi	2.82	2.91	6.28	4.67	3.85	4.74	7.22	6.39	6.86	6.85

(Source: Author, calculated according to the data collected)

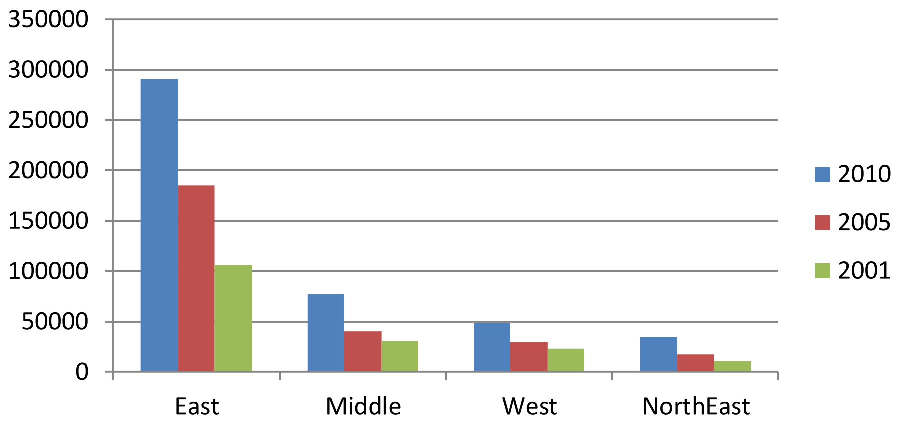
Table 15 Higher Education Rate of Jiangsu and Zhejiang (Some Provinces in the East of China)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Jiangsu	4.14	3.83	4.96	4.92	6.80	7.24	8.12	7.04	7.76	10.81
Zhejiang	3.40	5.77	6.17	7.47	5.42	8.42	8.59	9.53	10.04	9.33

(Source: Author, calculated according to the data collected)

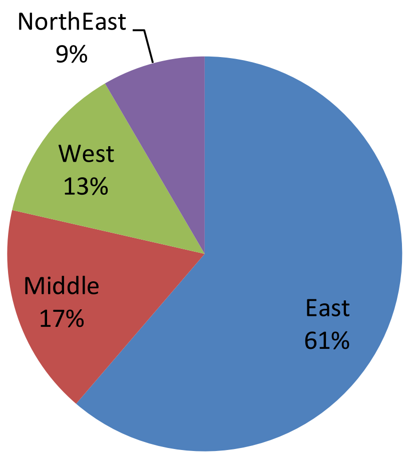
Based on the above analysis, it can be concluded that provinces in the east of China have better conditions to trigger innovation offset than provinces in the other parts of China. When facing the challenge, firms located in the eastern provinces can trigger the innovation offset better, while firms in West of China cannot handle environmental regulation as well.

Last but not least, look at the geographical distribution of industry. According to the calculation, around 60% of firms above the designated size cluster in the east of China (see Figure 12) and the proportion of output value to the whole country is over 61% (see Figure 13). The other parts of China, which have 20 provinces and occupy 90% of national territory, only possess around 40% of the industry firms and output.



(Source: Author, graphed according to the data collected)

Figure 12 Number of Firms above Designated Size in Different Part of China



(Source: Author, graphed according to the data collected)

Figure 13 Percentage of Output of Firms in Different Parts of China

Therefore, when considering the problem from the perspective of one specific industry, most firms belonging to the industry are located in the east of China and have already passed the turning point, hence they have more advantages in triggering innovation offset. Their behaviour and performance can cover the contrary performance of the firms in the same industry that are located in the relatively less-developed West China. Thus, on the average, the industry as a whole is showing a positive impact.

It can be concluded that, on the average, China is already in the stage where environmental regulations can lead to an increase in industrial competitiveness. However, when it comes to certain provinces in the west of China, they still have a long way to go.

Chapter 5: Conclusions and Recommendations

5.1 Introduction

This chapter first briefly reviewed the background and objectives of this research. Then, conclusions were made according to the results shown in Chapter 4 and the research questions were answered. Last, recommendations related to the policy will be provided.

5.2 Retrospect

Currently, more attention is paid to the association between environmental regulations and industrial competitiveness due to increasing pressures on economic development and environmental protection. At present, there are three hypotheses on the association, namely the traditional hypothesis, Porter's Hypothesis and the comprehensive "theory", as reviewed in Chapter 2, but due to many reasons there is no consensus. As for China, little research is conducted in this field, although it plays a significant role in the world's economic development and environmental protection. Therefore, this research aims at building an appropriate framework to explain the impact of environmental regulations on industrial competitiveness and explore the mechanism behind the association based on the data of China. Here are some conclusions.

5.3Conclusions and Discussions

Based on the previous chapters, several conclusions were made.

5.3.1 The U-Relationship between Environmental Regulation and Industrial Competitiveness

Both on the national level and the provincial level, it is the U-relationship between environmental regulations and industrial competitiveness, not the simple linear one, which differs with all of the three main hypotheses. The results were based on the econometric models of China. Such an association means that there is a turning point, before which environmental regulations will not have a positive impact on industrial competitiveness. This conclusion also demonstrates that the traditional hypothesis fits the situation first when regulations are lax; later, after the turning point, Porter's hypothesis works.

5.3.2 The General Equilibrium Theory Explaining the Mechanism

The General Equilibrium Theory was used to explain the mechanism behind the association in this research. Several sub-conclusions were made as follows:

1) The traditional hypothesis is integrated with Porter's Hypothesis within the framework of the General Equilibrium Theory.

Within this framework, the traditional hypothesis and Porter's Hypothesis do not contradict each other, because the former one is based on the rational-economic man assumption while the latter is on the basis of the bounded rationality assumption. The traditional hypothesis stresses that the response path to more stringent regulations moves along with the production possibility frontier, while Porter's Hypothesis means the response path is from the point within the frontier curve to the point approaching the frontier curve.

2) Innovation is the key point of the positive association between environmental regulations and industrial competitiveness.

Innovation can move the frontier curve outward. If innovation offset is triggered successfully, Porter's Hypothesis works and then a U-relationship could exist. And then in the long-run, environmental regulations have positive impacts on industrial competitiveness. If innovation offset fails to be triggered, a trade-off association between environmental regulation and industrial competitiveness works and continues

3) Stringent environmental regulations, well-designed policy and education are the keys to trigger innovation.

Stringent regulations can force firms to pay attention to more fundamental solutions rather than end-of-pipe or secondary treatment solutions (Porter & Van de Linde, 1995), which is proven by the econometric model, where stringent environmental regulations could have positive impacts while lax regulations would have a negative influence.

The idea that well-designed policy and better education can be helpful to trigger innovation originated from bounded rationality. Well-designed policy can reduce the cost of information collection and provide useful information; education can improve the cognitive and processing ability. Both of them can improve the people's rationality level and trigger innovation further.

5.4 The Interpretation of the Main Question

What is the influence of environmental regulations on industrial competitiveness in China? The descriptions were different on two levels, though they all displayed a U -relationship.

1) China enjoys a positive association between environmental regulation and industrial competitiveness on the whole.

From the perspective of a specific industry, China is already now at the stage where, on the whole, environmental regulations have positive impacts on industrial competitiveness. In other words, innovation can be triggered in China when facing stringent environmental regulations; most environmental policies are well-designed and stringent enough to have achieved a certain level.

2) Different provinces are at different stages where the impacts of environmental regulations on industrial competitiveness vary.

When comes to the performance of industry in different provinces, the situation is different. Additionally, not only will environmental regulations in the local province will influence competitiveness, but also the regulations in other provinces will have impacts due to the interaction between provinces. The direct effect, indirect effect and total effect of regulations on competitiveness are all in a U-relationship.

The eastern provinces have already met conditions which can activate innovation. They have more stringent environmental policies which already surpassed the turning point, better established institutions and higher rate of people receiving higher education. However, provinces in other parts of China, especially in the west of China, perform poorly compared with these eastern provinces.

But since more firms are located in the east of China, their behaviour and performance can cover the contrary performance of the firms in the same industry located in the relatively less-developed West China.

5.5 An Addition to the Existing Body of Knowledge and

The research provided a scientific evaluation system to measure the stringency of environmental regulations and industrial competitiveness. Hopefully, it could enrich the empirical studies in this field in China. In contrast to other research, it integrated the traditional hypothesis with Porter's Hypothesis within the general equilibrium framework. And it applied the framework to interpret the U-relationship which was shown by the econometric results.

5.6 Further Research Implications

Limited by the scope of this research, some aspects have not been considered that may influence the association between environmental regulations and industrial competitiveness.

First, in future research, land data can be investigated because it is a very important factor in measuring competitiveness. And the investment in environmental protection can be adopted in measuring the stringency of environmental regulations. At present these data are unavailable.

Second, the sample of future research could be cities instead of provinces. Province is still a very big administrative unit. Within the province, heterogeneity exists among cities.

Third is the endogeneity problem of variables. As discussed in Chapter 1, environmental variables could be endogenous (Fredriksson et al., 2003;Cole & Elliott, 2005;Levinson & Taylor, 2008). The association between industrial competitiveness and environmental variables could be bidirectional, i.e. the increased level of industrial competitiveness could also result in more stringent environmental regulations and lower pollution intensity. Endogeneity is always a tough problem for econometric models. This research has tried to find the IVs for environmental variables, but failed. Other methods were also tried to eliminate the potential influence of endogenous environmental variables, i.e. first differenced GMM and systematic GMM estimation. However, it also failed because the estimated models cannot pass the related tests. Fortunately, in the spatial durbin model (SDM), the Maximum Likelihood estimation used in this research has already eliminated the influence of endogenous variables (Anselin, 1988;LeSage, 1999). Therefore the results could be more reliable. In the future, with more time being spent, appropriate IVs may be found for environmental variables, or future researches could prove that endogeneity problems is not as serious as academics think.

Third, with the development of econometrics, more tests can be conducted to guarantee robustness of models, especially for the spatial model.

5.7 Recommendation for China

Returning to the case of China, although it is in good position to generate positive impacts of environmental regulations on industrial competitiveness on the whole, development is still unbalanced. Most provinces in middle, west and northeast of China still cannot enjoy a positive association between the two variables. There is much room for improvement. The government can do something to turn the situation around, at least in the following aspects.

5.7.1 Change the Instruments of Environmental Regulation

Currently, the main instruments of regulations are still the command-and-control as reviewed in Chapter 2. Although such instruments are always effective in reducing pollutant emissions, they sometimes do not reflect the market demand and are economically inefficient due to the government failure. Therefore, this kind of policy usually drains the production factor, which would distort the output arrangement between firms and government and makes the optimal combination impossible.

The research recommended the government to adopt market-based instruments. Because these instruments signal the market demand and market trends, they can reduce the possibility of government failure and provide more useful and correct information to the decision-makers, which is helpful to expand the boundary of rationality. Additionally, a market-based instrument is always designed better than the command-and-control instruments since it has the ability to self-adjust according the market signals and has less human intervention.

5.7.2 Adopt Stringent Regulations rather than Lax Regulations

As Porter stresses (1995) that the stringent regulations can focus greater company attention on fundamental solutions rather than end-of-pipe or secondary treatment solutions compared with lax regulations. Stringent regulations can thus trigger the innovation better and faster.

The U-relationship between environmental regulations and competitiveness has already been proven. Only the stringent regulations which pass the turning point can generate a positive effect on industrial competitiveness. Although there may be a trade-off at first, the government should not worry about it. In the long-run, the impact is positive as long as it is well designed, as discussed in 4.3.3. Thus, government should set their minds on implementing stringent environmental regulations.

5.7.3 Set Different Policies in Different Provinces and Strengthen the Interaction between Provinces

It is obvious that there is a coast-interior divide of environmental regulations and industrial competitiveness in China. Provinces in different parts of China are at the different stages of development. Eastern provinces, which are already at the stage where environmental regulations have positive impacts, need to promote their technology on cleaner production to other provinces, as they are also influenced by the industrial competitiveness and environmental regulations of other provinces, as is mentioned in 4.2.2. The direct effect, indirect effect and total effect of environmental regulations on competitiveness are all in a significant U-relationship.

The other provinces, especially the western provinces, need to improve the stringency of regulations, and learn advanced institutions from the eastern provinces in order to improve the design of their policies and invest more money in science and technology to trigger innovation activities.

5.7.4 Improve the Education Level of the Public

Education plays an important role in the activation of innovation. Education, higher education in particular, can help people improve the ability in cognition and information processing, which will improve the level of rationality. The results in the econometric model also support this idea. Therefore, the government should put more effort into improving the education level.

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Appendix

Appendix 1

The names of 36 industries are listed below.

Mining and Washing of Coal
Extraction of Petroleum and Natural Gas
Mining of Ferrous Metal Ores
Mining of Non-ferrous Metal Ores
Mining and Processing of Nonmetal Ores
Processing of Food from Agricultural Products
Manufacture of Foods
Manufacture of Beverage
Manufacture of Tobacco
Manufacture of Textile
Manufacture of Textile Wearing Apparel, Footware, and Caps
Manufacture of Leather, Fur, Feather & Its Products
Processing of Timbers, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
Manufacture of Furniture
Manufacture of Paper and Paper Products
Printing, Reproduction of Recording Media
Manufacture of Articles for Culture, Education and Sport Activities
Processing of Petroleum, Coking, Processing of Nuclear Fuel
Manufacture of Chemical Raw Material and Chemical Products
Manufacture of Medicines
Manufacture of Chemical Fiber
Manufacture of Rubber
Manufacture of Plastic
Manufacture of Nonmetallic Mineral Products
Manufacture and Processing of Ferrous Metals
Manufacture & Processing of Non-ferrous Metals
Manufacture of Metal Products
Manufacture of General Purpose Machinery
Manufacture of Special Purpose Machinery
Manufacture of Transport Equipment
Manufacture of Electrical Machinery & Equipment
Manufacture of Communication Equipment ,Computer and Other Electronic Equipment
Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work
Production and Supply of Electric Power and Heat Power
Production and Distribution of Gas

Appendix 2

The name of 30 Provinces and their locations are listed below[10].

East of China:

Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan

Middle of China:

Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan

West of China:

Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunan, Gansu, Qinghai, Ningxia, Xinjiang, Shaanxi

Northeast of China:

Liaoning, Jilin, Heilongjiang

Appendix 3

(Robust) LM Test Statistic for Spatial Error
Null Hypothesis: $\rho = 0$

$$LM - error = \frac{\left(\frac{EWE}{\hat{\sigma}_\varepsilon^2}\right)^2}{Trc} \sim \chi^2(1)$$

$$Robust\ LM - error = \frac{\left(\frac{EWE - (\frac{Trc}{J}) \cdot EWY}{\hat{\sigma}_\varepsilon^2}\right)^2}{Trc \cdot (\frac{1 - Trc}{J})} \sim \chi^2(1)$$

(Robust) LM Test Statistic for Spatial Lag
Null Hypothesis: $\lambda = 0$

$$LM - lag = \frac{\left(\frac{EWY}{\hat{\sigma}_\varepsilon^2}\right)^2}{J} \sim \chi^2(1)$$

$$Robust\ LM - lag = \frac{\left(\frac{EWY - EWE}{\hat{\sigma}_\varepsilon^2}\right)^2}{J - Trc} \sim \chi^2(1)$$

Where in all of the four formulas, $\hat{\varepsilon} = y - \boldsymbol{X}\hat{\beta}$; $\hat{\beta} = (\boldsymbol{X'X})\boldsymbol{X'}y$; $\hat{\sigma}_\varepsilon^2 = \hat{\varepsilon}'\hat{\varepsilon}/NT$; $EWE = \hat{\varepsilon}'(\boldsymbol{I_t} \otimes \boldsymbol{W})\hat{\varepsilon}$; $EWY = \hat{\varepsilon}'(\boldsymbol{I_t} \otimes \boldsymbol{W})y$; $\boldsymbol{M} = \mathbf{I} - \mathbf{X}(\mathbf{X'X})^{-1}\mathbf{X'}$; $Trc = T \cdot trace(\boldsymbol{WW} + \boldsymbol{W'W})$; $J = T \cdot trace(\boldsymbol{WW} + \boldsymbol{W'W}) + [(\boldsymbol{W}\hat{y})'\boldsymbol{M}(\boldsymbol{W}\hat{y})/\hat{\sigma}_\varepsilon^2]$

[10] Tibet, Taiwan, Hong Kong and Macao are not included in the research due to the availability of data.

Appendix 4

The descriptive statistics table of variables on the national level is as follows:

	Mean	Std. Dev. (overall)	Std. Dev. (between)	Std. Dev. (within)	Min	Max
IC	0.295	0.072	0.058	0.043	0.144	0.501
SER	0.569	0.105	0.073	0.076	0.216	0.865
PI	0.045	0.078	0.065	0.044	0.0000066	0.551
SI	7937.041	8985.721	7058.962	5671.280	184.870	45220.470
MS	8287.794	7960.360	7079.817	3807.902	84.000	39699

Appendix 5

The correlation table of variables on the national level is as follows.

	SER	SER^2	PI	D(SI)	MS
SER	1				
SER^2	-	1			
PI	-0.4192	-0.3774	1		
D(SI)	0.2657	0.2537	-0.1155	1	
MS	0.1798	0.1448	-0.1977	0.5483	1

Appendix 6

The descriptive statistics table of variables on the provincial level is as follows:

	Mean	Std. Dev. (overall)	Std. Dev. (between)	Std. Dev. (within)	Min	Max
IC	0.320	0.094	0.068	0.066	0.064	0.596
SER	0.662	0.181	0.139	0.119	0.127	0.953
PI	0.197	0.156	0.132	0.087	0.002	0.735
SI	9427.588	13389.470	11133.650	7684.463	194.160	82918.450
MS	10158.040	12958.940	11827.260	5679.849	388.000	65495.000
GDP_PC	1.666	1.348	1.182	0.680	0.298	7.248
POP	4313.570	2611.130	2647.251	144.936	523.100	10440.960
FDI	226.339	304.922	287.505	113.167	1.256	1568.854
INF	0.206	0.167	0.161	0.053	0.003	0.892
EDU	7.185	4.979	4.696	1.845	1.828	31.499

Appendix 7

The correlation table of variables on the provincial level is as follows.

	SER	SER^2	PI	d(SI)	MS
SER	1.00				
SER^2	-	1.00			
PI	-0.58	-0.58	1.00		
d(SI)	0.40	0.41	-0.52	1.00	
MS	0.41	0.42	-0.50	0.88	1.00
d(GDP_PC)	0.47	0.49	-0.62	0.47	0.43
d(POP)	0.14	0.15	-0.28	0.46	0.44
d(FDI)	0.19	0.18	-0.21	0.26	0.19
INF	0.51	0.52	-0.51	0.29	0.27
EDU	0.26	0.29	-0.45	0.09	0.07

	d(GDP_PC)	d(POP)	d(FDI)	INF	EDU
SER					
SER^2					
PI					
d(SI)					
MS					
d(GDP_PC)	1.00				
d(POP)	0.28	1.00			
d(FDI)	0.21	0.07	1.00		
INF	0.69	0.26	0.14	1.00	
EDU	0.68	0.23	0.10	0.79	1.00