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Environmental Regulations and Pollution Havens

An Empirical Study of the Most Polluting Industries

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Abstract

Environmental concerns in the last decades have given rise to environmental regulations, especially in high-income countries. The pollution haven hypothesis argues that differences in environmental regulations unintentionally give the least regulated countries a comparative advantage in the production of pollution intensive goods, turning them into pollution havens. I use the Heckscher–Ohlin–Vanek (HOV) framework to analyse this argument for the five most pollution intensive industries. The empirical approach is developed by Quiroga et al. (n.d.) and includes a sulphur dioxide based measure of environmental endowment in the HOV regression. I use an unbalanced panel for 103 countries between 1995 and 2012. Two industries show significant support for the alternative hypothesis (the Porter hypothesis) which states that regulations, instead of giving firms a competitive disadvantage, spur them to innovation and increase their competitiveness. In conclusion, I argue that the strong support in favour of the pollution haven hypothesis found by Quiroga et al. is driven by Japan and that their result is not robust to the inclusion of heteroskedasticity-robust standard errors.

Keywords: Comparative advantage, environmental endowment, environmental regulations, natural resources, pollution haven hypothesis, Porter hypothesis

JEL Classification: F18, O13, Q56

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Susanna Lindahl, Skellefteå, September 1, 2016

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Acronyms

Btu	British Thermal Unit
CMIP	Coupled Model Intercomparison Project
ECC	Environmental Compliance Costs
EIA	Energy Information Administration
FAO	Food and Agriculture Organization
FE	Fixed Effects
FDI	Foreign Direct Investment
GATT	General Agreement on Tariffs and Trade
HO	Heckscher–Ohlin
HOV	Heckscher–Ohlin–Vanek
NGPL	Natural Gas Plant Liquids
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Square
PAC	Pollution Abatement Costs
PHH	Pollution Haven Hypothesis
PoH	Porter Hypothesis
SITC	Standard International Trade Classification
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
WDI	World Development Indicator
WTO	World Trade Organization

1 Introduction

The pollution haven hypothesis (PHH) predicts that free trade combined with heterogeneous environmental regulations across countries results in a global shift in industrial composition. The consequence is that industries with low emissions mainly will be found in strictly regulated countries, whereas countries with lenient regulations will have a larger proportion of pollution intensive industries. There are two mechanisms which could explain such an industrial shift. Firms in unregulated countries might gain a comparative advantage in the production of pollution intensive goods, outrival firms from regulated countries and increase their market shares. This mechanism is sometimes referred to as the *industrial specialisation hypothesis*. Alternatively, pollution intensive firms might relocate from regulated to unregulated countries which is the essence of the *industrial-flight hypothesis*.[1]

The term *pollution haven* is used to describe a country with lax environmental regulations and enforcement, which produces a disproportionally large share of the world's pollution intensive goods. Some countries find this a desirable condition since the attraction of foreign direct investments (FDI) and increased export is believed to be positive for the domestic economy, even if the goods produced are pollution intensive. Other countries might be turned into pollution havens unwillingly, as a consequence of inability to implement and enforce strict regulations (Neumayer, 2001). According to the PHH, emissions will be displaced from regulated to unregulated countries, or equivalently, from high-income to low-income countries. Thus, the low-income countries risk being turned into pollution havens.

The PHH rests upon the notion that strict environmental regulations involve costs for firms which undermine their competitiveness. Quite on the contrary, the Porter hypothesis (PoH), named after Michael Porter, argues that environmental regulations act innovation enhancing upon firms, spurring them to become more efficient and competitive. According to this view, regulations constitute a comparative advantage and will in the long run increase the country's export in regulated industries (Porter and van der Linde, 1995). The prediction of the PHH is also contradicted by the capital-labour hypothesis which is based on factor endowment theory. It argues that low-income countries are unlikely to specialise in pollution intensive industries since these are generally intensive in capital and low-income countries typically have modest capital stocks. For the same reason pollution intensive firms have little incentive to reallocate to low–income countries (Lu, 2010).

[1]For a careful review of the PHH see Taylor (2004).

Within the EU and the U.S. the traditional arguments against strict regulations (that compliance costs lead to lost productivity, lower labour demand and reduced investment) have fuelled the discussion about harmonisation of regulations in order to create a level, fair playing field. If the stringency of regulations differ, there is a risk of a "race to the bottom", where jurisdictions strive for the lowest regulations in order to attract investors (Brunel and Levinson, 2013). More recently, the literature has elucidated the concept of *leakages* of transnational pollutants such as SO_2 or CO_2. A leakage arises if regulations in one country decrease domestic but not global emissions since the emitting activity is displaced to another country (Karp, 2011). According to the PHH, environmental policies in high-income countries cause emission leakages to low-income countries.

The PHH has been analysed in both theoretical and empirical studies throughout the last decades. Despite well-founded theoretical arguments (see, e.g., Siebert, 1974; Pethig, 1976; Siebert, 1977; Baumol and Oates, 1988), the empirical evidence is inconclusive. Early studies in the '90s typically found no or weak support for the hypothesis. Along with improvements in data availability and development of panel data techniques the empirical support for the hypothesis increased. However, a consensus has not yet been reached and for policy makers such as the World Trade Organization (WTO) a better understanding of the interplay between trade liberalisation and the environment would be highly valuable (Oxley, 2001).

The aim of this thesis it to examine whether differences in environmental regulations lead to an increased net export of pollution intensive goods from the least regulated countries. I follow a branch of the literature that employs the Heckscher–Ohlin–Vanek (HOV) framework in order to identify comparative advantages. In the HOV model, a country's net export is explained from its endowment of natural resources. A common approach is to include a measure of stringency of environmental regulations into the regression to evaluate the effect on trade flows. The methodology developed by Quiroga et al. (n.d.) and employed here takes a slightly different approach and includes a sulphur dioxide based measure of environmental *endowment* in the HOV regression. The environmental endowment describes how much waste and pollution generated by the production or consumption process that the environment must assimilate. A country with lenient regulations allows the quality of the environment to degrade when using the environment to assimilate waste and pollution in order to produce pollution intensive goods for export. As opposed to natural resources such as forest or iron, the environment is not directly used as input factor in the production process but is instead *indirectly* traded when pollution is displaced from strictly regulated to lenient countries. Thus, strict regulations decrease a country's environmental endowment whereas lenient regulations increases it.

In the original work Quiroga et al. (n.d.) follow the empirical application of the HOV model developed by Leamer (1984). They analyse how a country's environmental endowment affects the net export in the five most polluting industries identified by Tobey (1990). Quiroga et al. find strong and significant support for the PHH for the years 1990–2000 in four of the five industries examined. I replicate the analysis, but thanks to new time series on sulphur dioxide emissions recently released by the Coupled Model Intercomparison Project 6 (CMIP6) I am able to investigate this research question using an updated panel. I use an unbalanced panel for 103 countries between 1995 and 2012. My estimates significantly support the PoH in two of the five industries examined. This suggests that strict environmental regulations in the chemicals and non-metal mineral products industries spur innovation and form competitive firms. I argue that the strong support in favour of the PHH found by Quiroga et al. is solely driven by Japan. This illustrates that a weaknesses of the HOV framework is its sensitivity to sample selection. Lastly, I argue that the original support for the PHH is misleading since heteroskedasticity-robust standard errors are not applied even though heteroskedasticity is present in the data.

2 Literature Review

This chapter summarises empirical evidence from studies examining the effect of environmental regulations on FDI and trade flows. It presents explanations to the inconclusiveness of the evidence and discusses some of the methodological challenges recognised in the literature.

2.1 Empirical Evidence on the Pollution Haven Hypothesis

Statistics confirm that the share of pollution intensive goods in export has risen over time in developing countries and fallen in OECD countries (Reinert and Rajan, 2009). This is compatible with the PHH but can be explained by capital accumulation and economic growth in developing countries. Empirical studies therefore ask whether this global shift in industrial composition is a *result* of heterogeneous environmental regulations in combination with liberalised trade.

One group of empirical studies focusses on the industrial flight hypothesis and estimate the effect of environmental regulations on FDI flows. The evidence is mixed and in a meta-analysis, Rezza (2015) concludes that whether a study confirms or dismisses the PHH depends to a large extent on the research design. There are many types of FDIs and studies examining plant location decisions are most likely to support the PHH. Rezza recommends the use of disaggregated data in order to distinguish between market-seeking (horizontal) and efficiency-seeking (vertical) FDIs. The PHH is arguably more relevant for the latter group. However, the competing forces of the industrial-flight hypothesis and the capital-labour hypothesis are likely to cancel each other out, obstructing empiricists to find unequivocal support for any of them.

A second group of studies investigates how trade flows, typically flows of pollution intensive goods, are affected by heterogeneous environmental regulations. These studies commonly use gravity models or the HOV framework. van den Bergh and van Beers (1997) use a gravity model to estimate bilateral trade flows of pollution intensive goods between 21 OECD countries in 1992. They investigate whether strictly regulated countries have lower export and higher import than unregulated countries. Their initial results are insignificant, but when they test only non-resource based industries regulations have a significant negative effect on export in dirty industries. This supports the notion that geographical location is more important than environmental regulations for resource based industries.

Kahn (2003) employs bilateral gravity regressions to investigate U.S. trade flows in 1958 and 1994. Even though Kahn confirms some pollution haven consistent behaviour the evidence is weak. The hypothesis that import of dirty goods has increased most from poor, non-democratic nations, which generally offer cheap labour and lenient attitudes toward environmental regulations, is rejected.

Leamer (1984) develops an empirical specification of the HOV theory, frequently used in empirical studies. In a well-cited paper Tobey (1990) tests the hypothesis that environmental regulations have altered trade flows in the five most pollution intensive industries. Eleven resource endowments at first identified by Leamer are used to explain net export patterns in 1958 and 1975, respectively. The inclusion of a qualitative measure of regulations does not contribute to the determination of trade flows. Tobey extends the basic HOV model to allow for scale economics as well as non-homothetic preferences[2] but still he finds no significant support for the PHH. Tobey concludes that environmental regulations in developed countries do not seem to increase developing countries' net export of pollution intensive goods.

Peterson and Valluru (1997) employ Leamer's empirical HOV specification on cross-sectional data in order to analyse trade flows in agricultural products. They test six different proxy variables for environmental regulations which all turn out insignificant in the regressions. Environmental regulations appear to have little impact on comparative advantages in agricultural products.

Wilson et al. (2002) combine the empirical methods developed by Leamer (1984) and Tobey (1990). They extend the data set to a panel covering five years in the '90s and use instrumental variables for highly correlated variables. Wilson et al. find that higher environmental standards imply lower net export in four of the five dirty industries examined. Adoption of a global agreement on environmental standards on par with the most regulated countries would lead to a loss in net export corresponding to 0.37% of average GNP of the non-OECD countries examined, according to the study.

Cole and Elliott (2003) use cross-sectional data to test the PHH for 60 countries in 1995. They adopt the five pollution intensive industries identified in Tobey (1990) and include two measures of environmental regulations into the HOV regression. The coefficients of interest turn out insignificant and the authors conclude that their findings confirm the findings by Tobey. The effect of environmental regulations on trade flows appears negligible.

Quiroga et al. (n.d.) as well follow in the footsteps of Leamer and Tobey. They

[2]The assumption of homothetic preferences sustain that countries with different incomes who face the same relative prices will have the same consumption shares of commodities.

ask whether lenient environmental regulations give a comparative advantage in net export of pollution intensive goods. Their sample covers 84 countries between 1990–2000 and they find strong support for the PHH in four of the five industries examined.

2.2 Challenges in the Literature

As a result of the weak support for the PHH a consensus spread that trade and FDI flows are essentially unaffected by environmental regulations (Brunnermeier and Levinson, 2004). However, the hypothesis did not entirely pass away but instead, different explanations to the weak support were suggested in the literature. Brunnermeier and Levinson (2004) argue that the use of cross-sectional data was a major drawback in early studies. The introduction of panel data techniques has enabled researchers to discern pollution haven consistent behaviour. Such studies tend to find significant support for the hypothesis.

A second explanation to the lack of empirical support for the PHH is that environmental costs are small relative to total production costs and that the practical impact therefore is negligible. For instance, Tobey (1990) ranked industries according to regulatory stringency, proxied for by pollution abatement costs (PAC). In the five most polluting industries abatement costs were around 2-3% of total costs.

Ederington et al. (2005) suggest a third explanation, namely that most trade takes place between rich countries with more or less the same level of regulations. Thus, empirical studies which aggregate trade flows across multiple countries will find it difficult to discern pollution haven consistent behaviour. Ederington et al. show that regulatory stringency in OECD countries affects trade flows to non-OECD countries even though no significant effect is found when only OECD countries are included in the sample.

A last explanation to the poor empirical support for the PHH is the capital-labour hypothesis, mentioned above. In order to highlight the importance of capital Cole and Elliott study U.S. outward FDI to Brazil and Mexico. These countries are identified as the most likely pollution havens for U.S. firms since they are relatively capital intensive at the same time as regulations are relatively lax. Cole and Elliott estimate the effect of regulations in the U.S. on outward FDI and find that stricter regulations tend to increase FDI flows.

Similarly, van den Bergh and van Beers (1997) and Ederington et al. (2005) argue that natural resources play a crucial part. Many dirty industries are resource based and relatively immobile. Their strategies are less affected by regulations than footloose industries'. When Ederington et al. (2005) estimate the effect of increased regulations on trade flows for the *average* industry, it is difficult to establish a significant result. However, when the sample contains only footloose industries the evidence in favour of the PHH is robust.

The literature on the PHH faces a number of methodological challenges. One challenge is how to measure stringency of environmental regulations since there is no direct measure.[3] A common approach is to use private PAC as proxy under the assumption that strict regulations induce higher PAC, especially when the production process is pollution intensive. The U.S. is the only country that has collected time series on PAC for a significant period of time, which partly explains why this literature initially had a strong focus on the U.S. A serious shortcoming is the lack of PAC data for low-income countries (Karp, 2011).

Composite indices are commonly used to encompass the many dimensions of regulatory stringency. Walter and Ugelow (1979) compose an index of environmental stringency ranging from one through seven (high numbers reflect strict regulations). They base their index on information about environmental problems and policy response extracted from a 1976 UNCTAD survey. The index is used in empirical studies by, e.g., Tobey (1990). Dasgupta et al. (2001) compose an index from survey questions in UNCED 1992 country reports. The index captures environmental quality of air, water, land and living resources. van den Bergh and van Beers (1997) use OECD Environmental Indicators to construct an index for 21 OECD countries. Research centres at Yale University and Columbia University have constructed an Environmental Sustainability Index for a number of European countries. For the U.S. there is the Fund for Renewable Energy and the Environment (FREE) Index as well as the Green Index. Several other indexes can be found in the literature. The advantage of an index is that it includes many aspects of regulations and enforcement. The disadvantage is the use of an ordinal scale. It is difficult to sensibly interpret an index and the size of the regression coefficient.

Besides PAC and composite indexes a range of other proxies is found in the literature. Waldkirch and Gopinath (2008) use emissions of SO_2, NO_x and other particulates largely regulated at production facilities. Cole and Elliott (2003) use energy consumption to GDP ratio. Smarzynska and Wei (2001) use the change in CO_2, lead and water pollution as a share of GDP. Peterson and Valluru (1997) employ a number of different proxies, among them number of international environ-

[3]For an extensive review on different measures of regulatory stringency see Brunel and Levinson (2013).

mental treaties ratified, proportion of bird and mammal species being endangered, proportion of land area that is park or protected area, and proportion of population with access to safe water.

A second methodological challenge is that environmental regulations might be endogenous to trade and FDI flows if concerns with international competition affect a country's level of regulations. Some papers deal explicitly with the endogeneity question. Ederington and Minier (2003) model regulations as endogenous to net import and find that import penetration increases with stringency of regulations, that is, significant support for the PHH. They argue that studies which model regulations as exogenous to trade flows underestimate the effect. This finding is consistent with a study by Lu (2010), who finds support for the PHH when regulations are modelled as endogenous to per capita income. No significant result is found when the modelling is exogenous. Cole and Elliott (2003) regress net export on factor endowments including environmental regulations. Contrary to Lu (2010) and Ederington and Minier (2003), they do not find support for the PHH when using simultaneous equations to account for endogeneity.

This thesis adds to the literature an updated analysis based on panel data techniques. The results offer a partial explanation to the inconclusive results found in previous studies, namely the HOV framework's sensitivity to sample selection.

3 Theoretical Framework

This chapter gives a conceptual understanding of the relation between trade issues and the environment. It discusses the PHH and its opposite, the Porter hypothesis, and explains the HOV framework employed in the thesis.

3.1 Conceptual Understanding

Background

The linkages between trade liberalisation and the environment began to receive attention in the 1970s. At the first major international conference on environment, the UN Conference on the Human Environment in Stockholm 1972, the implications of environmental policies for trade were discussed. Slowly, policy makers started to ask how environmental regulations affect firm competitiveness, terms of trade and countries' performance on international markets (UNECE, 2007). Developing countries regarded environmental regulations as an impediment for growth whereas environmental groups in industrialised countries demanded environmental issues to be included in GATT negotiations (Oxley, 2001). Since then, a steady decrease in trade barriers has been accompanied by a steady increase in environmental regulations and much has been written about the interplay there between (Cole and Elliott, 2003).

The intensity of the trade versus environment debate increased in the early '90s. The tuna–dolphin dispute between the U.S. and Mexico proved that differences in environmental protection can be a substantial source of conflict. The U.S. imposed an import embargo on Mexican yellow-fin tuna, arguing that insufficient measures were taken in order to prevent accidental killing of dolphins. Mexico brought the case before the GATT panel which ruled in favour of Mexico and forced the U.S. to lift its embargo (Cameron, 2007). Shortly after the tuna-dolphin dispute the North American Free Trade Agreement was signed and critiques feared that the agreement would turn Mexico into a pollution haven for American firms as well as be a job disaster for the U.S. (Taylor, 2004).

A few years later, violent demonstrations at WTO meetings in Seattle and Genoa were partly a consequence of environmental concerns of trade liberalisation (Brunnermeier and Levinson, 2004). Trade versus environment is now a vividly discussed political issue and will continue to be since the EU made environmental concerns a key demand of its negotiating agenda in the Doha round (Oxley, 2001).

The Links Between Environment and Trade

Antweiler et al. (2001) divide trade's impact on pollution into three effects. First, trade liberalisation raises the level of economic activity and increases pollution. This *scale effect* has long been a major concern of environmentalists and was at the core of the demonstrations in Seattle and Genoa (Brunnermeier and Levinson, 2004). Defenders of liberalised trade maintain that trade raises national income and, given a positive correlation between income and demand for a clean environment, increased trade is in fact favourable for the environment. The second effect is that trade liberalisation causes specialisation and alters a country's composition of industries and output. Such a *composition* effect might be damaging for a country's local environment if it specialises in production of pollution intensive goods. On the other hand, if specialisation brings about efficiency gains through economies of scale resources can be freed and used for environmental protection. Lastly, trade liberalisation can cause a positive *technology effect* with transfers of green technology which improves environmental quality globally.

This thesis focusses on the composition effect which has given rise to the PHH. The PHH states that under liberalised trade, heterogeneous environmental regulations alter the least regulated countries' industrial composition such that they specialise in pollution intensive production. Similarly, highly regulated countries specialise in production of clean goods. However, the net effect of trade on the environment also depends on the relative strength of the technology and scale effects. A strong technology effect might lead to a positive effect of trade on the environment in unregulated countries (Antweiler et al., 2001).

At the same time as environmental regulations are predicted to affect trade flows, there is a possible reversed causality such that trade flows affect the level of regulations. Increased import might lead to intensive lobbying for protection. Since all members of the WTO resign from using trade barriers but are free to establish policies on environmental protection (given that no unnecessary obstacle to trade follows) countries may use environmental policy as second-best trade policy (Trefler, 1993). Thus, the prospect of taking advantage of trade and FDI flows might affect the formation of environmental policy.

Environmental Regulations and Competitiveness

One methodological challenge is how to find a suitable proxy variable for stringency of environmental regulations since there is no direct measure. As seen in the literature review there are numerous possible proxies. One difficulty is the multidimensionality arising from the large number of existing regulations designed for different purposes (Brunel and Levinson, 2013). There are regulations regarding emissions of different pollutants (chemicals, sewage, green house gases, etc.) into different environmental media (air, water, soil, etc.). There are local, regional and global regulations, some being designed to affect the production side and others the consumption side. The challenge is to find a measure which captures the relevant aspects for a particular research question. In addition, data needs to be available and comparable across countries and time.

Regulatory stringency is often defined in relation to incurred environmental compliance costs (ECCs). ECCs arise when external costs previously born by a wider society are internalised and accounted for by the emitting firms (Peterson and Valluru, 1997). Examples of ECCs are costs related to administration and enforcement, expenditures on new technology and know-how, operating and transactional costs, or costs arising from disrupted production, shifted management focus or discouraged investment (Jaffe et al., 1995).

In empirical studies high ECCs are interpreted as sign of stringent regulations. There are two opposing hypotheses regarding the effect of regulatory stringency on competitiveness. According to the conventional view, which is the foundation of the PHH, internalisation of costs causes a loss of firm competitiveness, decreased export and a shift of pollution intensive industries to lenient countries (Copeland and Taylor, 2004). A later, contrasting view is that regulations constitute a positive driving force for innovation. Michael Porter argues that stringent standards motivate companies to upgrade technology and enhance innovation. New ideas and solutions offset costs following from the regulations. High standards would in the long run raise productivity according to this view (Porter, 1998). A common critique to the PoH is that is does not explain why firms did not come up with the cost reducing innovations before ECCs were imposed on them.

The effect of regulations on trade and FDI flows is believed to be particularly evident in pollution intensive industries where the difference in ECCs between regulated and unregulated countries is the largest. Hence, empirical studies normally analyse highly polluting industries. The finding that lax regulations increase net export of dirty goods supports the PHH. In this case, unregulated countries have a comparative advantage and gain market shares in pollution intensive industries. On the contrary, finding that lax regulations decrease net export would be interpreted as support for the PoH. Unregulated countries lose competitiveness, innovation and market shares.

It is important to remember the distinction between the competitiveness of firms and a country's overall performance. Stringent regulations might be devastating for specific sectors or industries. At the same time, reallocation of resources due to the regulations might pave the road for and let new sectors flourish resulting in a positive net effect for the country (Potier and Less, 2008).

3.2 The Heckscher–Ohlin–Vanek Model

The Heckscher–Ohlin (HO) model is a natural framework to use when analysing sources of comparative advantages. The central concept is endowment of production factors. According to the HO theorem:

> *A country exports goods which are intense in the country's relatively abundant production factor, and imports goods which are intense in the country's relatively scarce production factor* (Gandolfo, 2014).

Vanek (1968) advances upon the HO model as he addresses the econometric problems that arise when countries are endowed with more than two production factors. Vanek recognises that as soon as three (or more) production factors are involved, there is no unique ordering of production technologies according to relative factor intensity, i.e., the goods produced cannot be ranked according to factor intensity. This brings about methodological difficulties, especially in the case where the number of goods produced exceeds the number or production factors – a likely situation in the real world. The net export vector is indeterminate and trade cannot be predicted from factor endowments. Vanek's solution is to focus on the factor *content of trade* or factor *services* embedded in trade flows, defined as the quantity of factors used to produce the exported goods less the quantity of factors needed in the production of the imported goods. The Heckscher–Ohlin–Vanek theorem states that:

> *A country is a net exporter of factor services of its relatively abundant factors and a net importer of the factor services of its relatively scarce factors* (Gandolfo, 2014).

The essence of the HOV model is that international trade is simply a way to exchange factor services: goods are merely bundles of factor services (Gandolfo, 2014).

In addition to the standard assumptions of the HO framework[4] the HOV model assumes that

[4]Standard assumptions regard zero transport costs, free trade, perfect competition, constant returns to scale and no complete specialisation.

i) there are *more* than two countries, final goods and factor endowments

ii) factors of production are immobile across countries but mobile between domestic sectors

iii) countries have equal tastes and preferences, i.e., for a given relative price of a final good the countries consume the same proportions of the good even though they might have different income levels

iv) production functions are identical across countries but are different for the different final goods

v) factor prices are equalised across countries (Cole and Elliott, 2003; Debaere, 2003; Leamer, 1980).

In his seminal contribution from 1984, Leamer develops an empirical specification of the HOV theory. Leamer shows that net export can approximately be expressed as linear functions of factor endowments. He uses cross-sectional data sets to estimate net export as a function of factor endowments in 1958 and 1975 for 58 countries. He uses ten types of goods (petroleum, raw materials, forest products, tropical agriculture, animal products, cereals, labour and capital intensive manufacturers respectively, machinery and chemicals) as well as eleven factors (physical capital, three types of labour, four types of land, coal, oil and minerals), which he argues are a reasonable reflection of the world's resources.

Leamer (1984) argues that "*...overall the simple linear model does an excellent job. It explains a large amount of the variability of net exports across countries*" (p. 187). The model confirms rather obvious sources of comparative advantage, for instance that holding of natural resources increases net export of natural resource products like raw materials and forest products. Unskilled labour and certain land types are shown to give an advantage in production of a set of agricultural products. More interesting is that Leamer identifies trends in sources of comparative advantages. For instance, the importance of skilled labour in manufactured products decreased between 1958 and 1975, whereas the role of capital was the opposite. Leamer concludes that the linear model "*identifies sources of comparative advantage that we all 'know' are there, thereby increasing the credibility of the results in cases when we do not 'know' the sources of comparative advantage*" (p. 187). One potential source of advantage is lax environmental regulations.

Leamer's method is utilised by, among others, Tobey (1990), Peterson and Valluru (1997), Wilson et al. (2002), Cole and Elliott (2003), Quiroga et al. (n.d.), and

Lu (2010). Factors commonly included in empirical models are capital, labour and natural resources such as land, minerals or fossil fuels. It is common to include a proxy for stringency of environmental regulations. The approach developed by Quiroga et al. (n.d.) is slightly different: it includes a measure of environmental *endowment* as a production factor. As opposed to natural resources which are directly included in the goods traded, environment services are *indirectly* traded through pollution embodied in net export. This viewpoint dates back to a seminal paper written by Ayres and Kneese (1969) where emissions of pollutants are seen as a part of the production and consumption process.

A country's environmental endowment is determined by

i) the country's natural assimilative capacity (i.e., the environment's ability to reduce pollutants by natural processes without degrading the quality of the environment)

ii) the demand for assimilative services (i.e., how much pollution we wish to release into the environment)

iii) the value attributed to a clean environment as a public good (Siebert, 2008).

Siebert (2008) explains that "*if a country is richly endowed with assimilative services by nature, it will have a trade advantage over a country only scarcely equipped with assimilative services*" (p. 174). In a very informal way, one can think about environmental endowment as how much of its clean environment a country is ready to sacrifice in order to engage in trade. A lenient attitude towards environmental regulations means sacrificing the own environment in order to export environmental services.

4 Methodology

This chapter presents the research question of the thesis and the empirical specification designed to answer it. It explains the measure of environmental endowment and discusses the contribution and delimitations of the thesis.

4.1 Research Question

The aim of this thesis is to analyse whether heterogeneous environmental policies cause a global shift in industrial composition such that production of pollution intensive goods becomes concentrated to countries with lax regulations. This happens either because firms in these countries gain competitiveness relative to firms in strictly regulated countries, or because higher levels of FDI flows are attracted to countries with low regulations. The research question can be summarised as follows:

Do strict environmental regulations in some countries give less regulated countries a comparative advantage in pollution intensive industries?

4.2 Empirical Specification

In order to answer the research question I employ the version of Leamer's specification most commonly used in empirical papers, for instance by Tobey (1990), Wilson et al. (2002), Cole and Elliott (2003), and Lu (2010) and Quiroga et al., where net export is predicted from factor endowments.[5] In addition, I include the measure of environmental endowment developed by Quiroga et al. (n.d.) in the regression. The estimated model is:

$$NX_{ijt} = \alpha_j + \delta_j E_{it} + \sum_{k=1}^{S} \beta_{jk} V_{ikt} + \epsilon_{ijt} \quad i = 1, \ldots, N \quad j = 1, \ldots, J \quad t = 1, \ldots, T$$

where NX_{ijt} is net export from country i in sector j at time t. E is the measure of environmental endowment (discussed in section 4.3). V_{ikt} is country i's endowment of factor k. α is an intercept and β_{jk} as well as δ_j are the slope coefficients to be estimated. There are S factors of production, N countries, J industries and T time periods. ϵ_{ijt} is the error term.

The parameter of interest is δ_j which is expected to be positive and significant given that the PHH is true. In that case, a higher environmental endowment, as

[5] For a derivation on how to arrive at this form, see, e.g., Cole and Elliott (2003) or Quiroga et al. (n.d.).

a consequence of low environmental regulations, increases net export. A positive coefficient suggests that differences in regulations give countries with a low regulations a comparative advantage in the production of pollution intensive goods. The environmental endowment is determined by regulations and by assimilative capacity. Assuming that a country's assimilative capacity is time invariant, the within-country variation in the environmental-endowment variable comes solely from variation in environmental regulations.

In many respects, the variables used in this thesis are the same as in Quiroga et al. (n.d.) who follow the endowment factors introduced by Leamer (1984). The included endowment factors are capital stock, labour force, area of cropland and forest as well as production of iron, copper, lead, zinc, coal, gas and oil. The investigated industries are the five most pollution intensive identified by Tobey (1990). These are iron and steel, non-ferrous metals, chemicals, pulp and paper, and non-metal mineral products. See chapter 5 for a detailed description of the data.

The model is estimated using the pooled ordinary least squares (OLS) estimator as well the country fixed effects (FE) estimator. The FE estimator reduces the risk of omitted variable bias but there is still a risk of bias if environmental endowment is endogenous to net export. However, endogeneity is unlikely since the estimated relation concerns a single industry against national environmental endowment (Cole and Elliott, 2003). Arguably, a country's total environmental endowment is most likely little affected by the conditions in one industry. Thus, environmental endowment is treated as exogenous.

4.3 The Measure of Environmental Endowment

The approach used by Quiroga et al. (n.d.) and adopted here is slightly different from many other empirical papers in the field. It is inspired by a measure of environmental endowment designed by Persson (2003) and aims at quantifying the environmental endowment a country can use as an indirect input factor in goods production (as opposed to finding a proxy for environmental regulations in most of the empirical papers in this literature).

The measure of environmental endowment is based on emissions of SO_2, a pollutant often analysed in the literature because of a number of suitable characteristics, namely:

i) SO_2 is a a by-product of production processes and thus relevant in the context. 85% of anthropogenic emissions of SO_2 come from combustion of coal and oil (fossil gas has a negligible sulphur content). The second largest source of anthropogenic emissions is smelting of ores (UNDP, 2000)

ii) SO_2 is subject to regulations due to negative effects on the environment or human health

iii) several abatement techniques are available, both pre- and post-combustion desulphurisation techniques

iv) emissions vary across countries and time and data is available for a large number of countries with different incomes (Persson, 2003; Grether et al., 2010; Quiroga et al., n.d.).

A country's SO_2 emissions are determined by three factors: the amount of fossil fuel consumed, the sulphur content of the fuels and the use of abatement technologies. A suitable proxy should reflect these three aspects (Persson, 2003). I will return to these three determinants shortly.

The proxy for environmental endowment designed by Quiroga et al. (n.d.) is a country's SO_2 emissions from fossil fuel use[6] divided by the share of coal and oil in the country's total energy consumption (cons.):

$$\text{envendow} = \frac{SO_2 \text{ emissions}}{\frac{\text{energy cons. from coal and oil}}{\text{total energy cons.}}}$$

The environmental endowment decreases with the use of abatement techniques and reduction in SO_2 emissions. Similarly, it decreases with the use of fossil fuels with lower sulphur content. Both oil and coal are widely traded on global markets and it is perfectly possible to demand low-sulphur fuels. The ratio in the denominator intend to compensate for the fact that a country might have low SO_2 emissions due to favourable conditions for hydro power or nuclear power even though it has lenient regulations. Quiroga et al. argue that countries generally use the energy sources they are naturally endowed with and do not deliberately affect this ratio. Thus, the share of coal and oil consumption in total energy consumption is rarely actively chosen (Persson, 2003; Quiroga et al., n.d.).

A caveat is that this measure is misleading for countries which unintentionally use fossil fuels with low SO_2 contents. In this case the measure will falsely be interpreted as a sign of stringency (Quiroga et al., n.d.). In addition, this measure loses validity

[6]Emissions of SO_2 also come from natural sources, for instance volcanoes, decaying organic matter and sea spray (Persson, 2003), not accounted for here.

if countries use renewable energy sources instead of fossil fuel for environmental reasons. In that case, the weighting becomes misleading. However, this is not yet the case on a large scale (even though we might see this happening in the future) and it is thus unlikely to cause bias. See Persson (2003) or Quiroga et al. (n.d.) for further discussion of the measure of environmental endowment.

4.4 Proposed Contribution

The main contribution of this thesis lies in the updated and improved data set. In an overview of empirical studies on environmental policy and trade, Siebert (2008) concludes that one of the main problems in the field is the scarce data on pollution, especially for low-income countries. For exactly this reason it has not been possible for Quiroga et al. (n.d.) to bring their data set up to date. Thanks to new data on SO_2 emissions, acquired from the CMIP6 in April 2016, I have been able to update the environmental-endowment variable. This enabled me to extend the panel in both the cross-sectional and the time dimension, bringing the research up to date. In addition, a minor contribution is an improved measure of forest (see section 5).

The second important contribution of the thesis is that I revisit the time period analysed by Quiroga et al. (1990–2000). With a sample comparable to the original sample I find that Japan strongly drives the result in favour of the PHH. Furthermore, I argue that the original support for the PHH is misleading since heteroskedasticity-robust standard errors are not applied even though heteroskedasticity is present in the data.

Lastly, I discuss the economic significance of the estimated coefficients for the environmental endowment-variable. Although highly relevant, it is not mentioned by Quiroga et al. However, the interpretation is not straight forward due to the design of the measure of environmental endowment and the use of net export as dependent variables.

4.5 Delimitations and Potential Problems

It is important to note that differences in factor endowments cannot explain all the global trade flows. Trade flows are also affected by other factors: demand, exchange rates, trade barriers, R&D expenditures, technology level, tariffs, etc. These are normally not accounted for in empirical studies utilising the HOV framework, where natural resources are in focus. However, it is slightly heroic to assume that all of the relevant factors not controlled for are time invariant. Thus, there is still a risk for biased estimates due to omitted variable bias. Since there are several factors not controlled for which are possibly time-variant, it is difficult to say whether a bias would be positive or negative.

Another source of bias might occur if the environmental regulations, and thus the environmental endowment, are in fact endogenous to net export. Ederington and Minier (2003) argue that exogenous estimates are downward biased but empirical evidence from different studies is inconclusive on this point. This thesis does not make use of simultaneous equations where environmental endowment is treated as endogenous, simply due to time constraints. However, it would have been a highly relevant robustness check.

I argue that a major drawback in empirical studies in the literature, this thesis included, is the way Leamer's method has come to be used. It is many times used to *find* sources of comparative advantages, instead of *confirming* them. For instance, if factor k obtains a positive coefficient in industry j, it is regarded as a source of comparative advantage. If, instead, it was known prior to the estimation that k is an important input factor in industry j, a positive coefficient would confirm what was already known. This way of working would improve credibility. Unfortunately, this is a general weakness in this literature. A well-motivated expectation on the coefficient *prior* to estimation is often missing, this thesis being no exception. At least in my case this depends on a lack of detailed knowledge.

The choice of data induces some limitations. If the PHH is confirmed, I cannot discern the source of the gained comparative advantage. Support for the PHH only means that net export from lenient countries has increased in the industries analysed, but it does not acknowledge whether the mechanism accord with the industrial specialisation hypothesis or the industrial flight hypothesis – or both. In order to do a more careful analysis of, other kind of data is needed.

Lastly, this analysis encompasses five industries which Tobey (1990) identifies as the most pollution intensive in the U.S. in 1977. These are not necessarily the most polluting in every country throughout the '90s and '00s. If these industries are not generally pollution intensive throughout the time period of interest, the likelihood of finding support for the PHH is reduced.

5 Data Description

The data set primarily used in this thesis is an unbalanced panel of 103 countries (listed in table A1) for the years 1995–2012. The set of countries is to a large extent constrained by the measure of capital stock for which there are many missing values, especially for low and lower middle income countries in the early '90s. In 1990–1994 more than one third of the observations are missing. In order to mitigate possible self selection bias I do not use these years when estimating the model. The exception is when I reinvestigate the original results by Quiroga et al. (n.d.). For this I use the original time period 1990–2000.

Quiroga et al. (n.d.) use a sample of 84 countries, out of which 78 are used in their FE regression. Due to a change in the capital-variable I have not been able to reconstruct the exact same panel as in the original paper.[7] However, the panel I use to reinvestigate the original findings covers 66 of the 84 countries used by Quiroga et al., plus twelve others. Thus, my panel for the 1990–2000 also includes 78 countries, overlaps with the original panel to 85% and I believe these two panels are comparable.

The resource endowments included in the HOV regression are capital stock, land types (forest and cropland) and labour, where the latter is divided into low, medium and highly skilled labour as a robustness check. Production of minerals (copper, iron, lead and zinc) and the non-renewable energy resources coal, oil and natural gas are included (the latter two combined in one variable in order to follow the original specification). The industries covered are iron and steel, chemicals, non-ferrous metals, pulp and paper and non-metallic mineral products. Independent variables are described in detail in table 1 and dependent variables in table 2.

The two sub panels covering 1990–2000 and 1995–2012, respectively, include the same variables except for the measure of forest. The original measure is a world development indicator (WDI) labelled "*Forest area, sq. km.*" and defined as "*natural or planted stands of trees…whether productive or not*". Contrary to the expectation, this variable turns out negative and significant in the pulp and paper industry in the original FE regression. Arguably, such a broad measure does not correctly capture the amount of forest a country has which gives a comparative advantage in production of the goods. Leamer (1984) points out that "*forest area offers a poor explanation of net exports of forest products presumably because it does not distinguish tropical*

[7]The reason is that the capital variable used by Quiroga et al., *WDI: Gross fixed capital formation (constant 2000 USD)*, is not available any more. The revised variable used here, *WDI: Gross fixed capital formation (constant 2005 USD)*, does not cover the exact same sample.

Table 1: Variable description

Variable	**Definition and source**
Net export (*dependent variable*)	Million U.S. dollar (current) of net export per year. *Source*: UN Comtrade Database.
Capital stock (*capital*)	Physical capital stock, billion (10^9) U.S. dollar. Calculated as the sum of annual gross domestic income (GDI), average life time of 15 years, depreciation rate of 13.3%. *Source:* WDI - *Gross fixed capital formation (constant 2005 USD).*
Labour force (*labour*)	Million of economically active people. *Source:* WDI - *Labor force, total.* The Barro Lee educational data on highest level of schooling completed (primary, secondary and tertiary) used to calculate unskilled, medium skilled and highly skilled labour. The latter only available every fifth year.
Cropland area (*cropland*)	Permanent cropland in thousand sq. km. *Source:* WDI - *Permanent cropland (% of land area)*, WDI - *Land area (sq. km).*
Forest area (*forest (sqkm)*)	Forest area in thousand sq. km. *Source:* WDI - *Forest area (Thousand sq. km).*
Area of productive forest (*forest (prod)*)	Forest area designated primarily for production of wood, fibre, bioenergy and/or non-wood forest products in million hectar. Available every 5th year, linearly interpolated. *Source:* FAO Forest Resource Assessment data - *Production forest.*
Copper, iron, lead, zinc (*cu, fe, pb, zn*)	Mine production in metric tons per year for each metal. *Source:* U.S. Geological Survey - Commodity statistics and information.
Coal production (*coal*)	Total primary coal production, million short tons per year. *Source:* U.S. EIA - International energy statistics.
Gas and oil production (*gasoil*)	Sum of gross heat content (quadrillion (10^15) Btu) contained in dry natural gas production and production of crude oil, natural gas plant liquids (NGPL) and other liquids . *Source:* U.S. EIA - International energy statistics.
Environmental endowment (*envendow*)	Anthropogenic SO_2 emissions in thousand tonnes divided by share of oil and coal in total energy consumption. *Source*: CMIP6 version 2016-04-12 on SO_2 emissions. International Energy Statistics from the U.S. Energy Information Administration (EIA) on oil, coal and total energy consumption.

rain forest from cooler softwood forest". Thus, I instead use a measure of productive forest which I believe is a more relevant measure of forest endowment in this context (see table 1 for definition).

Summary statistics for the variables in the main specification are provided in table 3. For all the variables there are, naturally, large differences between minimum

Table 2: Industry description according to SITC rev. 3

Industry	**Explanation**
Iron and steel (*IronSteel*)	Manufactured goods (primary forms, semi-finished products and finished products) made of iron and steel (SITC67).
Non-ferrous metals (*NonFerrMetals*)	Silver, platinum and other metals of the platinum group, copper, nickel, aluminium, lead, zinc, tin and miscellaneous non-ferrous base metals employed in metallurgy and cermets (SITC68).
Chemicals (*Chemicals*)	Organic chemicals (SITC51), inorganic chemicals (SITC52), fertilizers (SITC56), chemical materials and products not elsewhere found (SITC59).
Pulp and paper (*PulpPaper*)	Pulp and paper waste (SITC25), paper, paperboard and articles of paper pulp, of paper or of paperboard (SITC64).
Non-metallic mineral products (*NonMetMinProd*)	Lime, cement, glass, glassware, clay materials, pottery, mineral manufactures (not elsewhere found), pearls and precious or semi-precious stones (SITC66).

and maximum values. There are countries which have no or negligible endowments of cropland, forest, minerals and fossil fuels, whereas others are richly endowed. The number of observations vary from roughly 1500–1850. Net export in the pulp and paper industry together with the capital variable have fewest observations.

Since all the independent variables are always non-negative and a few, large countries have large endowments, the distributions are right skewed. The dependent variables fairly well follow a normal distribution.

Some of the independent variables show high pairwise correlations (see table 4) which could cause unreliable estimates. For instance, the correlation between zinc and lead is 0.947. This follows from the large share of countries which produce neither zinc nor lead. Dropping one of them or creating a composite index does not notably affect the results. Coal is also highly correlated with other variables, above 0.8 in four cases. One approach, employed by Peterson and Valluru (1997) and Lu (2010) is to include an index of energy production which encompasses production of coal, gas and oil. If I combine the coal-variable with the gasoil-variable this index has a correlation of 0.10 with the environmental endowment-variable. The estimated regression coefficients for the variable of interest are barely affected.

High pairwise correlations are most problematic when they concern the variable of interest (Wilson et al., 2002). Here, the environmental-endowment variable (*envendow*) has pairwise correlations above 0.8 with labour and coal. As mentioned above, changing the specification regarding the coal-variable does not notably affect the coefficient for the *envendow*. As a robustness check, the labour variable is divided into three variables according to skills level, which all have low correlations with *envendow* (the strongest correlation is 0.53). The results are robust to this change in specification. Thus, I believe that multicollinearity is not causing problems and I leave these control variables as they are in the original specification by Quiroga et al. (n.d.).

Table 3: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
year			1995	2012	1854
IronSteel	-175.015	3394.149	-29570.984	43802.075	1698
NonFerrMetals	59.855	3701.525	-33420.229	30266.808	1687
Chemicals	-734.272	3016.368	-22667.131	14309.638	1544
PulpPaper	59.669	2275.79	-11037.837	16127.632	1507
NonMetMinProd	50.288	2224.871	-21445.671	26493.18	1712
capital	533.747	1895.419	0.725	19556.813	1524
labour	24.398	86.205	0.071	795.863	1843
cropland	12.205	26.66	0.001	220	1833
forest (prod)	10.799	44.38	0	429.058	1740
fe	8090.08	33516.857	0	412000	1854
cu	125.513	517.446	0	5560	1854
pb	32.962	153.314	0	2800	1854
zn	90.361	333.814	0	4860	1854
coal	57.756	278.309	0	4017.92	1843
gasoil	1.877	5.757	0	45.905	1843
envendow	1323.115	4235.079	0.741	39887.484	1843

Table 4: Correlation table

Variables	capital	labour	cropland	forest (prod)	fe	cu	pb	zn	coal	gasoil	envendow
capital	1.000										
labour	0.367	1.000									
cropland	0.220	0.655	1.000								
forest (prod)	0.309	0.292	0.241	1.000							
fe	0.290	0.597	0.428	0.284	1.000						
cu	0.256	0.166	0.167	0.198	0.207	1.000					
pb	0.477	0.683	0.363	0.214	0.720	0.285	1.000				
zn	0.420	0.677	0.407	0.225	0.710	0.314	0.947	1.000			
coal	0.588	0.850	0.488	0.326	0.657	0.259	0.897	0.825	1.000		
gasoil	0.698	0.294	0.261	0.770	0.291	0.272	0.322	0.330	0.433	1.000	
envendow	0.627	0.827	0.501	0.584	0.592	0.300	0.745	0.725	0.899	0.665	1.000

6 Results

This chapter presents pooled OLS and FE estimates of the model as well as a number of robustness checks. The $\hat{\delta_j}$ consistently comes out significant[8] in two industries: chemicals and non-metal mineral products. The coefficient is negative offering support for the PoH. In the last section of the chapter, I reinvestigate the original findings and test the robustness of them.

6.1 Regression Estimates

First I estimate the model for the years 1995 to 2012 using pooled OLS (see table 5). I use heteroskedasticity-robust standard errors since the Breusch–Pagan test indicates heteroskedasticity at at least 5% significance level in all industries. The OLS estimates offer a fairly good starting point. A majority of the coefficients are significant, as expected since natural resources should be important determinants of comparative advantages in industries based on natural resources. Most, although not all, signs look reasonable. Iron positively influences net export in the iron and steel industry. Likewise, copper and zinc are positive and significant in the non-ferrous metal industry. Here lead turns out negative and significant which could be explained by the coexistence of different sectors and the use of alloys in this industry. In similar studies by Cole and Elliott (2003) and Quiroga et al. (n.d.) lead also has a negative and significant coefficient in the non-ferrous metals industry. In a disaggregated analysis by Quiroga et al. the coefficient is positive, as expected. The forest variables is expected to be positive in the chemical industry since black liquor, a waste product from the pulp and paper industry, is used as input. The coefficient is positive although not significant. In the pulp and paper industry, the forest variable is positive but insignificant, whereas cropland seem to constitute a comparative advantage. Neither capital nor labour force turn out positive and significant but instead they represent comparative disadvantages in several industries. Coal, gas and oil resources look generally more important as comparative advantages.

Resource endowments can not explain all variation in net export but the model seems to explain net export reasonably well, with pulp and paper industry being the doubtful exception. The R-square for the pulp and paper industry is 0.27 whereas it ranges from 0.49 to 0.73 in the other four industries.

The coefficient for the environmental endowment-variable (the $\hat{\delta_j}$) is significant in three industries: positive at 10% significance level in the iron and steel industry

[8] If not specified, *significant* means significant at 10% significance level or lower.

Table 5: Pooled OLS with robust standard errors

	(1) IronSteel	(2) NonFerrMetals	(3) Chemicals	(4) PulpPaper	(5) NonMetMinProd
capital	-1.028***	-1.676***	-0.664***	0.0729	-0.767***
	(-6.17)	(-13.79)	(-6.66)	(0.89)	(-6.78)
labour	-20.16***	-4.419	-4.052	-9.300***	-1.008
	(-3.71)	(-1.36)	(-1.23)	(-3.94)	(-0.49)
cropland	-16.70***	-14.73***	-36.14***	10.87***	11.47***
	(-3.38)	(-4.33)	(-12.16)	(4.17)	(3.40)
forest (prod)	40.78***	8.980**	2.256	4.966	12.45***
	(9.77)	(1.99)	(0.48)	(1.06)	(4.38)
fe	0.0452***	0.0154***	-0.0232***	0.00657**	0.00282
	(6.32)	(3.50)	(-5.14)	(2.29)	(1.10)
cu	-0.438***	3.027***	0.247***	0.232***	-0.268***
	(-5.91)	(7.55)	(4.09)	(5.45)	(-5.02)
pb	-5.362	-14.97***	-1.852	-19.39***	0.696
	(-0.74)	(-3.50)	(-0.68)	(-5.88)	(0.21)
zn	-1.052	5.033***	-0.853	7.351***	0.100
	(-0.58)	(4.44)	(-1.08)	(5.62)	(0.12)
coal	8.005**	-1.090	2.697	3.289***	6.056***
	(2.18)	(-0.40)	(1.58)	(2.59)	(4.29)
gasoil	-246.4***	255.5***	267.7***	22.48	-129.6***
	(-6.99)	(6.91)	(7.04)	(0.62)	(-4.46)
envendow	0.251*	0.0451	-0.0695	-0.196***	-0.142**
	(1.90)	(0.48)	(-0.61)	(-3.12)	(-1.97)
constant	250.8***	160.1**	-51.75	74.70	210.4***
	(3.32)	(2.42)	(-0.77)	(1.09)	(5.72)
obs.	1330	1321	1224	1191	1334
R^2	0.490	0.728	0.497	0.265	0.600

t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

and negative at 1% and 5% significance level in the pulp and paper and the non-metal mineral products industry, respectively. Thus, the OLS estimates significantly supports the PHH in one industry and the PoH in two industries.

Since the pooled OLS estimator does not account for unobserved heterogeneity I estimate the model again and include country fixed effects, a time trend as well as standard errors clustered on country level.[9] This is the main specification of the

[9]Clustered errors are robust to heteroskedasticity and allow within-country correlation in the error term. FE are used since the Hausman test consistently rejects the inclusion of random effects. The test *testparm* indicates that no time FE are needed in 4 out of 5 cases at 5% significance level, the chemical industry being the exception. Thus I do not employ time FE but include the year

Table 6: FE regression: Main spefication

	(1) IronSteel	(2) NonFerrMetals	(3) Chemicals	(4) PulpPaper	(5) NonMetMinProd
capital	-1.244*	-1.189	-2.658***	-0.403	-1.523***
	(-1.81)	(-1.50)	(-3.71)	(-0.82)	(-3.64)
labour	-18.76	35.41	-10.78	-12.44	29.14
	(-0.30)	(1.23)	(-0.23)	(-0.68)	(1.62)
cropland	-81.43*	-8.799	-47.45*	27.97	-40.55***
	(-1.88)	(-0.18)	(-1.80)	(1.62)	(-2.75)
forest (prod)	79.65	-118.5***	-165.7***	79.94***	-25.10
	(1.25)	(-2.95)	(-2.80)	(4.14)	(-1.63)
fe	0.0167	0.0145	-0.00839	-0.00746***	-0.00609
	(0.49)	(1.13)	(-1.44)	(-3.95)	(-1.55)
cu	-0.206	6.336***	-0.298	0.472*	-0.0466
	(-0.28)	(6.78)	(-0.65)	(1.74)	(-0.12)
pb	11.52***	-6.770	6.779**	-4.478**	4.822***
	(3.33)	(-1.63)	(2.04)	(-2.32)	(3.25)
zn	1.702	-5.408**	-3.620**	1.770	-0.177
	(0.89)	(-2.17)	(-1.99)	(1.52)	(-0.22)
coal	7.466	-4.749	4.571	2.748	11.97***
	(1.27)	(-0.59)	(1.28)	(0.87)	(4.39)
gasoil	-161.1	111.1	468.7**	313.0	518.8***
	(-0.48)	(0.49)	(2.05)	(1.47)	(2.98)
envendow	0.0330	0.160	-0.737***	-0.318	-0.524***
	(0.12)	(0.41)	(-2.63)	(-1.35)	(-3.09)
year	-11.02	30.20	8.874	-2.849	-13.06**
	(-0.70)	(1.47)	(0.30)	(-0.25)	(-2.00)
constant	22389.2	-59844.6	-14332.2	4763.2	25758.0**
	(0.71)	(-1.47)	(-0.24)	(0.21)	(1.99)
clusters	102	102	101	99	103
obs.	1330	1321	1224	1191	1334
R^2	0.434	0.569	0.509	0.432	0.746

t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

thesis and estimates are shown in table 6. A couple of differences from the OLS estimates are noteworthy. The forest variable is now positive and significant in the pulp and paper industry, whereas cropland is insignificant. Both lead and zinc are negative in the non-ferrous metal industry. This might not be that surprising since both of them are in fact negatively correlated with the dependent variable. R-

variable in order to capture a time trend. However, the year variable turns out insignificant in most cases.

square ranges from 0.43 to 0.75. The little support for the PHH given in the OLS regression disappears and two industries, chemicals and non-metal mineral products, offer significant support for the PoH.

6.2 Robustness Checks

This section contains a number of robustness checks. First I differentiate the labour force according to skills level. Second, I limit the model to include only the covariates which to my knowledge are relevant in each industry. Thereafter I elaborate on different time periods. Lastly, influential data points are identified and their role investigated. The support for the PoH in the chemical and in the non-metal mineral products industry is robust.

Differentiated Labour Force

A reasonable assumption is that different production processes require different types of labour skills. Thus, I use the Barro Lee educational data to distinguish between skilled, medium skilled and unskilled labour where the workers have completed tertiary, secondary and primary education respectively, see table 7. The Barro Lee data is available every fifth year reducing the number of observations to around 200. The inclusion of differentiated labour groups clearly increases R-square in all industries compared to the main specification, in the chemical industry by as much as 0.2. Despite this, the coefficients for the different labour types have very mixed signs and do not come out significant, probably a result of the low number of observations. The support for the PoH is still significant in the chemical and in the non-metal mineral products industries as well as in the iron and steel industry. Significant support for the PHH is present only in the non-ferrous metal industry.

Restricted Specifications

Both the work by Tobey (1990), Wilson et al. (2002), Cole and Elliott (2003), Lu (2010), and Quiroga et al. (n.d.) use the same vector of covariates when investigating several industries. However, it is realistic to assume that different industries depend on different input factors. Thus, I include only the covariates which are, to my knowledge, directly relevant for the specific industry (see table 8). Note that cropland is dropped in all regressions. Leamer (1984) divides land into four different types (tropical, dry, humid mesothermal and humid microthermal land) in order to derive comparative advantages. I have not found time series on differentiated land which

Table 7: Robustness check: FE regression with differentiated labor force

	(1) IronSteel	(2) NonFerrMetals	(3) Chemicals	(4) PulpPaper	(5) NonMetMinProd
capital	-2.191**	0.185	-2.356***	-0.458	-2.432***
	(-2.16)	(0.32)	(-5.27)	(-1.04)	(-5.77)
labour (unskilled)	-6.082	-45.91	8.224	-23.07	5.499
	(-0.23)	(-1.14)	(0.38)	(-1.04)	(0.30)
labour (medium)	28.46	29.90	-16.51	-8.072	4.414
	(1.23)	(0.66)	(-0.59)	(-0.76)	(0.44)
labour (skilled)	-44.76	-67.23	38.53	-91.10	-27.06
	(-0.61)	(-0.77)	(0.82)	(-1.54)	(-0.64)
cropland	-57.09	-3.682	-6.543	33.53	-68.04***
	(-0.92)	(-0.07)	(-0.42)	(1.26)	(-3.09)
forest (prod)	33.34	-112.8	-141.2***	60.63	1.903
	(0.30)	(-1.46)	(-2.95)	(1.64)	(0.08)
fe	0.0159	0.0115	-0.00393	-0.00745*	-0.0184***
	(0.42)	(0.49)	(-0.48)	(-1.97)	(-4.02)
cu	-0.821*	4.976***	-0.259	0.0378	-0.404
	(-1.96)	(12.95)	(-1.06)	(0.13)	(-1.36)
pb	5.388	-17.45	10.89*	-5.315	-3.269
	(0.39)	(-1.20)	(1.95)	(-0.87)	(-0.63)
zn	0.813	-3.055	-3.906**	1.072	0.456
	(0.21)	(-1.13)	(-2.41)	(0.52)	(0.45)
coal	14.93	-7.803	-0.968	2.701	23.01***
	(1.26)	(-0.71)	(-0.24)	(0.50)	(4.69)
gasoil	-315.3	198.1	464.2**	254.0	594.4***
	(-0.85)	(0.73)	(2.10)	(0.84)	(2.74)
envendow	-0.833*	0.591*	-0.732***	-0.326	-0.867***
	(-1.82)	(1.97)	(-4.02)	(-1.31)	(-4.65)
year	-10.36	34.38	7.161	12.92	4.221
	(-0.47)	(1.18)	(0.21)	(0.95)	(0.54)
constant	22862.4	-67403.8	-11624.6	-25375.2	-7149.2
	(0.53)	(-1.19)	(-0.17)	(-0.95)	(-0.46)
clusters	65	65	65	62	65
obs.	218	218	201	203	219
R^2	0.497	0.678	0.708	0.456	0.818

t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

would cover the time period used here. Moreover, two of the industries analysed by Leamer are tropical/Mediterranean agricultural products and cereals, where land type presumably is an important factor. To my knowledge, none of the industries analysed here is directly dependent on cropland. Thus, the variable is excluded from the regressions in this specification.

Table 8: Robustness check: FE regression for restricted specifications

	(1) IronSteel	(2) NonFerrMetals	(3) Chemicals	(4) PulpPaper	(5) NonMetMinProd
capital	-0.491	-1.379*	-2.531***	-0.522	-1.411***
	(-0.75)	(-1.86)	(-3.56)	(-1.14)	(-2.87)
labour	-51.73	20.69	-52.18	11.97	0.343
	(-0.99)	(1.19)	(-1.33)	(0.72)	(0.02)
forest (prod)	–	–	-155.8**	39.42	–
			(-2.21)	(1.59)	
fe	0.0304	–	–	–	–
	(1.03)				
cu	–	6.429***	–	–	–
		(7.11)			
pb	16.21**	-9.846**	–	–	–
	(2.23)	(-2.20)			
zn	-0.225	-3.431	–	–	–
	(-0.08)	(-1.21)			
coal	-0.556	-1.192	3.566	1.143	13.90***
	(-0.10)	(-0.17)	(1.25)	(0.48)	(6.22)
gasoil	35.89	52.37	512.7**	267.7	532.7***
	(0.11)	(0.25)	(2.36)	(1.15)	(2.84)
envendow	0.270	0.160	-0.701**	-0.370	-0.465**
	(0.96)	(0.44)	(-2.36)	(-1.51)	(-2.38)
year	-21.03	30.84	2.047	1.839	-18.54**
	(-1.21)	(1.64)	(0.07)	(0.16)	(-2.31)
constant	42326.9	-62042.4	-618.3	-4122.8	36585.6**
	(1.23)	(-1.65)	(-0.01)	(-0.18)	(2.29)
clusters	103	103	101	99	103
obs.	1413	1406	1230	1197	1422
R^2	0.420	0.558	0.483	0.377	0.707

t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Forest is kept in the chemical and in the pulp and paper industry. Iron is only kept in the iron and steel industry and copper only in the non-ferrous metals industry. The four minerals are dropped from the chemical, pulp and paper and non-metal mineral products industries.

The $\hat{\delta}_j$ is fairly unaffected compared to the main specification. The same two industries, chemicals and non-metal mineral products, still obtain negative and significant coefficients for the environmental-endowment variable, offering support for the PoH.

Changed Time Periods

The support for the PoH in two industries (chemicals and non-metal mineral products) found in the main specification is robust to the inclusion of the years 1990–1994, where there are many missing values for the capital variable. I estimate the model according to the different specifications (the main specification, with differentiated labour force and the restricted specifications) for the years 1990–2012 and the sign and significance level of the $\hat{\delta_j}$ are altered only in very few cases.

In addition, I rerun the different specifications for two later time periods, 2000–2012 and 2005–2012, and here as well the support for PoH in the same two industries remains. In addition, there are tendencies for significant support for the PoH in the iron and steel industry as well as in the pulp and paper industry. In the specification with differentiated labour force the significant support for the PHH in the non-ferrous metal industry remains. Thus, the support for the PoH in the two industries seem robust to changes in time period but a more comprehensive analysis of the recent development during the '00s would be desirable.

Influential Data Points

Since all the independent variables are right skewed the data set is likely to contain a number of outliers and data points with high leverage. Especially countries with large endowments might have a high influence on the estimated slope coefficients. For instance, when comparing time-averages, the U.S. has the largest capital stock, twice as large as Japan which comes as number two. Chile has the highest production of copper, almost four times as large as the production in the U.S., the worlds second largest producer. When it comes to labour force, China and India are far ahead of all other countries. The environmental endowment is by far the largest in China, the U.S. and Russia.

Data points with high leverage are especially problematic when they concern the variable of interest. In order to identify countries possibly driving the results I plot residuals versus fitted values, leverage versus squared residuals as well each dependent variable versus each independent variable. I use the plots to identify a range of countries (21 to be exact) which might have a strong influence on the $\hat{\delta_j}$. The support for the PoH is robust to the exclusion of a number of countries one by one but it is worth having a closer look at the role played by China. When the main specification is estimated with China excluded from the sample, the support for the PoH increases (see table 9). The estimated $\hat{\delta_j}$ is now negative and significant

Table 9: Robustness check: FE regression with China excluded from sample

	(1) IronSteel	(2) NonFerrMetals	(3) Chemicals	(4) PulpPaper	(5) NonMetMinProd
capital	-1.335**	-2.296***	-2.506***	-0.805**	-1.572***
	(-2.31)	(-5.00)	(-2.86)	(-2.32)	(-4.23)
labour	50.13**	37.25*	-1.566	5.685	47.45***
	(2.50)	(1.92)	(-0.03)	(0.50)	(4.33)
cropland	-27.55	-116.6	-81.32*	50.01**	5.638
	(-0.47)	(-1.57)	(-1.80)	(2.07)	(0.28)
forest (prod)	94.02***	-118.5***	-177.0***	78.42***	-30.27**
	(3.41)	(-3.85)	(-3.67)	(6.25)	(-2.07)
fe	0.00148	0.0111	-0.0174	-0.00120	-0.000102
	(0.16)	(1.06)	(-1.53)	(-0.31)	(-0.03)
cu	-0.250	6.224***	-0.185	0.266	-0.164
	(-0.37)	(8.62)	(-0.39)	(1.05)	(-0.50)
pb	0.371	4.158	10.00*	-5.448	0.605
	(0.07)	(0.59)	(1.78)	(-1.14)	(0.21)
zn	2.488	-6.916***	-4.781**	2.378**	-0.0972
	(1.40)	(-3.00)	(-2.49)	(2.04)	(-0.11)
coal	-15.22	28.96*	10.05	-2.460	-1.232
	(-1.27)	(1.73)	(0.95)	(-0.50)	(-0.27)
gasoil	-433.3*	166.4	532.8**	184.0	385.3***
	(-1.69)	(1.01)	(2.20)	(1.28)	(2.91)
envendow	0.0323	-0.429*	-0.652*	-0.541***	-0.554***
	(0.13)	(-1.94)	(-1.81)	(-3.78)	(-3.97)
year	-11.72	32.54*	10.69	-4.808	-15.32***
	(-0.80)	(1.71)	(0.36)	(-0.44)	(-2.65)
constant	23588.8	-63527.7*	-18537.6	8999.2	30551.9***
	(0.81)	(-1.68)	(-0.31)	(0.41)	(2.65)
clusters	101	101	100	98	102
obs.	1312	1303	1206	1173	1316
R^2	0.225	0.409	0.404	0.437	0.366

t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

in all industries except for the iron and steel industry. This suggests that China is driving the results in favour of the PHH, especially in the non-ferrous metal and in the pulp and paper industries which become negative and significant only when China is dropped.

According to the PHH, a high environmental endowment (reflecting lenient regulations) leads to high levels of net export in pollution intensive industries. China has a large environmental endowment which increased by 108% between the years

1995 to 2012 (illustrated in figure 1). Given that the PHH is true, Chinese net export should have increased as well, especially in the two industries which become negative and significant when China is dropped. However, Chinese net export shows a steadily decreasing trend in non-ferrous metals and a modest but steady decrease in the pulp and paper industry (see figure 2). These findings are unexpected and difficult to explain. The net export is likely to be influenced by factors which are not covered by this data set, such as terms of trade, exchange rates or demand for the goods, and therefore difficult to analyse. Alternatively, there is a risk of misspecification, measurement errors or that the measure of environmental endowment does not capture what it is expected to capture.

Due to these incompatible results I take a closer look at the environmental endowment-variable. Given the generally accepted opinion that regulations are stricter in high-income countries (Copeland and Taylor, 1994; Dasgupta et al., 2001), I expect a rich country to have a lower environmental endowment than a poor country, ceteris paribus. To verify this, I calculate environmental endowment per capita and its correlation with constant GDP per capita. The correlation is 0.06 for the years 1995–2012. This way of reasoning might be too simplified but given the widespread belief in a positive correlation, this weak correlation could with advantage have been addressed in the original paper.

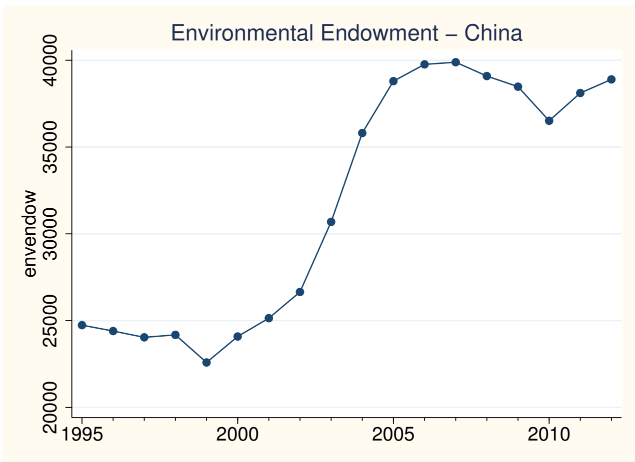

Figure 1: Development of Chinese environmental endowment

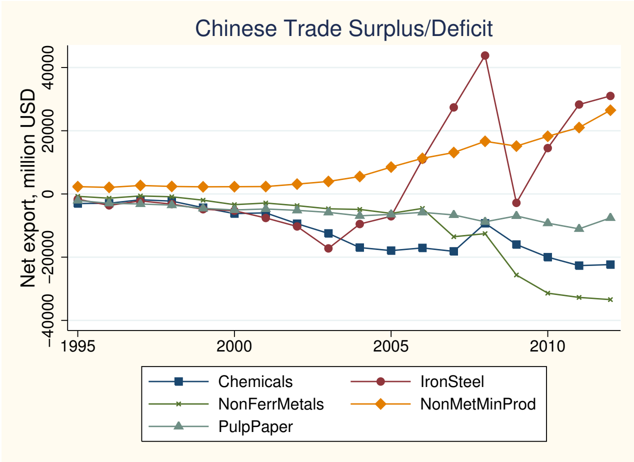

Figure 2: Development of Chinese net export

6.3 Economic Significance

In order to interpret the economic significance of the estimates above, one can either interpret the slope coefficient of the *envendow* variable or calculate elasticities. For the significant industries the $\hat{\delta}_j$ is around -0.6, predicting that a one unit increase in environmental endowment leads to a 0.6 unit decrease in net export. The environmental endowment is measured in thousand tonnes of SO_2 emissions. Net export is measured in million U.S. dollar. This means that if the environmental endowment increases by one thousand tonnes[10], net export would, on average, decrease by 0.6 million U.S. dollar. Thousand tonnes are approximately what very small nations like Aruba, Dominica or Guinea-Bissau emit yearly.

The second way to understand the economic significance of the estimates is to calculate the elasticities (ε). The elasticity is given by $\varepsilon = \frac{dY}{dX}\frac{X}{Y} = \hat{\delta}_j \frac{X}{Y}$. X and Y are the mean values for *envendow* and net export, respectively, given by the summary statistics in table 3. The elasticities from the two significant industries in the main regression (table 6) are calculated as follows:

$$\text{Chemical industry: } \varepsilon = -0.737 * \tfrac{1323}{-734} = 1.33$$

$$\text{Non-metal mineral products industry: } \varepsilon = -0.524 * \tfrac{1323}{50.3} = -13.8$$

In the chemical industry, the elasticity of 1.33 is positive even though the estimated

[10] Note that this is not equivalent to an increase in SO_2 emissions by thousand tonnes, since the environmental endowment is not directly proportional to SO_2 emissions due to the denominator in the measure (see section 4.3).

regression coefficient is negative. This arises from the fact that the elasticity is calculated with respect to *net* export and the mean net export is negative. In the non-metal mineral products industry, the elasticity is almost –14 meaning that a one percent increase in environmental endowment would, on average, decrease net export with 14%. This high elasticity is also a consequence of net export being the dependent variable. Even if export and import are high in absolute terms, they cancel each other out and the net export can be close to zero. A 14% increase in net export is not necessarily a large increase in absolute terms.

Although none of the interpretations is plain and simple, they both suggest that the economic significance of the environmental endowment on net export is at least not negligible.

6.4 A Reinvestigation of the Original Results

The estimates above contradict the support for the PHH found by Quiroga et al. (n.d.). In order to find an explanation of the discrepancies, I re-estimate the FE regression for the original time period (1990–2000) using the original variables (i.e., the original forest variable from the World Bank). I do not specify standard errors since Stata's default option is used in the original paper.

Estimates from the replication are seen in table 10 which can be compared to the original findings shown in table A2. In both tables, all industries except the pulp and paper industry show significant support for the PHH. The pulp and paper industry obtains a negative and significant coefficient for environmental endowment. The signs and significance levels of all the estimated slope coefficients correspond very well to the original findings even though the sample used is slightly different. The magnitude of the estimates differ from the originals' due to differences in measurement units.

There are two things to note. First, for the FE regression in original paper no specification is made regarding standard errors (although heteroskedasticity is present and the original pooled OLS regression employs robust standard errors). Arguably, it is reasonable to use clustered errors which are heteroskedasticity-robust but allow within-group correlation. When these standard errors are used, three industries have significant $\hat{\delta}_j$ coefficients: iron and steel along with non-metal mineral products are positive at 5% and 10% significance level, respectively. Pulp and paper is negative at 1% significance level. The last two industries are insignificant. Thus, the inclusion of clustered errors reduce the support for the PHH drastically.

The second thing to note is that Japan strongly drives the results, which is

Table 10: Replication of original FE regression 1990–2000

	(1) IronSteel	(2) NonFerrMetals	(3) Chemicals	(4) PulpPaper	(5) NonMetMinProd
capital	0.395*	-0.653***	-0.295	-0.653***	-0.720***
	(1.82)	(-4.56)	(-1.19)	(-3.88)	(-4.88)
labour	5.284	-27.65***	-12.20	-19.96**	24.02***
	(0.46)	(-3.61)	(-0.96)	(-2.20)	(3.05)
cropland	35.31	54.97***	21.95	91.49***	17.04
	(1.58)	(3.71)	(0.88)	(5.16)	(1.12)
forest (sqkm)	5.701**	9.015***	10.27***	0.749	7.819***
	(2.52)	(6.03)	(4.12)	(0.42)	(5.07)
fe	-0.00534	0.0427***	0.00288	0.0189**	0.0219***
	(-0.44)	(5.29)	(0.22)	(1.98)	(2.64)
cu	0.293	0.923***	0.328	0.0578	0.398***
	(1.61)	(7.67)	(1.64)	(0.41)	(3.21)
pb	12.72***	4.120***	6.114***	-0.496	3.505***
	(6.76)	(3.31)	(2.96)	(-0.34)	(2.73)
zn	-3.022***	-2.157***	-5.027***	-2.015***	-2.337***
	(-3.60)	(-3.88)	(-5.43)	(-3.09)	(-4.08)
coal	-17.93***	-13.42***	-7.961***	-5.375***	-13.80***
	(-6.81)	(-7.71)	(-2.76)	(-2.62)	(-7.69)
gasoil	-6.414	130.2***	-65.23	-6.023	100.3***
	(-0.11)	(3.48)	(-1.05)	(-0.13)	(2.60)
envendow	0.636***	0.337***	0.235**	-0.277***	0.480***
	(7.45)	(5.97)	(2.51)	(-4.17)	(8.26)
constant	-3768.4***	-3823.3***	-3856.1***	577.3	-4137.7***
	(-3.85)	(-5.87)	(-3.44)	(0.70)	(-6.24)
clusters	76	76	75	69	77
obs.	599	593	549	532	601
R^2	0.304	0.548	0.216	0.237	0.568

t statistics in parentheses

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

not acknowledged in the original paper. If Japan is excluded from the sample, the *envendow* coefficient is positive and significant only in the iron and steel industry (see table 11). In the chemicals and pulp and paper industries the coefficient is negative and significant. The non-ferrous metal industry and the non-metal mineral products industry obtain insignificant coefficients.

When Japan is excluded *and* country-clustered standard errors are used the $\hat{\delta_j}$ becomes insignificant in four of the industries. Only in the pulp and paper industry the coefficient is significant, with a negative sign. Thus, I argue that the support for

Table 11: Replication with robust standard errors and Japan excluded

	(1)	(2)	(3)	(4)	(5)
	IronSteel	NonFerrMetals	Chemicals	PulpPaper	NonMetMinProd
capital	-0.680	-1.866***	-2.516***	-0.774**	-2.024***
	(-0.88)	(-8.49)	(-3.22)	(-2.59)	(-4.34)
labour	11.12	-21.59**	1.972	-19.61	30.91**
	(0.59)	(-2.31)	(0.19)	(-1.33)	(2.03)
cropland	51.79*	74.22***	48.81*	93.67***	37.31**
	(1.77)	(3.71)	(1.95)	(3.30)	(2.28)
forest (sqkm)	4.995	8.280***	8.972**	0.688	6.958***
	(1.48)	(5.71)	(2.64)	(0.28)	(3.09)
fe	-0.00652	0.0416***	-0.000758	0.0188	0.0205**
	(-0.25)	(4.43)	(-0.04)	(1.33)	(2.59)
cu	0.0722	0.674***	-0.0252	0.0327	0.128
	(0.36)	(5.70)	(-0.16)	(0.24)	(0.95)
pb	12.52**	3.789*	6.046***	-0.582	3.160**
	(2.56)	(1.75)	(2.85)	(-0.19)	(2.13)
zn	-1.927*	-0.902	-3.091***	-1.876**	-0.972
	(-1.80)	(-1.35)	(-3.13)	(-2.02)	(-0.81)
coal	-13.74**	-8.670**	0.197	-4.863	-8.670**
	(-2.49)	(-2.39)	(0.03)	(-0.94)	(-2.09)
gasoil	-17.08	119.3	-64.94	-6.523	87.84
	(-0.32)	(1.27)	(-0.80)	(-0.06)	(1.39)
envendow	0.309	-0.0273	-0.373	-0.312***	0.0832
	(1.04)	(-0.29)	(-1.61)	(-3.05)	(0.68)
constant	-3105.4*	-2955.4***	-2365.6	579.2	-3233.8***
	(-1.95)	(-4.02)	(-1.51)	(0.49)	(-3.03)
clusters	75	75	74	68	76
obs.	588	582	538	521	590
R^2	0.335	0.708	0.349	0.241	0.677

t statistics in parentheses

* p<0.10, ** p<0.05, *** p<0.01

the PHH found in the original article is not robust.[11]

Since Japan seems to be a strong driver of the support for the PHH, I expect an increase (decrease) in environmental endowment along with an increase (decrease) in net export. However, as seen in figure 3 and 4, the environmental endowment decreased in Japan in the '90s (except for the years 1993–1995) whereas net export in most industries increased. This is unexpected given the finding that Japan drives the findings of Quiroga et al. (n.d.) in favour of the PHH.

[11] Japan is of course included in the original data set used in Quiroga et al. (n.d.) as well.

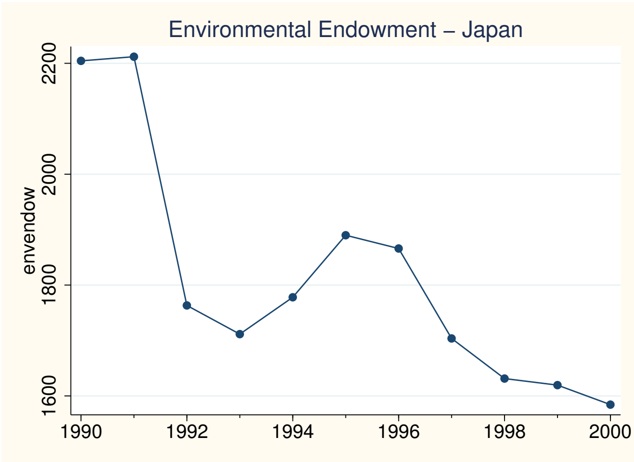

Figure 3: Development of Japanese environmental endowment during the '90s

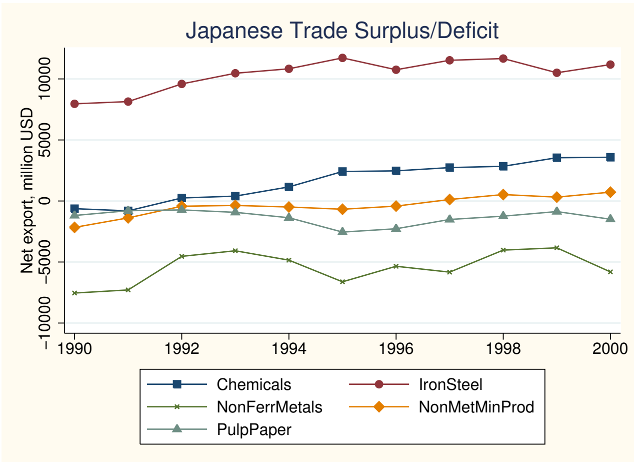

Figure 4: Development of Japanese net export

7 Conclusions

The results found in this thesis suggest that low-income countries are rarely turned into pollution havens. In the five pollution-intensive industries examined, the concentration of pollution-intensive industries does not seem to increase in low-income countries as a result of strict environmental policies in high-income countries, as argued by the PHH. Quite on the contrary, the chemical and the non-metal mineral products industries support Michel Porter's hypothesis that regulations can increase competitiveness of domestic firms and encourage export. Instead of being a disadvantage, regulations in these industries seem to give a comparative advantage, at least in the long run. This result is robust to a number of changes in the empirical specification.

The most common argument in the literature against the PoH is that the hypothesis leaves unexplained why firms do not undertake efficiency and innovation enhancing measures *before* the regulations are imposed on them. This argument rests upon the assumption that the measures are cost-reducing. I would like to object to this assumption and argue that far from all emission-reducing measures are cost-reducing since the emitting of pollutants often involve no or very low costs. In addition, it is many times difficult for a firm to predict how much an abatement technology will cost to introduce or how much more efficient the firm can become. I believe it is in many cases reasonable to expect that firms do not undertake measures in order to decrease emissions before they are prescribed to.

If strict environmental regulations indeed spur firms to innovation and efficiency, as argued by the PoH, environmental standards could be harmonised across the globe without hurting the industries in low-income countries. My results suggests that tighter regulations in the chemical and the non-metal mineral products industries could be beneficial to the own country. Regulations could enhance innovation and competitiveness in these two industries. However, the insignificant results for the iron and steel, non-ferrous metals and pulp and paper industries underline the importance of being cautious with general conclusions and policy advice.

For the time period 1995–2012, the estimated coefficient for the capital-variable is negative and significant more often than not. This might sound surprising given the general view that pollution intensive industries are also capital intensive. However, this finding is far from unique: studies by Wilson et al. (2002), Cole and Elliott (2003), and Lu (2010) examine four or five of the most polluting industries and the capital-variable turns out negative and significant in two, one and three industries, respectively. This supports the notion that natural resources, not capital, are the most important input factors.

The findings of this thesis show that this empirical application of the HOV framework is highly sensible to sample selection. I show that Japan is a strong driver of the support for the PHH found by Quiroga et al. (n.d.) for the time period 1990–2000 and that China strongly affects the estimated coefficients in favour of the PoH for the time period 1995–2012. Since the sample covering the later time period does not include Japan I cannot investigate its role during this period. The fact that one single country can have a large influence on the estimated coefficients might be a partial explanation to the mixed empirical evidence on the PHH found in the literature. I would like to stress the importance of careful investigation of influential data points in empirical studies in order to find countries which might drive the result. An alternative is to employ econometric techniques which assign less weight to extreme values.

On the basis of the robustness checks performed, I argue that the negative coefficient for the environmental endowment-variable is robust in two of the industries analysed. I have not performed similar robustness checks for the estimated slope coefficients of the covariates and I am therefore unable to assess to what extent they are driven by certain data points with high leverage.

Even though pollution havens seem to be a rare phenomenon, given the results in this thesis, one should not rule out the possibility that specific countries serve as pollution havens. My results indicate that Japan might have been a pollution haven during the '90s. Nonetheless, a weaknesses in this study is the inconsistent findings regarding the relationship between net export and environmental endowment, for both Japan and China. I believe that the inconsistencies should not be dismissed as a result of measurement errors, since the sources used are widely recognised as trustworthy. It is possible that other factors not covered by the data set, e.g., trade barriers, terms of trade and domestic and foreign demand, determine trade flows and cause biased estimates. However, the time trend in the model intends to mitigate such bias by controlling for a general globalisation trend. A more likely explanation to the inconsistent results relates to the aggregation level of the measure of environmental endowment. The development of Chinese environmental endowment illustrated in figure 1 shows the *national* endowment. It is possible that the environmental endowment rose sharply in the iron and steel as well as in the non-metal mineral products industry, and simultaneously decreased in the pulp and paper and non-ferrous metals industries. That would be consistent with the PHH and could explain the seemingly inconsistent result. A last possibility is that this measure is an insufficient reflection of the stringency of a country's environmental regulations. I find the very low correlation between environmental endowment per capita and GDP per capita troublesome. The original study by Quiroga et al. (n.d.) does not explicitly address the expectation on this correlation. I suggest a further study to carefully analyse the roles of China and Japan.

In my opinion, the main weakness in this field is that empirical studies (this thesis included) are generally indistinct in their expectations on estimated coefficients for the factor endowments. I would like to stress the importance of detailed knowledge of the industries in order to give well-motivated expectations on each coefficient. This would improve the credibility of empirical studies. In addition, better knowledge about how input factors are used in different industries would enable researchers to customise the covariate vector in each regression.

Some studies in this branch of literature model regulations as endogenous to trade flows, arguing that a reversed causality causes downward bias in exogenous models. In this thesis, the environmental endowment is exogenous to trade flows under the argument that a country's total environmental endowment is unaffected by trade flows in one single industry. However, this assumption might be violated if one industry is very important for a country as a whole. For instance, the pulp and paper industry is of great importance to the Swedish economy, and it is possible that a decreased export in this industry would affect regulations and environmental endowment. Thus, I suggest a study with endogenous environmental endowments and simultaneous equations, similar to Cole and Elliott (2003). Yet another aspect to analyse is whether there is a lag between the factor endowments and their effect on net export. If, for instance, new regulations alter the environmental endowment the net export might be affected first after a year, or more. Lagged net export might be better explained by the model than contemporaneous net export.

My last suggestion for further research is to update the empirical method and verify its contemporary relevance. Researchers have continued to focus on the five industries identified by Tobey in 1990 with data from 1977, even though these are not necessarily the most relevant when analysing the most polluting industries in recent decades. Moreover, the factor endowments normally included in empirical studies were developed by Leamer in 1984 and build (among others) upon contemporaneous data availability and economic importance. This is likely to have changed during the passed decades. An analysis of the world as it looks today is, of course, of uttermost importance to the policy makers of today.

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Appendix A: Tables

Table A1: List of 103 countries included in the sample for the time period 1995–2012. Countries listed according to income (inc.) group

Low inc.	**Lower middle inc.**	**Upper middle inc.**	**High inc. non OECD**	**High inc. OECD**
Benin	Armenia	Albania	Argentina	Australia
Burundi	Bangladesh	Algeria	Brunei Darussalam	Austria
Cambodia	Bolivia	Belarus	Croatia	Belgium
Gambia	Cameroon	Belize	Cyprus	Canada
Madagascar	Egypt	Botswana	Latvia	Chile
Mali	El Salvador	Brazil	Lithuania	Czech Republic
Mozambique	Georgia	Bulgaria	Malta	Denmark
Rwanda	Honduras	China	Russia	Estonia
Tanzania	India	Costa Rica	Singapore	Finland
Togo	Indonesia	Cuba	Trinidad and Tobago	France
Uganda	Kenya	Dominican Republic	Uruguay	Greece
	Kyrgyzstan	Ecuador	Venezuela	Hungary
	Lesotho	Gabon		Israel
	Moldova	Iran		Italy
	Morocco	Jordan		Luxembourg
	Nigeria	Kazakhstan		Netherlands
	Pakistan	Lebanon		New Zealand
	Philippines	Malaysia		Norway
	Senegal	Mauritius		Poland
	Sudan	Mexico		Portugal
	Swaziland	Namibia		Slovakia
	Ukraine	Panama		Slovenia
	Vietnam	Paraguay		South Korea
		Peru		Spain
		Romania		Sweden
		Serbia		Switzerland
		South Africa		United States
		Thailand		
		Tunisia		
		Turkey		

Table A2: Estimates from *Pollution Haven Evidence in most Polluting Industries* by Quiroga et al. (my formatting). The variable SO_2 corresponds to *envendow*.

Fixed Effect Panel Data Estimation 1990–2000
(Dependent variable: thousands of U.S. dollars of annual nex export 1990–2000)

	Iron and steel	Non-ferrous metals	Chemicals	Pulp and paper	Non-metallic mineral products
Capital	-81	-865***	-1073***	-812***	-1085***
	(222)	(151)	(350)	(156)	(148)
Labor	0	0***	0	0	0**
	(0)	(0)	(0)	(0)	(0)
Crop	46	30	-72	24	40**
	(31)	(21)	(49)	(22)	(21)
Forest	4**	4***	7**	-3**	6***
	(2)	(1)	(3)	(1)	(1)
Copper	0	0	0	0	0*
	(0)	(0)	(0)	(0)	(0)
Iron	-14	35***	-17	-1	24***
	(13)	(9)	(20)	(9)	(8)
Zinc	-5***	-4***	-5***	-3***	-5***
	(1)	(1)	(2)	(1)	(1)
Lead	13***	8***	7*	3*	8***
	(2)	(2)	(4)	(2)	(2)
Coal[a]	-7***	-8***	-1	-3*	-10***
	(2)	(1)	(3)	(1)	(1)
Gasoil	0**	0***	0	0***	0
	(0)	(0)	(0)	(0)	(0)
SO_2	643***	706***	781***	-327***	660***
	(132)	(90)	(208)	(-93)	(88)
Const[a]	-2484***	-1431***	-1862	1839***	-3177***
	(774)	(526)	(1219)	(543)	(516)
Observ.	613	613	613	613	613
Groups	78	78	78	78	78

Notes: Standard deviation is reported in parentheses.

*, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively.

[a]Coefficients and standard deviation are expressed in thousands.