UNIVERSITY OF GOTHENBURG

The Effect of Environmental Policy Stringency on Environmental Innovations

A Cross Country Comparison

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Abstract:
This thesis is a cross-country comparison based on panel-data across 30 countries from 1990-2012. It uses a Negative Binomial Regression Model to test The Porter Hypothesis to see if environmental policy stringency affects the number of environmental innovations in a country. A composite index "EPS," developed by the OECD, with a scale that ranges from 0 to 6 measures policy stringency. Patent applications from the IP5 patent family measure environmental innovations. The findings indicate that a more stringent level of environmental policies in a country do lead to a higher number of environmental patent applications. The results of the thesis show that one step on the EPS scale increases the rate of the number of patent applications by a factor of 1.144 to 1.156. The thesis also divides policies into market-based and non-market-based instruments to see which kind of regulations have the greatest impact on innovations. The results show that non-market-based regulations have a greater impact in the short term, while market-based regulations have a greater impact in the long term. This thesis shows that it could be economically preferable to change our environmental habits and see economic growth and environmental protection as complements rather than contradictions.

Keywords: Policy stringency, environmental- regulations, innovations, EPS, eco-patents Porter Hypothesis

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Abbreviations

BRIICS - Brazil, Russia, India, Indonesia, China, South Africa

CO2 - Carbon dioxide

EPO - European Patent Office

EPS - Environmental policy stringency

EU - The European Union

FDI - Foreign direct investment

GDP - Gross domestic product

IP5 - Forum for the five of the world's largest intellectual property offices.

IP5 families - Patent that has been filed at least at two international patent offices

IPR - Intellectual property rights

NB model - Negative Binomial Regression Model

OECD - Organisation for Economic Co-operation and Development

OLS - Ordinary least square (regression)

OVB - Omitted variable bias

PACE - Pollution abatement control expenditures

R&D - Research and development

UCLA - University of California, Los Angeles

USD - American dollar

WEF - World Economic Forum

1. Introduction

The motivation for this study stems from the current environmental improvement due to the Covid19 pandemic. The crisis has shown us that it is still possible to turn the environmental crises around, by displaying a substantial reduction in emissions, which has already led to environmental improvements. These reductions in emissions are not surprising since there has also been a decrease in industrial productions and international travelling. However, since keeping the world economy on lockdown and restricting international connections are not economically sustainable, other things have to change in order to save the planet.

The relationship between environmental protection and economic growth is often viewed as a trade-off, both by the private sector and governments. During centuries, economic growth and competitive advantages, have been prioritised on a global scale, leading to significant environmental losses, creating a global overheating of the planet (Eriksen, 2015). Since the acknowledgement of the extreme environmental problems, countries have chosen different ways of regulating pollution, more stringent or more lax regulations due to different believes, abilities and basis. It is of great importance to evaluate these choices and to learn about the relationship between environmental protection and economic growth. The traditional perception of environmental protection and a firm's competitiveness as conflicting elements is something that has changed in later years. Instead, positive economic improvements can be found as a consequence of protecting the environment (Eriksen, 2015).

> "Economic growth and ecological sustainability are not necessarily antagonistic. However, the regions with fast economic growth require some balancing act to optimise eco-economic development, with win-win outcomes for economic growth and an ecological resource base to help ensure long term sustainability" (Zhang, Hanjra, Hui and Khan, 2009, pp. 73).

Economic growth is the process of finding innovative ways to use the same amount of resources and time for higher output (David de la Croix, 2015). Innovations, in terms of technological improvements, are a requirement for economic growth, and regulations are a requirement for environmental protection (Zhao, 2019). Environmental regulation will inevitably increase costs, in a static world, where firms already made their cost-minimising decision. In the last 20-30 years, we have seen a shift from a static model to a more dynamic one based on innovations. This shift has affected international competitiveness and studies reveal that advantages are gained from the capacity to improve and innovate rather than having the cheapest input and the largest scale (Porter and van der Linde, 1995).

The purpose of this thesis is to examine whether the stringency level of environmental policies in a nation will lead to an increase in environmental innovations. The motivation behind this purpose is the theoretical connection between an increased number of environmental innovations, economic growth and competitive advantages. In the neoclassical view, it is generally thought that stricter environmental policies have positive effects on the environment, but adverse effects on the effectiveness of companies since regulations often increase costs (Frank and Cartwright, 2013, pp. 49). However, while that might be true, it has also been hypothesised that stricter environmental policies can increase economic growth and competitiveness by creating incentives for environmental-related innovations that decrease the firm's costs and in the long term generate economic growth (Porter and Van Der Linde, 1995).

The term policy stringency is mainly used in the field of ecological economics (Kemenade and Teixeira, 2017). Kemenade and Teixeira (2017) mention how other previous authors define policy stringency. Haščič, Johnstone and Kalamova (2010) define the term as an indicator of how ambitious the environmental targets are related to the typical path. More stringent policies increase costs of polluting and therefore increase incentives for innovation. Costantini and Crespi (2008) define the terms as the degree to which the regulations are implemented, to increase incentives for sustainable production processes. Harring (2008) explains policy stringency as the success in implementing environmental policy (Kemenade and Teixeira, 2017).

To reach the purpose, this study will investigate the hypothesised positive effect stricter environmental policies are said to have on innovations by analysing data on environmental policy stringency (EPS) and data on innovation through patents on environmental-related regulations (OECD, 2020). This thesis will, therefore, aim to answer the following research questions:

H1

Does the level of environmental policy stringency increase the number of a nation's environmental innovations?

H2

Do market-based policies have a higher positive effect on the number of innovations than do non-market-based policies?

The relationship between environmental policies and competitiveness have previously been researched, and many times so in line with either of two contradicting theories; The Pollution Haven Hypothesis and the Porter Hypothesis. The Pollution Haven Hypothesis stems from the basics of free trade and comparative advantages, arguing that differences in environmental regulation and free international trade will create pollution havens and give advantages to countries with low environmental regulations (Taylor, 2004). While the Porter Hypothesis instead argues that countries with high environmental regulations create comparative advantages since proper regulations give incentives to create innovation (Porter and van de Linde, 1995). This thesis will not investigate the existence of pollution havens, but rather investigate the claim of the Porter Hypothesis. This thesis will use environmental innovations as an outcome and further discuss the effect of environmental innovations on economic growth.

Furthermore, like many previous studies, (e.g. Johnstone, Haščič, Hemar, Poirier, (2012) and Morales-Lago, Bengochea-Morancho and Martínez-Zarzoso (2016)) this thesis uses patents on environmental-related technology as a measurement for environmental innovations. In order to ensure quality innovations and comparable cross-country data (Haščič, Johnstone and Silva, 2015), only data on patents from the IP5 family are used. From the same IP5 family data set, data for total patents are collected as a control variable in the econometric model. To measure environmental policy stringency, this thesis uses a composite index, developed by Botta and Kozluk (2014) for the OECD called EPS. In order to answer *H1* and *H2*, this thesis will perform a Negative Binomial Regression Model. Not many studies have used EPS to investigate the effect on environmental innovations through environmental patents before, and the contribution of this study is its econometric model that combines EPS with total patents as a control variable, and the inclusion of number of countries and range of time. Furthermore, this thesis will also empirically investigate the different effects market-based and non-market-based regulations have on innovations, in a wider time period and in combination with a larger set of countries than, that to our knowledge, has been done before.

The results of this study are in line with what many previous studies have shown and show that a higher level of environmental policy stringency has a positive and significant effect on innovations. However, contrary to what most theories suggest, this thesis shows that in the short-term non-market-based environmental regulations have a greater effect on environmental innovations than do market-based regulations. Although, in the long term, the results shows that market-based policies have a greater effect. The thesis also discusses the results in comparison with the theoretical framework. The results can be explained by the Porter Hypothesis and show, based on theories of economic growth, that an increase in environmental policy stringency can lead to competitive advantages and economic growth.

This thesis is from this point, structured as follows; Chapter 2 presents the background of environmental policies and innovations. Chapter 3 presents all the relevant theories for the subject, from fundamental economic theories to more specific theories like the Porter Hypothesis and the Hypothesis of Induced Innovation. Chapter 4 presents the data selection, the EPS-index and some concerns. Chapter 6 presents the empirical method. Chapter 7 presents the results and a robustness check. Chapter 8 provides a discussion based on the result and previous literature and provides a suggestion for further research. Finally, chapter 9 presents the conclusion.

2. Environmental- Regulations and Innovations

This chapter will capture the basic knowledge of environmental policy, what it is and how it is used. Further on, it will also give a brief background of environmental innovations and their effect on economic growth and productivity.

2.1 Environmental Regulations

Regulations consist of policies implemented by the government to oversee market activity and the behaviour of private actors in society. The intervention is justified through market failures and aims to ensure societal wellbeing (OECD, 1996). The rising urgency of environmental-related issues is forcing policymakers to head in the direction of sustainable development (Millenium Ecosystem Assessment, 2005). Environmental policies, which can be divided into market-based and non-market-based policies, are developed to prevent harmful effects on ecosystems created by human activities and can be designed in different ways. Environmental values are usually not considered within organisational decision making, leading to consequences such as market failures and externalities, which are the reason behind regulating harmful human activities (Popp, 2010). The history of environmental policy extends back to ancient times; different forms of environmental regulations have throughout history been applied to societies, creating environmental laws. Although environmental concern has been acknowledged for a long time, the awareness of climate consequences emerging from economic growth, developed and was given political attention from the 1950s onwards. The Cold War and the threat of nuclear weapons and environmental problems lead to the formation of a radical green party, in West Germany (at that time), die Grünen. The environment has since been a part of politics and vice versa, emphasising the fact that politics are not the same everywhere (Doyle, McEachern and MacGregor, 2016, pp.38).

In the essay entitled "Tragedy of the Commons", written by Garret Hardin in 1968, Hardin answers the question of how to best protect the ecosystems. Tragedy of the commons describes the relationship between population growth and the overuse of shared resources. When the common is "free for all", individuals will act independently, in their self-interest, resulting in a situation that is bad from a universal perspective. One of the most used examples is unregulated fisheries. Instead of collective thinking that would preserve the fish and offers an infinite resource, individuals will act in their self-interest and thereby over-exploit the fishery. The consequence will be dead water, impossible to recover from. Hardin argues that the solution to the problem of "tragedy of the commons" would be a system of private property, encouraging individuals to protect resources through self-interests instead. Another approach to solving the tragedy of the commons would be to regulate the use of the resource; i.e. environmental regulations are needed (Cunningham and Cunningham, 2015. pp. 28, 524).

Ideally, environmental regulations will both protect ecosystems, serve the need for human health and give economic advantages. Traditionally these interests have been perceived as contradictions. However, they are increasingly overlapping, acknowledged by policymakers. A sustainable environment is included as a fundamental right in the 1987 World Commission on Environment and Development (Brundtland Commission) and provides a baseline to guide subsequent laws. International environmental agreements have emerged slow but steady throughout time, addressing different problems linked to the environment. Over 170 treaties and conventions have been negotiated (Cunningham and Cunningham, 2015, pp. 542). However, international agreements have one fundamental problem, the fact that there is no supranational organisation able to enforce such an agreement (Kolstad, 2011, pp. 403). Environmental protection is an international issue since negative externalities affect more than just one country. Privatising common resources cannot always be done since some resources cannot be controlled; one example is the air we breathe. It is a pure public good, nonexcludable and nonrival. Likewise, pollution will be nonexcludable, demonstrably environmental regulation is an international issue (Kolstad, 2011, pp. 90). The international perspective is the reason behind basing this study on a cross-country analysis, the importance of looking at multiple countries instead of just one.

2.2 Market Failures and the Solution of Regulations

Market failures and externalities can explain underinvestment in environmental R&D. Naturally, pollution is not priced by the market, and therefore a firm will not reduce its emissions due to lack of incentives. Neither will a firm have incentives to develop new technology without any form of environmental regulation. Both consumers and producers will value private benefits over social benefits (Popp, 2010). Another market failure happens naturally when firms are unable to fully capture the reward of innovations. Often, innovations need to be made into public knowledge in order to benefit from them. If the public benefits from the innovation but not the innovator, it does not create enough incentives to develop such innovations (Popp, 2010). The theory of market failure argues that intervention from the government can be justified in order to deal with inefficiencies caused by externalities, public or open access goods or other market failures (André, 2015).

Interventions to meet the market failures, discussed above, often consists of policies. Regulations and different policy instruments make it possible for the government to correct environmental externalities and knowledge market failures. The latter is a general problem across technology and is often addressed through patent protection or funding of research. In order to direct the innovations more towards green innovation, other policy instruments like carbon taxes or cap-and-trade systems can be applied. Other more general policy mechanisms can be applied, such as targeted subsidies for adopting renewable energy. (Popp, 2010).

2.3 Environmental Innovation

The relationship between the environment and innovation has during recent years grown closer. Green innovations can tackle a country's environmental problems without curtailing economic activities (Beise and Rennings, 2004). The task of innovations is to offset both costs and burdens and is often induced by regulations (Rennings, 2000). The definition of innovation, created by OECD, seen as the conventional view of innovation, is separated into three categories; process innovation, product innovation and organisational innovation. The first one occurs when less input can produce the same amount of output. The second one refers to either improvement of goods and services or new goods and services. Lastly, the third one consists of new forms of management. The biggest weakness of this definition is that it does not distinguish environmental and non-environmental innovations (Renning, 2000). The intention of environmental innovations can be both reducing environmental harm but also a business objective to increase profitability. The environmental effect does not even have to be the direct effect and purpose of the innovation but can instead be a positive side effect of an innovation (Beise and Rennings, 2004).

One central aspect of growth theories is technological change (Verspagen, 1992). Studies have shown that there is a clear connection between innovation and economic growth. Hasan and Tucci (2010) showed through panel data with 58 countries over 23 years that those countries that increased their level of patenting also had higher economic growth (Hasan and Tucci, 2010).

The biggest obstacle to environmental innovations is the double-externalities problem. It occurs due to positive spillovers once an innovation is launched on the market. The social benefit becomes greater than the firm's benefits since the innovator alone carries the costs. When the private return for the innovator is less than the social return, it creates a lack of incentives for environmental technology and underinvestment in R&D. Without any form of regulations, such as patents, firms will not be rewarded for the social benefits they create (Oltra, 2008). The other problems for private actors would be the high risk of adoption and imitation of other private actors (Oltra, 2008). Because of the problem that benefits from a new environmental technology accrue to society at large, public funding of R&D is often the first impetus for new research (Popp, Newell and Jaffe 2010).

3. Theoretical framework

The theoretical framework will briefly explain the traditional economic view on regulations and efficiency loss. The theoretical framework will also touch upon innovation as a competitive advantage. Further on, the Porter Hypothesis will be explained, which is the theory of interest for this study. The theory of Induced Innovation will also be presented. Lastly, the difference between market-based and non-market-based policy instruments will be explained.

3.1 Regulations on Efficiency Loss

The neoclassical view of microeconomics would argue that regulations that add costs to companies will create some form of deadweight loss and thereby lead to disadvantages for those companies affected by the regulation. The most common example of regulations creating efficiency loss is taxes. Since the instrument ads either a cost of production or a higher purchasing price in the market, the production volume will be smaller, and firms will no longer sell at the optimal level. The gap between the new production level, with tax, and the old production level, without tax, represent the efficiency loss. An environmental tax will engender efficiency loss for companies and add disadvantages to the companies (Frank and Cartwright, 2013, pp. 49).

3.2 The Pollution Haven Hypothesis

A theory that supports the neoclassical view explained in 3.1 is The Pollution Haven Hypothesis. The theory argues that free international trade and differences in environmental standards will reallocate the production of emission-intensive goods, from the country with stringent environmental regulations to the country with lax environmental regulations. Furthermore, the theory draws two conclusions. The first implies that pollution rises in low-income countries and creates pollution havens while pollution reduces in high-income counties. The second implies that total pollution levels rise with diverse environmental standards and trade (Taylor, 2004).

With environmental regulations, emissions turn into a cost for firms. The cost will be high for firms subject to a high level of stringency and low for firms subject to a low level of stringency. Economic theory would thereby indicate that countries with lax environmental regulations have an economic advantage in polluting industries. The advantage will lead to countries specialising in the production of emission-intense goods while higher regulated countries specialise in cleaner industries and instead import goods from dirty industries. A higher level of environmental regulation will not only create a disadvantage for domestic firms, but it will also have the consequence of firms relocating to countries with lower regulations. The Pollution Haven Hypothesis is based on one of the primary models for trade and international specialisation, Heckscher Ohlin, explaining that countries will specialise in goods for which they have comparative advantages to produce (Kolstad, 2011, pp. 388-390). An important notion is that this thesis does not try to disprove the Pollution Haven hypothesis but rather find evidence for the Porter Hypothesis.

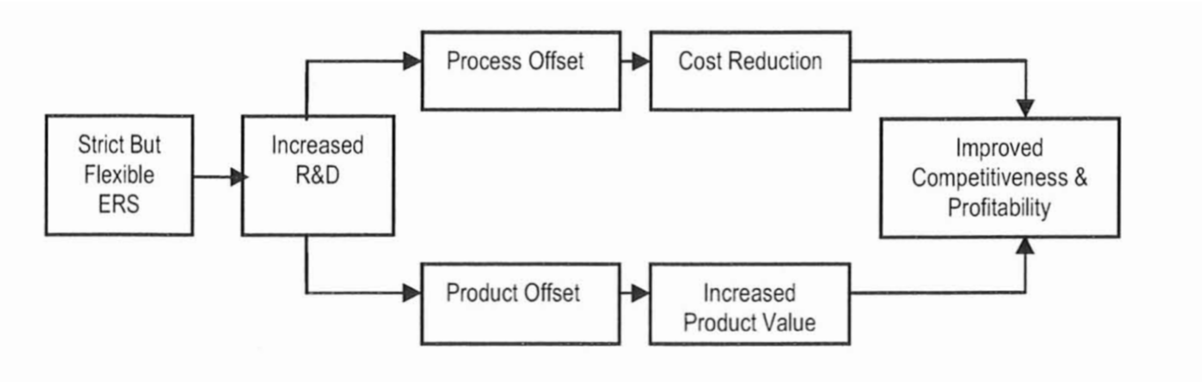
3.3 The Porter Hypothesis

Traditionally the view of environmental regulations among economists has been that regulations increase costs of firms and industries since they require some form of input either in capital or labour but does not contribute to an increase in profit (Ambec and Barla 2006). In the nineties, this view was challenged by Porter (1990) and Porter and van der Linde (1995). Porter argued that companies achieve competitive advantages through acts of innovations. Competitiveness is of high importance for nations and depends on a nation's capacity to innovate and upgrade (Porter, 1990).

The Porter Hypothesis argues that environmental regulations can trigger new forms of innovations that will entirely reduce the cost of the regulations and might even create an absolute advantage over similar firms and branches in countries where there are no regulations. The Porter Hypothesis supports the choice of stringent, well-designed environmental regulations because they could lead to not only social benefits but also private benefits for regulated firms. Hence, regulations protecting the environment are not necessarily detrimental for firms, but instead, environmental regulations can enhance competitiveness (Porter and van der Linde, 1995). The Porter Hypothesis has faced some criticism stating that the theory is based on the fact that firms will ignore profitable opportunities. Otherwise, regulations would not be needed to get companies to create innovations to increase profit (Ambec and Barla, 2006). Another criticism that the Porter Hypothesis has faced is the question of whether bureaucrats are better informed about business conditions than managers (Ambec and Barla, 2006). If the Porter Hypothesis is valid, it has a high impact on the cost-benefits assessment of environmental policies that often claims to erode domestic competitiveness on the international market (André, 2015). Instead, regulation will contribute to first-mover advantages for domestic firms (Porter and van der Linde, 1995).

The Porter Hypothesis is divided into a weak and a strong version. The weak version only claims that environmental regulation will stimulate some forms of innovations. However, additional innovations will come with opportunity costs that exceed the benefits (not counting the social benefits of reduced pollution). Further on, the strong version of the hypothesis ignores the profit-maximising paradigm and claims that firms, operating under normal circumstances, will react to regulations by creating innovations that will, not only offset the costs of compliance but even make firms better off (Jaffe and Palmer, 1997).

Figure 1: Schematic representation of the Porter Hypothesis (Ambec and Barla, 2006)



3.4 The Hypothesis of Induced Innovation

Another theory in line with The Porter Hypothesis is The Hypothesis of Induced Innovation (Hicks, 1963). Many of the environmental problems we face today can be solved through technological progress. The relationship between policy and environmentally friendly technology is further discussed in this theory (Popp 2002). The hypothesis of induced innovation dates back to the well known "The theory of Wages" from 1932 by Hicks (1963). When regulated firms face a higher relative cost of polluting compared to other production costs, firms will have an increased incentive to develop new emission-reducing technologies (Hicks, 1963; Dechezlepretre and Sato, 2017). R&D is an investment motivated by profit and driven in the direction of increased relative costs (Popp, Newell and Jaffe, 2010).

> "A change in the relative prices of the factors of production is itself a spur to the invention, and to the invention of a particular kind-directed to economising the use of a factor which has become relatively expensive" (Hicks, 1963, pp. 124).

A common example, connected to green technology was the significant increase of new, alternatives sources of energy as a response to a chock in the oil price. In order to significantly reduce emissions, the cost of abatement often relies on innovation (Dechezlepretre and Sato, 2017).

3.5 Technology and Growth Theories

One of the first models for economic growth is the Harrod Domar model, developed in 1939, which suggest that economic growth solely is dependent on two factors, productivity of capital and savings. However, economic growth is more complex and dependent on more factors than the Harrod Domar model account for (Zaoh, 2019). A model that does account for more than just capital and savings is The Solow model, developed in 1956 by Nobel laureate Robert Solow. The Solow model, which is a neoclassical growth model is an extension of the Harrod Domar model. The Solow model explains economic growth as dependent on, population, labour, capital accumulation and as an exogenous factor; technological improvement (Zaoh, 2019). The next big step within for the field of growth theories, according to Zaoh (2019) is the endogenous growth model, developed by Nobel laureate of 2018 Paul Romer. The endogenous growth model does, in contrary to the Solow model, account technology as an endogenous factor for economic growth. Zaoh (2019) states in his paper that Romer's work clearly demonstrates that new technology is the key to long-run economic growth. However, regardless if technological improvement is viewed as endogenous or exogenous for economic growth, it is clear that technological improvement, i.e. innovations have an impact on economic growth.

3.6 Market-based and Non-market-based Policy Instruments

Addressing externalities can be done in different ways through different types of policy instruments. Two main approaches are usually applied to align the social and private costs of activities, separating the market-based instruments from the non-market-based ones. Market-based policy instruments set a price on emissions. The two most common market-based instruments generally applied to environmental issues are; tradable pollution permit systems (or quotas), addressing property rights, and environmental taxes (De Serres, Murtin and Nicoletti, 2010). Other market-based instruments that can be seen as a form of tax are; subsidies for environmentally friendly activities and deposit refund systems, charging for the disposal of a product and then giving a subsidy when returning the disposal. It is often used on bottles and batteries (De Serres et al. 2010).

Non-market-based policy instruments do not price emissions in the way that market-based instruments do. One non-market-based policy instrument is command-and-control, which allows governments to impose direct regulations by setting a standard, either through technology or performance. Technology standards are simply forcing operators to use specific technology, and performance standards aim at specific environmental targets without requiring new technology. Another non-market-based instrument is active (green) technology-support policies. This policy can be a range of different decision to create incentives for the development of technology through R&D. Examples are green certificates or public fundings for private research. The last instrument is; Voluntary approaches, such as rating and labelling programmes, improving customer awareness of the climate impact of products (De Serres et al., 2010).

To understand how well different environmental policy instruments, affect innovation, it is of interest to examine the effect of different characteristics of the instrument. Johnstone et al. (2010) investigate the effect of three characteristics; stringency, predictability and flexibility. Stringency measures how ambitious the environmental target is. Predictability measures the signal if it is consistent, foreseeable and credible. Lastly, flexibility measures how well the innovator is able to identify the best way to meet the objective. The study from Johnstones et al. (2010) shows that all of these characteristics on environmental policies have positive impacts on innovation. However, the authors also discuss the complexity of mapping the characteristics of specific forms of instruments (Johnstone et al., 2010). The characteristics are not something that this thesis will investigate further, although what impact both market-based- and non-market-based instruments, have on innovation will be looked at.

Popp (2010) reviews the literature on innovation and regulation and discuss the implication for the development of climate policy. The articles state that market-based policies are, in general thought to provide more substantial incentives for innovation (Popp, 2010). Although there is also another view, Bauman, Lee and Seelei (2008) raises the possibility that non-market-based instruments, command and control, may even induce more incentives to develop innovations (Bauman et al. 2008). Botta and Kozluk (2014) show that the number of policy instruments has increased, mainly by broader adoption of market-based policies and also conclude a greater impact on innovations due to market-based compared to non-market-based. De Santis and Jona Lasinio (2015) confirm that command and control measures do not provide enough incentives to innovate. However, emission taxes or tradable allowance leave more freedom (De Santis and Jona Lasinio, 2015). Thus, the expected results from the model in this thesis are, based on theory, that market-based environmental policy instruments will show a greater effect on environmental innovations than will non-market-based environmental policy instruments.

4. Literature Review

This thesis investigates the relationship between environmental regulation and environmental innovations, a relationship that has been the focus of several studies, both qualitative and quantitative, in modern time. Different ways to measure regulations and innovations have been used, and the research has been applied to a variety of branches and countries. Under this section, various approaches and results, historically made, will be presented. Starting from the early studies and moving forward in time until today.

Early studies like Lanjouw and Mody (1996), Jaffe and Palmer (1997) and Brunnermeier and Cohen (2003), used PACE, pollution abatement control expenditures to measure the stringency of environmental regulations. To measure the number of innovations, Jaffe and Palmer (1997) looked at both data of expenditures for R&D and data on industry-wide patenting activity. Lanjouw and Mody (1996) and Brunnermeier and Cohen (2003) found a positive correlation between PACE and innovation, whilst Jaffe and Palmer (1997) did not get significant results (Popp, 2019). Other earlier studies have instead looked at the relationship between energy prices and innovation. Newell, Jaffe and Stavins (1999) and Popp (2002) both concluded that higher energy prices induce the innovations of energy-efficient technologies (Dechezlepretre & Sato 2017). The two studies just mentioned also concluded that innovative response happens within five years after a change in energy price (See Popp, 2010 for review of the literature).

Furthermore, studies have been made in different branches. In the automobile industry, Knittel (2011) looked at the relationship between fuel efficiency and vehicle characteristics to measure technological progress. The study found that technological progress was highest in the years with the highest gasoline prices for cars, but not trucks (Popp 2019). In the automobile industry, Lee, Veloso and Hounshell (2011) instead studied the emission control technology and what effect different types of regulation had on technological progress. The study was conducted on the US auto industry over a time period from 1970-2008 and investigated if performance standards affected innovation. The result was positive as the regulation allowed flexibility as to how the target was reached (Popp 2019). Furthermore, in the transportation sector, Kim (2014) used panel data of twelve countries from 1990 to 2012 and showed that higher gasoline prices induce innovation on automobile technologies but discourage innovation on oil extraction (Popp 2019).

More recent studies also confirm similar results. Aghion, Dechezlepretre, Hemous, Martin and Van Reenen (2016) showed that firms tend to increase innovation of clean technologies as a response to an increase in fuel prices (Dechezlepretre & Sato 2017). Gerarden (2018) showed that consumer subsidies for solar panels both increase demand and encourages producers to lower the costs by innovation. In recent times there have also been studies investigating the effect of different policy instruments on innovation. Fabrizi, Guarini and Meliciani (2018) showed that market-based instruments induce innovation, while non-market-based instruments are generally insignificant (Popp, 2019).

Ramanathan, He, Black, Ghobadian, Gallear (2016) performed a qualitative study on the relationship between environmental regulations, innovations and firm performance, using nine case studies of Chinese and UK firms. All nine firms had sustainability on their agenda, and innovation contributed to their competitive advantages. The main results from the study show that environmental regulation can both lead to an increase in innovation but can also be a negative factor due to an administrative burden and therefore does not enhance the firm's benefit of sustainability. The outcome depends on the flexibility of the regulation. A regulation can be inflexible because of rigid command and control but also as a result of being ambiguous, sudden and overcomplicated (Ramanathan et al. 2016).

Lundh (2017) investigated the validity of the Pollution Haven Hypothesis by empirically showing what effect environmental policy stringency has on FDI flows from OECD countries to BRIICS countries. As does this thesis, Lundh (2017) used the composite index EPS, developed by Botta and Kozluk (2014) as the measurement for policy stringency. Based on the results from the empirical method, Lundh (2017) discussed that the environmental effects of policy stringency show weak but significant support for the Pollution Haven Hypothesis.

Next, two studies made by Johnstone et al. (2010) and Johnstone et al. (2012) investigated the effect on environmental policy stringency on innovations and both concluded that environmental policy stringency has a positive effect on innovation. Both studies used data from the World Economic Forum's "Executive Opinion Survey", hereby referred to as the WEF survey to measure environmental policy stringency, and number of patent application, as does this thesis, to measure innovation. Johnstone et al. (2010) used a large number of countries from 1975-2007 and looked at innovation activity and how it depends on the characteristics of environmental policies. The characteristics being tested were stringency, predictability and flexibility. The study created three hypotheses claiming that all three characteristics have a positive effect on inventive activity in environmental activities, within the fields of air, water and waste. All three hypothesis where confirmed. Johnstone et al. (2012) conducted a study on a panel of 77 countries between 2001 and 2007. An extension of the empirical test was also conducted where countries were divided into four different income groups by using dummy variables. The results for both tests were positive, and evidence for that greater environmental policy stringency has a positive effect on environmental innovations are presented.

Kemenade and Teixeira (2017) investigated environmental policy stringency and eco-innovation performance through a cross-country analysis. The data used were mainly perception based. Eco-innovation performance was measured through the export of eco-products, and employment in eco-industries and environmental policy stringency were measured through the share of total companies declaring environmental regulation as relevant for pursuing eco-innovation. The study showed that environmental policy stringency does not emerge as a significant factor for eco-innovation performance (Kemenade and Teixeira, 2017). A similar study but with positive and significant results is Morales-Lago et al. (2016) that used EPS to measure the effect of policy stringency on innovation, as does this thesis. The study of Morales-Lago et al. (2016) supports the weak version of the Porter Hypothesis since the results show that the coefficient for EPS has a positive value. Hence Moralez et al. (2016) concluded that regulations create a reaction in firms to offset the loss caused by an increase in costs. In contrast to this thesis, Morales et al. (2016) used fewer countries and different control variables.

Almost all of the studies, within the field of environmental regulations, so far are focused on developed countries with stable economies. This is natural since developed countries were first to enact environmental protection. There is a missing aspect in addressing the problem of developing economies with significant environmental concerns. The trade-off between environmental protection and economic growth previous mentioned is often even more critical in the aspect of developing countries (Popp et al. 2010)

In general, previous literature within the field of environmental regulations and innovation show how market-based regulations encourage more innovation than performance and technological standards. However, there are also empirical studies partly contradicting market-based instruments providing more innovation than command and control. Popp (2003) investigated a change to emission permits from command-and-control, recognising a drop-in innovation. A similar case of Taylor (2012) shows how traditional regulation, being replaced by a cap-and-trade program, also caused a drop-in patenting activity (Dechezlepretre & Sato, 2017).

In previous studies, there is contradicting evidence of whether the effects of stricter policies strengthen or weaken the economy of a nation and whether policy stringency has a negative or positive effect on innovation. Lundh (2014) show proofs for the pollution haven hypothesis while Johnstone et al. (2010), and several other studies, show that a higher level of policy stringency can have a positive effect on innovation. Although many studies conclude that environmental regulations will create incentives to induce environmental innovation, to reduce costs, there is still not a consensus of what kind of policy instrument is the most efficient. A gap in previous research and the main problem for most researchers investigating policy stringency is that there is no unbiased and coherent way to measure policy stringency. There are, as discussed in chapter 2, social motivations in concluding the effects of environmental policies. This thesis, therefore, aims to contribute to the field, by adding strength and robustness to existing research that shows that there are positive effects from environmental policy stringency on environmental innovations. The thesis includes a time range between 1990-2012, a combination of countries and an econometric model, that has, to our knowledge, never been done before. Furthermore, this thesis also contributes with a more in-depth investigation on environmental policy stringency, by empirically investigate the effect between market-based and non-market-based policy instruments.

5. Data

In this chapter, the data selection and sources for the data will be presented. The collection and choice of data is a vital part of any empirical study. One of the challenges, to reach a valid conclusion, both for this study and previous studies within the same field, have been the choice of data and data collection. Therefore, also some concerns regarding the data, and comparison to previous studies will be discussed.

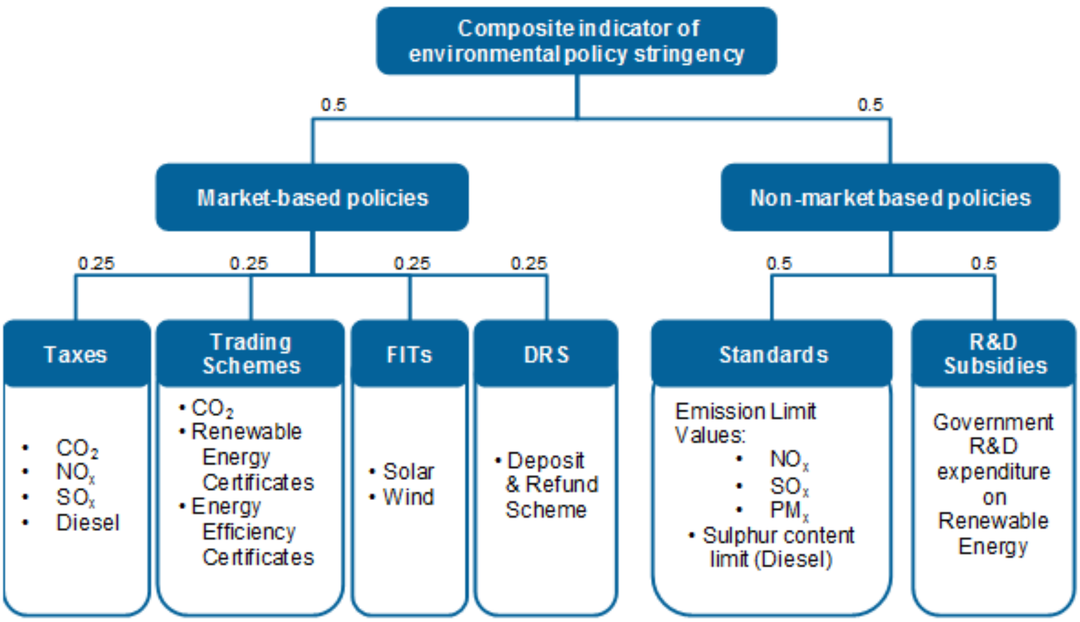
This thesis uses panel data from 30 countries collected from the year 1990 until 2012. Twenty-six of the selected countries are OECD countries (Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, The Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, The United States and The United Kingdom). Four of the selected countries are BRICS countries (India, Indonesia, China and South Africa). The variable of interest is "Environmental Policy Stringency", the dependent variable is "Patents on Environmental Technology", and the control variable is "Total Patents". All data is obtained from the OECD database (OECD, 2020). The data selection for countries and years are based on data availability (see 5.4).

5.1 Environmental Policy Stringency

To answer *H1*; Does the level of environmental policy stringency increase the number of a nation's environmental innovations? A measurement for environmental stringency needs to be obtained. In order to do so, this study will use an economy-wide composite index created by Enrico Botta and Tomasz Koźluk (2014) for the OECD, hereby referred to as EPS and obtained from the OECD database (Botta and Koźluk, 2014).

EPS is a composite index that ranges from 0 to 6, where 6 is the most stringent level of regulation and 0 is when the stringency level is non-existent. Being a composite index, EPS is the results of aggregated indicators where all single policies included get an individual score that together builds up to one final score (see figure 2). EPS can be divided into "market-based-policies" and "non-market policies" which in turn is a collective of several different single instruments, such as taxes and trading schemes included in market-based policies, and R&D subsidies included in non-market policies (Botta and Koźluk, 2014). Therefore, to answer *H2*; If market-based policies have a higher positive effect on the number of innovations than do non-market-based policies? Data for the scores of the "market-based policies" and the "non-market-based policies" have been obtained as well (OECD, 2020).

Figure 2 Structure of Economy-Wide indicator EPS (Botta and Koźluk, 2014)



Both Lundh (2017) and Botta and Kozluk (2014) discusses the advantages of using a composite index like EPS as a proxy, in that it does not suffer to a large extent of the multidimensional problem. Another favourable aspect of EPS, according to Lundh (2017), is that the proxy has a broad coverage for both countries and time which enables this thesis to include many countries through a wide time range. Finally, EPS covers a broad range of both market-based instruments and non-market-based instruments which is advantageous to answer *H2*.

According to Kozluk and Garsous (2016), EPS have been used as a measurement for policy stringency in the following studies. Lundh (2017) where EPS is used to measure the effect on FDI flows, Kozluk and Timiliiotis (2016) where EPS is used to investigate trade patterns and Morales-Lage et al. (2016) where EPS is used to measure the outcomes on innovation, as in this thesis. Other researchers that used EPS to measure innovation is De Santis and Lasinio (2015) who looked at the effect of EPS for some EU countries on labour productivity and innovation. Probst and Sauter (2015) investigated the effects of EPS on CO2 emissions, and Witajewski-Baltvilksa, Verdolinib and Tavonic (2015) used EPS to investigate the learning curve of renewable energy technologies.

5.2 Environmental Patents

As an indicator of environmental innovations, this thesis will use data obtained from the OECD database (OECD, 2020) of the number of patent applications on environmental technology (hereby referred to as environmental patents). The reference date that will be used for the patent applications is the priority date, which is the earliest date closest to the day of invention, and the reference country that will be used is the home country of the inventor. Patents on environmental technology, as an indicator for technological innovations, have successfully been used in previous studies (e.g. Johnson et al. 2010 and Johnson et al. 2012) and is the most frequently used indicator for technological output since the majority of innovations get patented (Dernis, Guellec and van Pottelsberghe, 2001). Moreover, according to Dernis et al. (2001), the relationship between outputs from innovations and patents are broadly recognised, and there is a very close (or almost perfect) link between the two.

Although the link between patents and inventions is clear, using the number of patents as an indicator for inventions for cross country comparison still comes with a few problems. Morales-Lage et al. (2016) mention that according to Haščič (2014), some problems arise. One problem is that the patent gives the inventor the legal right only in the nation or territory where the patents office is situated. Therefore, to obtain international protection, the inventor needs to seek protection for their invention at different patents offices that belong to different territories. This leads to a counting problem, namely that the same innovation can be counted more than once. Another problem mentioned is that the range of economic value for patent applications is quite broad, i.e. many applications do not have high quality and thus low economic value (Morales-Lage et al. 2016). To address the two problems mentioned above and other arising issues, different types of patents families have been created. A patent family is according to the European Patent Office definition; A set of patent applications covering the same or similar technical content and that are related to each other through priority claims (EPO, 2020). According to Haščič et al. (2015), patent families are the most suitable for international comparison because they solve the problem with double counting. Haščič et al. (2015) also mention that using patent families consisting of claimed priorities solves the problem regarding the quality of the patent application since the cost of patenting is high and firms would only go abroad for protection if they except a high value of the invention (Haščič et al. 2015). High-quality patents are of interest to this study since the purpose is to investigate the positive effects environmental policy stringency can have on innovations and in the end, economic growth. Another favourable aspect of patent families, according to Dernis et al. (2001), is that the data has worldwide coverage. The worldwide coverage of data helps to avoid a bias called "the home advantage" that could otherwise occur if, e.g. a study was to include a non-European country in a cross-country comparison but use data from the EPO. The mentioned scenario could create a biased since inventors are most likely to first apply for patents on their home territory. Thus, the non-European country included would appear to have relatively few patents applications compared to the European countries included, even though that might not be the real case.

Therefore, to ensure the quality of innovations, that the data is not biased due to double counts, and also with regards to the geographical spread of the countries included in the study, this thesis will use only data on number of patent applications that belong to the IP5 Patent families. IP5 refers to the world's five largest international patent offices (The European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the US Patent and Trademark Office and the State Intellectual Property Office of the People Republic of China). The IP5 offices jointly take care of 80% of all world patent applications (fiveIPoffices, 2020). Moreover, IP5 patent families are, according to the OECD definition, those patents that have been filed, at least at two international patent offices worldwide, one of which has to be among the IP5 offices (OECD, 2020).

5.3 Total Patents

There are naturally more factors than just environmental policies that will affect the outcome of the number of environmental patents. To control for such factors, this thesis will use data on number of applications for total patents (hereby referred to as total patents) for every country and year. This has been done in line with Johnson et al. (2010) and Johnson et al. (2012). The number of total patents will, according to a two-stage regression done by Johnson et al. (2012), capture the effects of four factors being of particular importance. Those four factors are gross domestic product (GDP), R&D expenditures, strength of intellectual property rights (IPR) regimes and openness to trade. GDP and R&D are expected to have a positive impact on innovations since GDP captures the general economic wellbeing of a nation, and R&D expenditures capture the resources available to invent. Openness to trade has, according to Johnson et al. (2012), previously been shown to have positive effects on innovations since firms will get more incentives to invent when being exposed to international competition. Finally, Johnstone et al. (2012) includes strength of IPR regimes with the motivation that the incentives to invent are expected to increase if firms feel like their inventions will be protected and thus profit. Thus, by including total patents as a control variable in the main regression, the differences and broad aspects of how the general climate for patent applications is in a specific country will be caught. Also, Haščič et al. (2015) bring up some advantages of using total patents as a control variable when dealing with cross country comparisons for environmental patents. Those advantages are; total patents control for differences in inventive capacity, the propensity to patent and other factors that could affect patent applications in general. As with the number of patents applications for environmental-related technology, patents applications from the IP5 patent family is used when collecting data for total patents.

5.4 Concerns

How to accurately measure environmental policy stringency has been one of the main constraints in finding valid empirical proofs of its effects. This problem has been discussed in many previous studies, e.g. Dechezlepretre and Sato (2017). There is no preferred, coherent, and utterly unbiased way to compare environmental policies across countries and time. Brunel and Levinson (2013) discuss four conceptual problems in their study, namely multidimensionality, simultaneity, industrial composition and capital vintage. Also, Botta and Koźluk (2014) mention some problems. The first problem of multidimensionality is due to the quantity and different dimensions of environmental regulations and the different media they regulate, but also the number of policy instruments and their different features. Botta and

Koźluk (2014) dealt with parts of the multidimensional problem when creating the EPS by designing and using rules for sampling that can be applied uniformly across the sample. They also adopted a sectoral approach which assumes that the overall stringency of environmental regulations can be approximated by looking at policy instruments that regulate externalities damaging the environment in some elected regions (Botta and Koźluk, 2014).

The second problem mentioned by Botta and Koźluk (2014) concerns sampling, which is closely connected to multidimensionality. It arises due to the situation that industries, affected by the environmental policies, might be driven by the policies themselves. The third problem according to Botta and Koźluk (2014) concerns identification which refers to identifying to what degree policy stringency actually can take credit for the expected consequences of stringent regulations, since many realised outcomes can come from several different sources of regulations. Differences between both characteristics and law enforcement among countries make the measurement of the true impact of particular regulations difficult. Finally, one more problem with EPS is that it does not include soft policy instruments, such as land-use regulations (Lundh, 2017). There is, in conclusion, no perfect and unified way to measure environmental policy stringency, and there will always be a trade-off among different types of problems when choosing a proxy. Table 1 below shows the correlation between other commonly used measurements and the EPS (Kozluk and Garsous, 2016).

Table 1: correlation between EPS and other environmental policy stringency measurements (Kozluk and Garsous, 2016)

CLIMI (EBRD)	*0.45***	*OECD countries and BRIICS. 2008*
World Economic Forum's Executive Opinion Survey	*0.50****	*OECD countries and BRIICS. 2002- 2012*
Energy Prices (Sato et al. 2015)	*0.50****	*OECD countries and BRIICS. 1990-2012*
Landfilled waste (share. Sauvage 2014)	*0.59****	*ECD countries and BRIICS excluding Indonesia. 1995-2012*

*Note: ***, **, * denote significance at 1%, 5% and 10% respectively.*

Furthermore, Botta and Koźluk (2014) mention that lack of data has been, and still is, a big problem for researchers that want to compare and measure the effect of environmental policies. Especially for those that want to compare developing countries or countries over more extended time periods. To deal with the lack of data, this thesis will only include countries and years for which there are data available for both EPS and patents on environmental technology. The main concerns regarding the data of the number of patent applications as a connection to innovations are according to the OECD (2020) that not every innovation gets patented, either because they are not patentable or because some corporations simply want to keep their innovation a secret. Some other issues regarding the usage of data on patents are according to the OECD (2020) comparison over time. The problem is that patent laws change over time which can make an analysis of time trends difficult. Not only does patent laws change over time, but they are also quite different between nations, which can make cross-country comparisons troublesome. Although, as mentioned in 5.2 and 5.3 using patent families and total patents as a control variable address many of the issues regarding cross-country comparison.

5.5 Descriptive Statistics

Table 2

Variable	Name	N	Mean	Std. Dev.	Variance	min	max
Environmental Policy Strigency	EPS	690	1.593	0.924	0.854	0.208	4.133
Market-based EPS	MARKETEPS	690	1.078	0.817	0.668	0.	3.983
Non-market-based EPS	NONMARKET EPS	690	2.107	1.227	1.507	0.	5.5
Environmental Patents	ENVIPAT	690	379.077	892.147	795926.9	0.	6865.11
Total Patents	TOTPAT	690	4518.666	10026.13	100523282.8	0.1429	57334.64

Table 2 shows the number of observations, the standard deviation, the variance and the minimum and maximum value for the main variables that will be included in the main regression. As can be seen the data for Environmental patents ($ENVIPAT$) is overdispersed.

Figure 3: Mean EPS by Country, 1990-2012

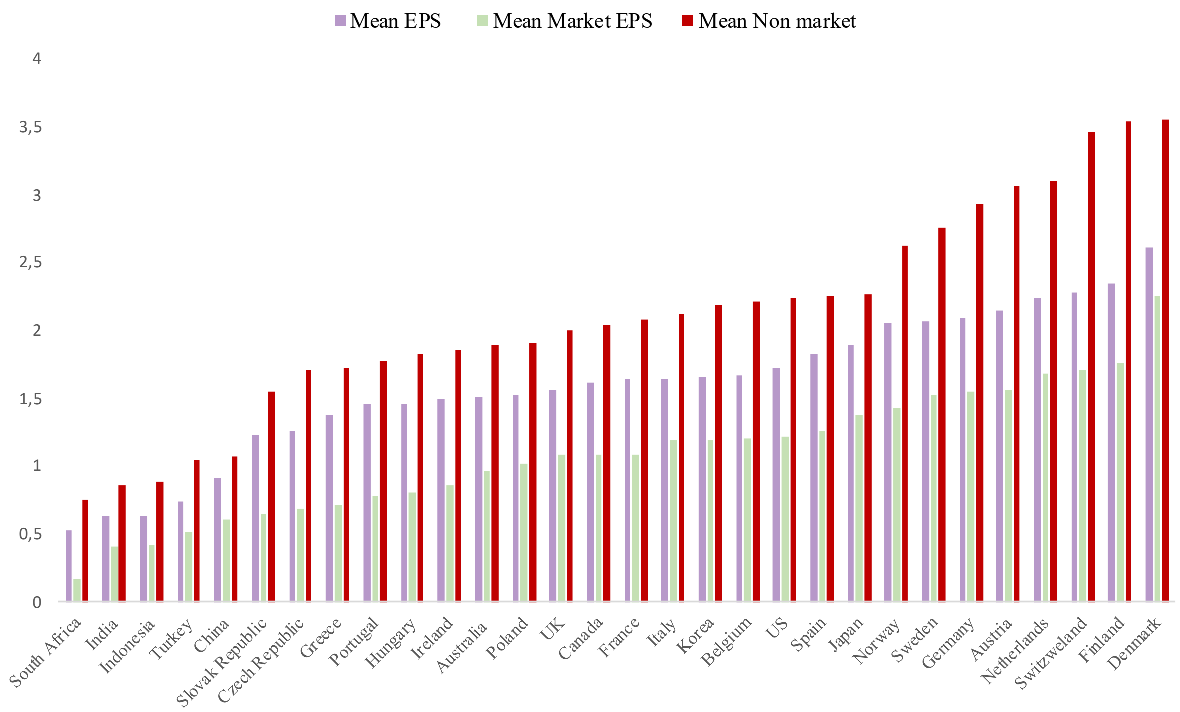


Figure 3 shows the mean EPS, market-based EPS and non-market-based EPS by country from 1990 until 2012. As can be seen, the mean for non-market EPS is higher than the mean for market-based EPS for all countries. The non-OECD countries and turkey have the lowest EPS and the Nordic European countries, Austria, Germany, The Netherlands and Switzerland have the highest.

Figure 4: Total mean EPS from 1990-2012

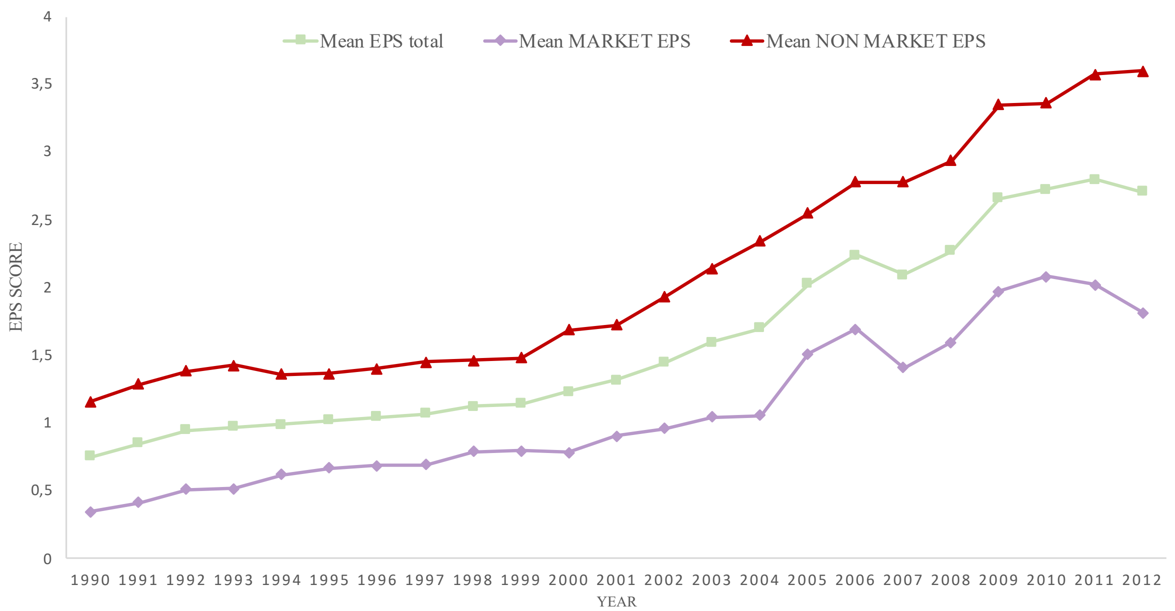


Figure 4 shows the mean EPS for all countries by year. As can be seen, there is more fluctuations and slower growth in market-based EPS than in non-market-based EPS.

Figure 5: Mean total patents and mean environmental patents from 1990-2012

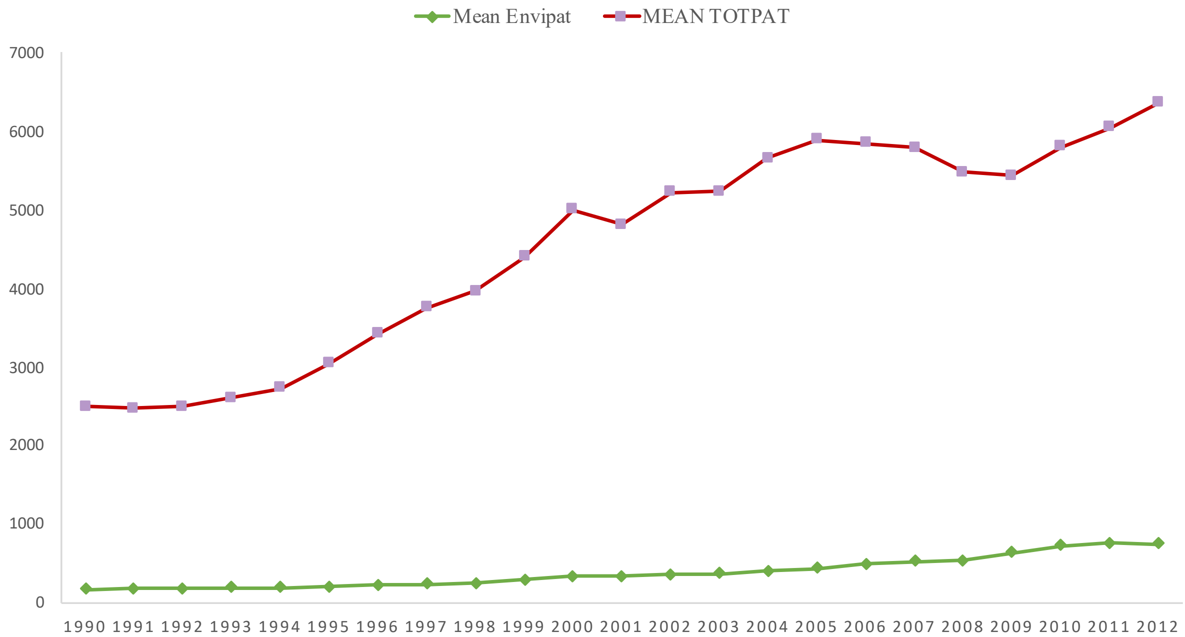


Figure 5 shows the mean value of total patents excluding environmental patents and environmental patents from the IP5 family for all countries from 1990 until 2012. Total patents excluding environmental patents have increased by 154.29%, and environmental patents have increased with 334,6%. The share of environmental patents of total patents has increased from 6,4 % to 10,5 %.

Figure 6: Mean share of environmental patents per total patents by country, 1990-2012

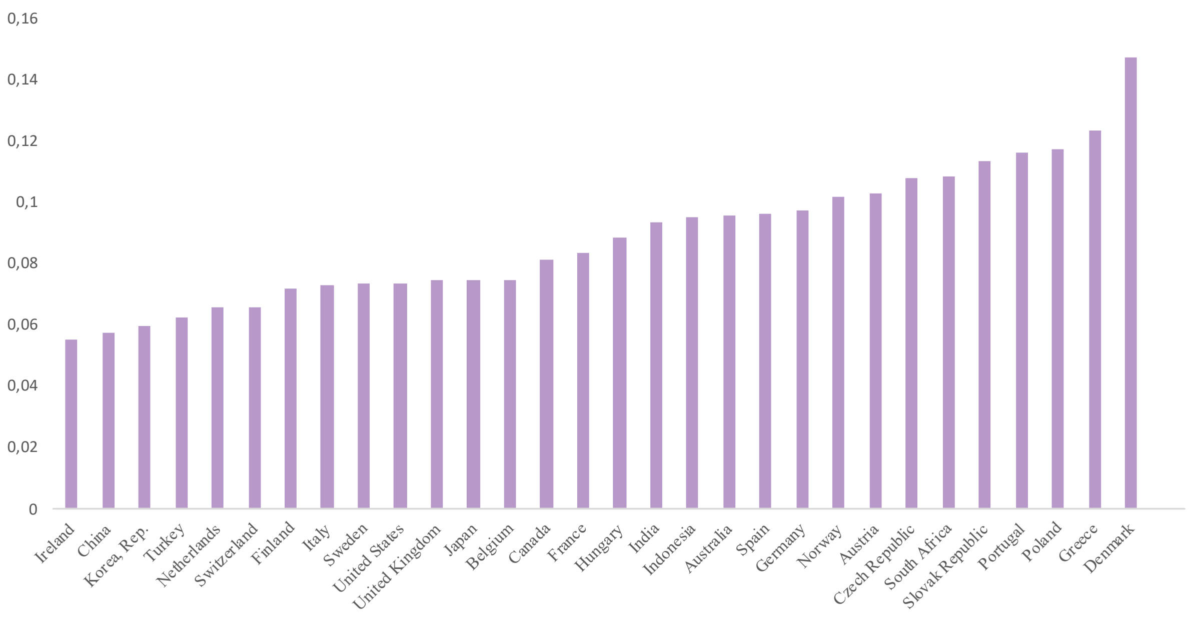


Figure 6 shows the mean number of patent applications on environmental-related technology by country from 1990-2012.

6. Empirical Method

This thesis is an empirical cross-country analysis of a balanced panel data set for 30 countries over a time range of 23 years, obtained from the OECD database (OECD, 2020). This section will present the method, the econometric model for the main regression and some methodological concerns.

6.1 Econometric Model Specification

This thesis aims to examine if the stringency level of environmental policies can affect environmental innovation, and hence economic growth. Therefore, this thesis will investigate the effect of EPS on the number of environmental patents. Hence, the dependent variable consists of count data (number of patents). When the dependent variable consists of count data, some conventional approaches for the choices of the econometric method are to either use an OLS model with log transformation, the Poisson Model, or the Negative Binomial Regression Model. According to the UCLA Stat Guide (2020), the OLS model comes with some issues due to the loss of data when log transforming zero and that the model cannot deal with overdispersion. The Poisson model fits with data which have a conditional mean equal to the conditional variance such as:

$$var(y) = E(y) = \mu$$

(Rodrigues, 2013)

The Negative Binomial Regression Model (hereby referred to as NB model) is a generalisation of the Poisson model in that a multiplicative random effect, usually denoted as θ, which represents unobserved heterogeneity, is added. The NB model fits with overdispersed data, i.e. data with a conditional variance larger than the conditional mean (Rodrigues, 2013). The variance of the unobserved effects is σ^2, as can be seen in the equation below for the variance of the NB model such as:

$$E(y) = \mu$$
$$var(y) = \mu(1 + \sigma^2\mu)$$

(Rodrigues, 2013)

Since the dependent variable, environmental patents, consist of count data that is overdispersed, a NB model will be used to estimate the causal effects of EPS on environmental patents. The NB model is also used by Johnstone et al. (2010) and Johnstone et al. (2012). Since this thesis uses a similar approach, as the studies just mentioned, with number of patent applications as the dependent variable and an index for environmental policy stringency with a six-step range, there is previous empirical proof that the NB model is a good fit for the type of data used in this thesis. The model equation for the NB model is as follows:

$$E\big(\log(y)\big) = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k$$

The outcome should be interpreted as follows: one-unit change in x_1 gives an additive change of β1 for the expected log counts of the outcome variable y (UCLA, 2019). From the first NB model equation, the following equation can be derived:

$$E(y) = exp(\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k)$$

This version of the NB model equation can be interpreted as follows: one unit change in X1 gives a multiplicative change of $exp(\beta_1)$ for the expected counts of y. This version of the NB model equation is also referred to as an incidence rate ratio option (UCLA, 2019).

To test *H1* the main econometric model is a random effect NB model as follows:

$$E(ENVIPAT_{it}) = exp(\beta_1 EPS_{it-1} + \beta_2 TOTPAT_{it-1} + \alpha_t + \varepsilon_{it}) \quad (1)$$

Where i represents the country and t represents the year. As explained in the data chapter, patents can be closely linked to technological innovations and will, therefore, give us a good approximation of the real outcome. Thus, the dependent variable is environmental patents ($ENVIPAT$). The variable of interest is EPS with a one-year time lag in line with Morales-Lage et al. (2016) and thus the coefficient of interest, hence the effect of EPS on environmental patents, is represented by β_i. Lundh (2017) also uses EPS with time lags, namely for one, two and three years as a robustness check. The reason behind using a one-year lag in the regression is simply because, in reality, it takes time to research and develop an innovation that will result in a patent application. It is unrealistic that a patent application is submitted just after the implementation of a particular policy. Lundh (2017) mentions that it takes time for most firms to adjust to changes in relative costs, caused by environmental regulation. Hence, it is the regulations from earlier years that do effect innovations. The one-year time lag will best catch the short-term effects of environmental policy stringency on environmental patents. In the result section, a model with a five-year time lag of EPS will also be presented to catch the long-term effects of environmental policy stringency.

The number of total patents, excluding the number of environmental patent applications ($TOTPAT$), is used as a control variable in line with Johnstone et al. (2012) to control for effects that come from factors such as IPR, GDP, trade and R&D. Johnston et al. (2012) show in their study "Environmental Policy Stringency and Technological Innovation: Evidence from Survey Data and Patent Counts" that total patents catch the effects of IPR, R&D as a percentage of GDP, trade and GDP. Johnson et al. (2012) show that total patents catch these effects by performing a two-stage regression model where total patents are estimated using IPR, R&D as a percentage of GDP, trade and GDP. Fitted values of total patents are then obtained and used as a control variable to catch the causal effects on environmental patents from policy stringency. The results from the two-stage model that uses the fitted values from total patents, and the model that directly uses total patents as a control variable, gives close and comparable results (Johnson et al. 2012). Hence, it has been shown that total patents catch most relevant factors that would affect environmental patents and can serve as a valid control variable standing alone. As a robustness check a regression has been conducted using GDP, R&D and trade as control variables, see 7.2. Total patents will, like EPS, be used with a one-year time lag.

Since this thesis is dealing with data over 23 years, yearly fixed effects are included in the model and represented by α_t to account for changes over time that are constant across countries and not explained by the other regressors (Hanck, Arnold, Gerber and Martin Schmelzer, 2019, pp. 225). Finally, the error term ε_{it} accounts for everything that affects ($ENVIPAT$), and that is not explained by any of the regressors.

Another precaution similar to yearly fixed effects, which avoids some omitted variable bias, measurement errors and other unobserved aspects creating biased results, is to include country fixed effects (Angrist and Pischke, 2009, pp. 165-169). The country fixed effect will account for country-specific elements, like certain cultural aspects and how well firms follow policies. This thesis will, therefore, test a second regression (2) using a conditional fixed effect NB model for panel data as proposed by Hausman, Hall, and Griliches (1984). The study developed statistical models for investigating the effect of R&D on the number of patents applications by firms in the US. The fixed effect NB model (2) thus includes country fixed effects which are represented by μ_i which, i.e. will catch the unobservable heterogeneity that does not change over time, in each country. The fixed effect NB model will also include fixed yearly effects which as in model (1) is represented by α_t (See Hausman et al. (1984) for fixed effect NB model derivation).

$$E(ENVIPAT_{it}) = exp(\beta_1 EPS_{it-1} + \beta_2 TOTPAT_{it-1} + \alpha_t + \mu_i + \varepsilon_{it}) \quad (2)$$

To test *H2*, this thesis will include both a random effect NB model (3) and a fixed effect NB model (4) using data for market-based EPS and non-market-based EPS as variables of interest instead of using data for the complete EPS measurement. The coefficients for market-based EPS and non-market-based EPS will then be compared to each other in order to conclude whether market-based EPS or non-market-based EPS generates the greatest effects on environmental-related innovations. Thus, the econometric models to test *H2* is as follows:

$$E(ENVIPAT_{it-1}) = exp(\beta_1 MARKETEPS_{it-1} + \beta_2 NONMARKETEPS_{it-1} + \beta_3 TOTPAT_{it-1} + \alpha_t + \varepsilon_i) \quad (3)$$

$$E(ENVIPAT_{it-1}) = exp(\beta_1 MARKETEPS_{it-1} + \beta_2 NONMARKETEPS_{it-1} + \beta_3 TOTPAT_{it-1} + \alpha_t + \mu_i + \varepsilon_i) \quad (4)$$

Same as in the previous models, i represents country and t represents year. The dependent variable is still the number of patents on environmental-related technology ($ENVIPAT$) and to control for effects from IPR, R&D, GDP, trade and other unobserved factors, data on the number of total patents, excluding environmental patents ($TOTPAT$), is used. What is new compared to the first two models is that EPS is split into market-based policies ($MARKETEPS$) and non-market-based policies ($NONMARKETEPS$). The coefficients of interest are thus β_1, which will show the effect of market-based EPS on environmental patents and β_2, which will show the effect of non-market-eps on environmental patents. Both $NONMARKETEPS$ and $MARKETEPS$ have a one-year time lag for the same reasons as mentioned earlier regarding the EPS one-year time lag. Yearly fixed effects are included in both model (3) and model (4) and represented by α_t and the country fixed effects included in model (4) are represented by μ_i.

6.2 Concerns

One problem that most researchers come across, and what Angrist and Pischke (2009, pp.44-45) states are one of the most important aspects to consider, concerning regressions, is omitted variables bias (OVB). OVB occurs when a regressor, affecting the dependent variable, is correlated with an explanatory variable but left out of the regression. The left-out variable will, in that case, create a bias that will under- or overestimate the coefficient for the explanatory variable (Mason, 2015). Hence, the right amount of control variables is essential to include in a regression, and a short regression with too few control variables might be what mostly generates OVB (Angrist and Pischke, 2009, pp.44-45). The regression in this thesis includes only one control variable ($TOTPAT$). Usually, regressions for similar research questions include at least a handful of control variables (e.g. Kemande and Teixeira (2017)). Hence, there is no denying that this method, like any other method, might suffer from some level of omitted variable bias. However, since the usage of total patents as the only control variable is well-motivated and empirically checked for, (see chapter 6.1), we find it reasonable to only use total patents as a control variable. Morales-Lage et al. (2016) also use only a few control variables (total factor productivity and value-added) when investigating the effect of EPS on the number of environmental patents which further motivates our choice of using only total patents as a control variable.

When working with panel data, there are some concerns regarding missing observations. Also, as already mentioned in chapter 5.1, the lack of data is one of the main reasons why it is difficult for researchers to investigate the effects of environmental policy stringency. The panel data set that this thesis uses have some missing observations but are still strongly balanced. Another concern worth mentioning is the subjective usage of lagged explanatory variables. This thesis uses EPS with a one-year time lag, and although it is the most reasonable option, it has to be mentioned that doing so, this thesis assumes that EPS_{t-1} is not correlated with the error term. In order to somewhat address this issue, total patents are also used with a one-year time lag to obtain what Angrist and Pischke (2009, pp. 47-48) address as good control variables. According to Angrist and Pischke (2009, pp. 47-48), a good control variable is fixed at the time the variable of interest was determined and hence using partly address the issue.

7. Results

In the following part, the results from the random effects NB model and the fixed effects NB model will be presented. First, the results showing the short-term effects of EPS, market-based

EPS and non-market-based EPS will be presented, and then the results showing the long-term effects of EPS, market-based EPS and non-market-based EPS. Furthermore, the results from the fixed effect NB model and the results from the random effects NB model will be compared and discussed and finally, four robustness checks will be presented.

7.1 Main results

Table 3 shows the outcomes from the random effect NB model in column (1) (3), and the results from the fixed effects NB model in column (2) and (4). As explained in chapter 6, this thesis has performed the NB model with an incidence rate ratio option which gives results that can be interpreted such as; for a one unit increase in EPS (everything else held constant) the expected rate of counts of $ENVIPAT$ will increase by a factor of β1 if β1 > 1 and decrease with a factor of β1 if β1 < 0 (UCLA, 2019). Hence the coefficients presented below are the incidence rate ratios for the regressors and are already expressed as exponential values.

Table 3: Short term results

Dependent Variable: ENVIPAT	(1)	(2)	(3)	(4)
EPS_{t-1}	1.156 (0.047)***	1.144 (0.047)**		
$MARKETEPS_{t-1}$			1.065 (0.032)**	1.061 (0.032)*
$NONMARKETEPS_{t-1}$			1.084 (0.031)***	1.077 (0.031)***
$TOTPAT_{t-1}$	1.000019 (2.81e-06)***	1.000018 (2.85e-06)***	1.000018 (2.81e-06)***	1.000018 (2.85e-06)***
Constant	3.440 (0.424)***	3.461 (0.426)***	3.414 (0.425)***	3.440 (0.428)***
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	660	660	630	630
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parenthesis *p<0.1 **p<0.05 ***P<0.01*

As can be seen in Table 3, the coefficient for EPS is positive and statistically significant without and with fixed effects on a 1% and 5% level respectively. The coefficient for EPS shows that an increase of one step on the stringency-scale (everything else held constant) will increase the rate of the number of patent applications for environmental-related technology by a factor of 1.144 to 1.156 in the short term. These results are as expected and in line with Johnstone et al. (2012), who presents an increase of 6-18% on environmental patents with a one-unit increase in EPS. It is essential to acknowledge that the scale of EPS goes from 0 to 6; this means that an increase with 1 unit is quite a significant change.

As for model (3) and model (4), the coefficient for market-based EPS is positive and statistically significant without and with fixed effects on a 5% and 10% level respectively whereas the coefficient for market-based EPS is positive and statistically significant both without and with fixed effects on a 1% level. The coefficient for market-based EPS shows (everything else held constant) that an increase of one step on the stringency-scale will increase the rate for the number of environmental patents by a factor of 1.0611 to 1.0647. In comparison, the coefficient for non-market-based EPS shows (everything else held constant) that an increase of one step on the stringency-scale will increase the rate for the number of patent applications for environmental-related technology by a factor of 1.0796 to 1.083. The result shows that non-market EPS is both more significant and have a higher effect on environmental patents. These results are not as expected and are in contrast with most literature.

For comparison, it is also interesting to investigate the long term effect of EPS on innovations. This thesis will, therefore, check the long term effect for *H1* using EPS and TOTPAT with a 5-year time lag. The results are presented below using both a random effect NB model (5) and a fixed effect NB model. Also, *H2* will be tested for long term effects and both a random effect NB model (7), and a fixed effect NB model (8) are presented.

$$E(ENVIPAT_{it}) = exp(\beta_1 EPS_{it-5} + \beta_2 TOTPAT_{it-5} + \alpha_t + \varepsilon_{it}) \quad (5)$$

$$E(ENVIPAT_{it}) = exp(\beta_1 EPS_{it-5} + \beta_2 TOTPAT_{it-5} + \alpha_t + \mu_i + \varepsilon_{it}) \quad (6)$$

$$E(ENVIPAT_{it}) = exp(\beta_1 MARKETEPS_{it-5} + \beta_2 NONMARKETEPS_{it-5} + \beta_3 TOTPAT_{it-5} + \alpha_t + \varepsilon_{it}) \quad (7)$$

$$E(ENVIPAT_{it}) = exp(\beta_1 MARKETEPS_{it-5} + \beta_2 NONMARKETEPS_{it-5} + \beta_3 TOTPAT_{it-5} + \alpha_t + \mu_i + \varepsilon_i t) \quad (8)$$

Table 4: Long term results

Dependent Variable: ENVIPAT	(1)	(2)	(3)	(4)
EPSt-5	1.150 (0.052)**	1.138 (0.052)**		
MARKETEPSt-5			1.088 (0.037)**	1.085 (0.037)**
NONMARKETEPSt-5			1.059 (0.033)*	1.052 (0.033)
TOTPATt-5	1.00001 (3.08e-06)**	1.00001 (3.13e-06)	1.00001 (3.09e-06)**	1.00001 (3.14e-06)**
Constant	4.279 (0.532)***	4.302 (0.534)***	4.330 (0.545)***	4.359 (0.548)***
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	540	540	540	540
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parenthesis *p<0.1 **p<0.05 ***P<0.01*

As can be seen in table 4, EPS with a five-year time lag is still significant and positive, although with a slightly lower effect in long term than short term. Furthermore, as can be seen, the outcome shows opposite results regarding market EPS and non-market EPS, which suggest that in short term non-market-based EPS will have a greater effect. However, in a long term perspective, the results show that market-based EPS will have a greater effect.

For both table 3 and table 4, the results show that adding country fixed effects does not substantially change the results. However, all results from the fixed effect NB model shows slightly lower values, and statistically insignificant long term results regarding non-market EPS. To determine which model is the best fit, the Hausman test (Sheytanova, 2015) were conducted with a null hypothesis that states that the differences of the coefficients of the fixed NB model (2) and the random effect NB model (1) are not systematic. If the null hypothesis can be rejected, the fixed effects NB model is preferable, and if not, the random effect NB model is preferable (Sheytanova, 2015). The P-value from the Hausman test showed a value of 0.1796 which means the null hypothesis cannot be rejected, and thus, the random effect NB model is to prefer. Moreover, Johnstone et al. (2012) refrain from using country fixed effects in their regression because of convergence problems and little variation over time in the policy variables from the WEF survey. Thus, with regards to the outcome from conducting the Hausman test, the results from the random effect NB model is preferred.

7.2 Robustness Checks

Given the argument about the delayed effects of environmental policies discussed in section 5, *H1* and *H2* were tested with both a random effect NB model and a fixed effect NB model, using a two-year time lag for EPS, market-based EPS and non-market-based EPS. The outcome showed significant and similar results as with the one-year time lag. Results can be seen in Appendix A.

Another aspect to acknowledge is that China, with respect to economic growth from 1990 until 2012, distinguishes from the rest of the countries included in this thesis. Therefore, *H1* and *H2* were tested with both a random effect NB model and a fixed effect NB model when excluding China. The outcome showed significant and similar results as the main models. Results can be seen in Appendix B.

Furthermore, as a third robustness check, the thesis will control the aspect of adding another control variable. In order to do so, data on the effect of air pollution obtained from the OECD (2020) has been applied. Air pollution effect is measured by; mortality from air pollution, (fine particulate matter (PM2.5)), per 1 million inhabitants (OECD, 2020). The reason for choosing mortality from air pollution as a control variable is simply because a country with high mortality rate from air pollution can be expected to have greater incentives to invent environmental-related technology in order to decrease the mortality rate. *H1* and *H2* were tested, both with a random effect NB model and a fixed effect NB model, including mortality from air pollution. The outcome showed significant and similar result as the main models. Results can be seen in Appendix C.

As a final robustness check, given the concerns about OVB in chapter 6, *H1* and *H2* were tested with both a random effect NB model and a fixed effect NB model using data on total nominal GDP, net trade, gross domestic spending on R&D and air pollution effects (OECD, 2020) as control variables instead of total patents. All data were obtained from the OECD database. Total nominal GDP is measured in USD, net trade is the differences in exports and imports for a country in a year and is measured in million USD. Finally, gross domestic spending on R&D is measured in USD constant prices with 2010 as a base year. As been stated in chapter 5.3, Trade, GDP and R&D are expected to affect the number of innovations. All variables including EPS, Market-based EPS and Non-Market-based EPS were tested with a one-year time lag. The results for both *H1* and *H2* showed significant and similar results as the main models. Results can be seen in Appendix D.

8. Discussion

In order to continue the path towards a more sustainable future, the world needs more smart solutions and green technology (Millennium Ecosystem Assessment, 2005). With the results presented above, this thesis shows that countries with higher environmental policy stringency are expected to have a greater number of environmental innovations. Below follows a discussion around the results and a recommendation for future research.

Since the coefficient of EPS is positive and significant, the results support the Porter Hypothesis arguing that environmental regulations can trigger new forms of innovation and hence reduce the cost of complying with the regulations for the firm. In other terms, this means that a more stringent environmental regulation will push firms into an increase of environmental patent applications, representing environmental innovation. Through environmental innovations, the firms will lower their cost of polluting and increase their profitability, instead of not innovating and taking the costs of complying with the regulation. The results give significant evidence for the weak version of the Porter Hypothesis, claiming that environmental regulations can foster some form of environmental-related innovation. However, the results do not give direct evidence for the strong version of the hypothesis, although economic growth theories can further argue that innovations will result in higher economic growth. In conclusion, this thesis does not imply that the reduction in costs for firms, due to innovations, leads to economic growth. But rather that innovations might lead to economic growth according to models like the Solow model and The Endogenous growth model, that suggests technological improvement will lead to economic growth, The results also comply with the Hypothesis of Induced Innovation. The relative cost of polluting increases, due to regulations, compared to other production costs, which results in an increased incentive to develop new emission-reducing technologies. When the cost of polluting becomes significantly higher, firms can either innovate to offset the costs, take the cost and receive lower profit, or move elsewhere. The latter approach complies with the Pollution Haven Hypothesis and is a consequence that cannot be denied.

With more environmental innovations in a country, firms will experience higher profitability since the cost of polluting has decreased. Higher profitability will give countries with more stringent policies competitive advantages over countries with a laxer approach. This approach is also compliable with the Porter Hypothesis since competitive advantages, to a high degree, stems from the first-mover effect. Through stronger incentives to exploit innovations, and profit through patents, countries with stricter regulations will experience advantages compared to the countries where regulations were enforced later. This advantage gives firms in nations with stringent environmental regulations a better competitive position on the international market.

The NB model shows interesting results of market- and non-market-based EPS. From the thesis's theoretical view and with the insights of other studies, it would be more likely to get a higher impact of market-based instruments, short-term. The results from this study show the exact opposite. It is the non-market-based instruments, such as performance standards and technological standards that give a stronger impact on innovations for the countries of interest, in short term. In the theoretical framework, we expected the market-based instruments to have a more significant impact, but the results showed otherwise. The surprising results could partly be explained by non-market policies having a more substantial impact in the short term, since it takes time for firms to adjust to changes in relative costs caused by market-based policies, such as taxes or tradable allowance. Another explanation for these results could be that non-market-based instruments force firms to change their behaviour while market-based instead give the firms a chance to do business as usual and take the costs. Moreover, since this study does not investigate the characteristics of different policy instruments further, we cannot draw any conclusions about how different attributes of the policies affect incentives to innovate.

As can be seen in Figure 4, there is a significant drop in mean market-based EPS around 2008 and 2012 while non-market-based EPS stay quite stable through all of the years. The fact that market-based fluctuate more depending on the situation in the world economy could be a reason that market-based, in short term, presents lower effects than non-market-based. In challenging economic times, environmental taxes are easier and more necessary to reduce while command and control instruments stay the same. The choice to reduce taxes and other market-based instruments has currently been made, due to the Corona crisis. Another explanation why non-market-based instruments get higher values short-term could be the fact that non-market-based instruments, such as public funding for R&D, has the best effect on the market failure, knowledge spillover, that hinders R&D.

The most common pattern among the countries included in the thesis, as can be seen in *figure 3*, is the fact that all of the BRIICS countries are at the bottom scale of the EPS. The Nordic countries are the countries with considerable higher environmental policy stringency. One plausible reason to why the BRIICS countries have relatively low EPS scores, compared to the Nordic countries, is that the BRIICS countries are more or less still in a developing phase where economic growth and the focus on catching up may be prioritised over environmental concerns. As mentioned, and as can be seen in figure 4 the scores for market-based EPS drops during the financial crises, this indicates that when economic support is needed countries are willing to loosen the market-based environmental regulations to ease the costs for firms. A similar conclusion can thus be drawn about the BRIICS countries since they, compared to the wealthiest OECD countries, generally have a more unstable economic climate. Another plausible explanation for the difference in EPS between the countries could be that there are cultural differences in caring for the environment.

Designing environmental regulations contains several vital aspects. Not only do authorities have to consider the protection of the environment, but also foreign competition with lower prices. The traditional trade-off between these two is no longer an obstacle but rather two components possible to benefit from each other. It is beneficial as long as well-design environmental policies are applied to society. When nations accomplish well-designed regulations, firms will start to offset new costs of production to be able to stay competitive on the market.

It is still essential to recognise the Pollution Haven Hypothesis. How the firm will respond to a more stringent regulation is hard to predict. The Pollution Haven Hypothesis can still be valid since companies also have the option to move their businesses to countries with lower regulations. The option to move businesses is vital for the government to take into consideration when implementing environmental regulation.

The effect of regulations on innovations has been investigated many times through different variables, with different data and through different ways of measuring. Future research within the field can enable more targeted policies and solutions for the reduction of pollution. Countries with well-targeted policies can benefit from the insights and gain competitive advantages over countries without well-targeted policies. Our recommendation for future research, within the field of environmental regulations and environmental innovation, is to devote a more detailed work into which form of regulation gives the strongest incentives for environmental innovation and can potentially have the most significant effect on pollution. Another aspect, important to address, is research on specific countries. Like mentioned before, studies within the field of environmental regulation and protection are most often made on developed economies. We would recommend further research to focus on; what type of regulations are most effective for countries where economic growth is highly prioritised. It could also be of interest to do focused industry studies, e.g. emission-intensive industries, where well-designed regulations could contribute to a drastic decrease in emissions. Another interesting aspect for further research, as briefly mentioned in 7.2, is to investigate the effects on how the level of pollution in countries affect environmental innovations. Such as if there are greater incentives to invent environmental technology due to a higher mortality rate from air pollution. Finally, since most literature so far has just argued that environmental policy stringency has either a positive or a negative effect for certain aspects in society, but not disproved the contradicting theories (e.g. The Pollution Haven Hypothesis vs The Porter Hypothesis). It is of great importance to make an overall evaluation of environmental policy stringency and calculate the net effect as a whole on society.

9. Conclusion

Even if all market failures were addressed, it would still be difficult to create incentives for R&D since the benefits from environmental innovations are mostly external. Because of this, environmental policies are necessary to turn negative environmental changes around. This study shows that environmental protection and economic growth do not need to contradict each other. Environmental regulations can play an essential role in a country's economic wellbeing since stronger regulations protect the environment and lead to an increase in environmental innovations, which could give competitive advantages on the international market and contribute to economic growth.

In summary, our findings show positive results for *H1*, in line with previous studies and the weak version of The Porter Hypothesis. For *H2*, the short-term results contradict what most previous studies have shown. The results states than non-market-based policies give greater incentives for environmental innovations in short term. Although in long term, market-based policies have a greater effect on environmental innovations.

This thesis contributes to the research on environmental- policies and innovation through a new combination of data, range of time, and the countries selected. Thus, the results ads validity to existing evidence for The Porter Hypothesis and the notion that environmental policy stringency can have a positive effect on economic growth through an increase in innovations. It is inevitable that we now, and in the future, have to transform our environmental habits, and this thesis shows that it can be economically preferable to do so.

10. References

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Appendix A

Table A.1: Results with a 2-year time lag for EPS, market-based, non-market-based EPS and total patents from random effect NB regression in in column (1) and (3) and fixed effect NB regression in column (2) and (4).

Table B.1: Results from regression with two-year time lag for regressors

Dependent Variable: ENVIPAT	(1)	(2)	(3)	(4)
EPS_{t-2}	1.166 (0.048)***	1.154 (0.048)****		
$MARKETEPS_{t-2}$			1.064 (0.033)**	1.061 (0.033)*
$NONMARKETEPS_{t-2}$			1.094 (0.032)***	1.087 (0.032)***
$TOTPAT_{t-2}$	1.000017 (2.94e-06)****	1.000016 (2.98e-06)***	1.000017 (2.94e-06)***	1.000016 (2.98e-06)***
Constant	3.351 (0.426)***	3.370 (0.429)***	3.315 (0.425)***	3.334 (0.429)***
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	630	630	630	630
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parenthesis *p<0.1 **p<0.05 ***P<0.01*

Appendix B

Table B.1: Regression results from when excluding China from random effect NB regression in column (1) and (3) and fixed effect NB regression in column (2) and (4). Both EPS, market-based EPS and non-market-based EPS have a one-year time lag.

Table B.1: Short term results from regression when excluding China

Dependent Variable: ENVIPAT	(1)	(2)	(3)	(4)
EPS_{t-1}	1.153 (0.040)***	1.143 (0.040)***		
$MARKETEPS_{t-1}$			1.048 (0.028)*	1.045 (0.028)*
$NONMARKETEPS_{t-1}$			1.096 (0.026)***	1.090 (0.026)***
$TOTPAT_{t-1}$	1.000015 (2.77e-06)***	1.000014 (2.81e-06)***	1.000015 (2.77e-06)***	1.000014 (2.81e-06)***
Constant	5.211055 (0.629408)***	5.240868 (0.6324266)***	5.120453 (0.6235051)***	5.155515 (0.6270541)***
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	638	638	638	638
Log likelihood	-2959.284	-2685.2597	-2958.52	-2684.5781
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parenthesis *p<0.1 **p<0.05 ***P<0.01*

Table B.2: Regression results when excluding including effects from air pollution as measured in mortality per 1 million inhabitants in the main regression. for EPS. Random effect NB model with EPS as variable of interest in in column (1) and with market-based EPS and non-market-based EPS as variables of interest in in column (3). Fixed effect NB model with EPS as variable of interest in in column (2) and with market-based EPS and non-market-based EPS as variables of interest in in column (4). Both EPS, effects from air pollution, market-based EPS and non-market-based EPS have a one-year time lag.

Table B.2: Long term results from regression excluding China

Dependent Variable: ENVIPAT	(5)	(6)	(7)	(8)
EPS$_{t-5}$	1.148 (0.044)***	1.140 (0.044)***		
MARKETEPS$_{t-5}$			1.088 (0.032)***	1.085 (1.086)***
NONMARKETEPS$_{t-5}$			1.059066 (0.028)**	1.053941 (0.028)**
TOTPAT$_{t-5}$	1.000008 (2.88e-06)***	1.000007 (2.92e-06)**	1.000008 (2.89e-06)***	1.000007 (2.93e-06)**
Constant	6.771 (0.847)***	6.803 (0.849)***	6.867 (0.869)***	6.908 (0.873)***
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	522	522	522	522
Log likelihood	-2466.568	-2194.4988	-2466.3409	-2194.2257
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parenthesis *p<0.1 **p<0.05 ***P<0.01*

Appendix C

Table C.1: Regression results when including effects from air pollution as measured in mortality per 1 million inhabitants in the main regression. Random effect NB model with EPS as variable of interest in in column (1) and with market-based EPS and non-market-based EPS as variables of interest in in column (3). Fixed effect NB model with EPS as variable of interest in in column (2) and with market-based EPS and non-market-based EPS as variables of interest in in column (4). Both EPS, effects from air pollution, market-based EPS and non-market-based EPS have a one-year time lag.

Table C.1: Short terms results when including air pollution

Dependent Variable: ENVIPAT	(1)	(2)	(3)	(4)
EPS_{t-1}	1.143 (0.0440988)***	1.133 (0.043731)***		
$MARKETEPS_{t-1}$			1.053 (0.0297618)*	1.050 (0.0296168)*
$NONMARKETEPS_{t-1}$			1.083 (0.0287139)***	1.078 (0.0285561)***
$TOTPAT_{t-1}$	1.00001 (3.01e-06)***	1.00001 (3.05e-06)***	1.000011 (3.02e-06)***	1.00001 (3.06e-06)***
$AIRPOLLUTION_{t-1}$	1.003	1.003	1.003	1.003
Constant	1.239	1.179	1.216	1.158
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	660	660	630	630
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parenthesis *p<0.1 **p<0.05 ***P<0.01*

Appendix D

Table D.1: Regression results using total nominal GDP is measured in USD (GDP), Net trade as measured in USD ($TRADE$), gross domestic spending on R&D as measured in USD constant prices with 2010 as a base year ($R\&D$), and effects from air pollution ($AIRPOLLUTION$) as control variables. All control variables have a one-year time lag. Random effect NB model with EPS as variable of interest in in column (1) and with Market-based EPS and non-market-based EPS as variables of interest in in column (3). Fixed effect NB model with EPS as variable of interest in in column (2) and with Market-based EPS and non-market-based EPS as variables of interest in in column (4). Both EPS, market-based EPS and non-market-based EPS have a one-year time lag.

Table D.1

Dependet Variable: ENVIPAT	(1)	(2)	(3)	(4)
EPSt-1	1.158 (0.037)***	1.150 (0.037)***		
MARKETEPSt-1			1.056 (0.025)**	1.053 (0.025)**
NONMARKETEPSt-1			1.097 (0.026)***	1.092 (0.026)***
GDPt-1	0.9999996 (7.34e-08)***	0.9999996 (7.47e-08)***	0.9999997 (7.54e-08)***	0.9999997 (7.68e-08)***
R&Dt-1	1.000015 (2.30e-06)***	1.000014 (2.35e-06)***	1.000014 (2.38e-06)***	1.000014 (2.43e-06)***
AIRPOLLUTIONt-1	1.000678 (0.0003659)*	1.000874 (0.0003631)**	1.000685 (0.0003657)*	1.000882 (0.000363)**
TRADEt-1	1 (2.02e-07)	1 (2.02e-07)	1 (2.02e-07)	1 (2.03e-07)
Fixed country effects	NO	YES	NO	YES
Fixed year effects	YES	YES	YES	YES
Observations	507	507	507	507
(Prob>Chi2)	0.000	0.000	0.000	0.000

*Standard errors in parentehsis *p<0.1 **p<0.05 ***P<0.01*