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THREE ESSAYS ON EXPORT CONCENTRATION, INTERNATIONAL ENVIRONMENTAL AGREEMENTS, AND THE CARBON CONTENT OF TRADE

Mihai Paraschiv
University of Kentucky, mihaiparaschiv85@outlook.com
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Mihai Paraschiv, Student

Dr. Josh Ederington, Major Professor

Dr. Jenny Minier, Director of Graduate Studies

THREE ESSAYS ON EXPORT CONCENTRATION, INTERNATIONAL ENVIRONMENTAL AGREEMENTS, AND THE CARBON CONTENT OF TRADE

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Business and Economics at the University of Kentucky

By
Mihai Paraschiv
Lexington, Kentucky

Director: Dr. Josh Ederington, Professor of Economics
Lexington, Kentucky 2016

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ABSTRACT OF DISSERTATION

THREE ESSAYS ON EXPORT CONCENTRATION, INTERNATIONAL ENVIRONMENTAL AGREEMENTS, AND THE CARBON CONTENT OF TRADE

A common finding in the international trade literature is that economic integration leads to export diversification. By documenting a positive link between joining the European Economic and Monetary Union and bilateral export concentration, the leading essay shows that this is not always the case. Using a panel data approach, I find that exports between the Eurozone members are on average more concentrated than those among countries which do not share the euro. Central to this outcome is that some economic integration agreements, such as the European Economic and Monetary Union, may lead to a drop in not only trade but horizontal FDI costs as well. Theoretically, the results can be explained by the substitutability between exporting and horizontal FDI within a two-sector, two-firm type model which allows for sectoral trade cost heterogeneity.

Since the early 1970s, a series of international environmental agreements (IEAs) were signed, ratified, and enforced throughout the developed and developing nations. Regarding IEAs as potential barriers to trade, the second essay seeks to quantify their impact on industry-level exports by using a gravity regression approach. I proceed by classifying industries into dirty and clean based on their average emission intensities and find that the ratification of IEAs is associated with a significant reduction in export flows. The decrease is more pronounced for industries which are classified as dirty or for those which are characterized by high emission intensities per unit of output. Additionally, climate change IEAs bring about a compositional shift towards cleaner exports. Lastly, climate change and acid rain IEAs are found to engender leakage effects. No such evidence is recovered for ozone depletion accords.

The third essay adds to the literature on the Kyoto protocol and the carbon content of bilateral trade. It does so by analyzing the effect of ratifying the Kyoto protocol on exports, the carbon dioxide (CO_2) intensity of exports, and the CO_2 emissions embodied in exports within a novel dataset of 149 countries. For parties that took on binding emission caps, the ratification of Kyoto protocol leads to (*i*) lower CO_2 emissions embodied in exports, (*ii*) lower CO_2 emission intensities, but (*iii*) higher overall exports. For the same group of countries, a year-by-year analysis underlines a permanent decline in both the CO_2 emission intensity and the CO_2 content of their exports. Furthermore, the analysis also points out to a short-run decline in exports. In the long run, however, exports are estimated to recover. Also, the commitment type or whether a party was designated as a transition economy at the time of ratification are found to shape the above three outcomes.

KEYWORDS: gravity; euro; economic integration; international environmental agreements; carbon content of trade

Author's signature: Mihai Paraschiv

Date: July 26, 2016

THREE ESSAYS ON EXPORT CONCENTRATION, INTERNATIONAL ENVIRONMENTAL AGREEMENTS, AND THE CARBON CONTENT OF TRADE

By
Mihai Paraschiv

Director of Dissertation: Dr. Josh Ederington

Director of Graduate Studies: Dr. Jenny Minier

Date: July 26, 2016

To my parents, Ion and Ioana, and to my brother Sorin, all to whom I am greatly indebted towards.

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Chapter 1 Introduction

This dissertation contributes to two major branches of the international trade research. The first essay is aimed at better understanding the response of exporting activities to engagement in economic integration agreements (EIAs). This analysis may be of added importance given the growing tendency of sovereign nations to participate in this particular type of accords. For instance the Trans-Pacific Partnership (TPP), a trade agreement, was signed earlier this year and expected to enter into force no later than 2018. Even more, the Trans-Atlantic Trade and Investment Partnership (TTIP), a trade and investment arrangement, is currently being negotiated by the United States and the European Union. The second and third essays add to the literature on international environmental agreements (IEAs) and their competitiveness effects. The third essay also contributes to the small, but rapidly growing, body of literature concerning IEAs and their effect on the emission content of trade. The results it brings forward may also carry additional value for Kyoto parties which, under the protocol's Doha amendment, took on emission targets for the 2013-2020 period.

The first essay evaluates the link between economic integration agreements (EIAs) and export diversity. Since 1950 world trade has increased by a factor of twenty seven (Hoekman, 2015). To a large extent, this unprecedented pattern owes itself to global and regional economic integration efforts which lowered trade and investment costs alike. Between 1958 and 2015 more than 263 trade agreements, covering both goods and services, have entered into force. Even more bilateral investment agreements, 2270, were enforced over the same period (UNCTAD IIA Database). In 1983, 68 countries were part of currency unions. This figure remained relatively unchanged for the next two decades only to increase starting in 1999, when the euro was introduced in eleven European countries[1]. Since then, an additional eight nations have adopted the euro currency and others are likely to join in the near future. These international arrangements can be simply categorized as trade and financial integration accords or more generally as economic integration agreements. With these trends set to continue it is important to further evaluate the effects of integration on economic activities.

Often times, economic integration is associated with increased export diversity. However, the first essay shows that this is not always the case, and that whether integration leads to export diversity depends on each EIA type in part. This essay contributes to the international trade literature in two major ways. *(i)* It develops a theoretical framework in which, aside from trade costs, the EIAs' effects on the diversification pattern of bilateral exports are also shaped by horizontal foreign direct investment (FDI) costs. In turn, the model yields two testable predictions. On one hand, if the decline in investment costs exceeds the drop in trade costs, the EIA under scrutiny should induce bilateral export concentration rather than diversifica-

[1] The count of trade agreements and currency unions are based on the Regional Trade Agreements

tion. Deeper integration agreements such as the formation of economic and monetary unions should square well with this description. For example, the European Economic and Monetary Union (i.e., the Eurozone) has been found to reduce horizontal FDI costs relatively more. On the other hand, EIAs which engender a relatively larger reduction in trade costs should lead to a diversification of export flows. Shallow integration accords such as free trade agreements are most likely to fit this depiction. This key theoretical insight should not be at all surprising given that, more often than not, horizontal FDI is regarded as a substitute for trade. But despite this, horizontal FDI costs as a potential determinant of export diversification has been overlooked by previous studies. *(ii)* Guided by the theoretical insights, the first essay also shows that the Eurozone formation had a negative effect on bilateral export diversification. Specifically, exports between Eurozone members are, on average, more concentrated than similar flows between countries which do not share the euro. Conversely, joint membership within regional trade agreements leads to more diverse exports. This evidence suggests that export diversification responds differently to each EIA type and that a case-by-case evaluation of EIAs goes a long way in accurately assessing their effects on the diversity of trade. To the best of my knowledge, this represents the only study which quantifies the effect of joining the Eurozone on bilateral export diversification.

The second essay seeks to evaluate the potential competitiveness effects of international environmental agreements (IEAs). The adoption of IEAs by national governments started to gain momentum during the early 1970s. However, the environmental policies pursued post-ratification are often publicized as sources of additional production costs (e.g., investment expenditures with energy efficient machinery, acquisition of filters, or adjustment of production processes) and comparative disadvantage. Moreover, the classic theory of trade postulates that nations specialize in the production and exportation of goods at which they have comparative advantage. The scenario in which trade classics are correct coupled with that in which environmental regulation is a source of comparative disadvantage lie at the heart of the arguments linking IEAs with losses of international competitiveness. This kind of logic was invoked numerous times throughout the recent past. In fact, the arguments made by the United States for not adopting the Kyoto protocol, or by Canada to back out of it, were based on this very idea. The second essay evaluates this reasoning by estimating the effect of IEAs adoption on industry-level exports. This analysis differs, however, from those in other studies along two important margins. *(i)* The focus is placed onto the count of adopted IEAs as a measure of a country's environmental commitment. This way, thirteen air pollution IEAs spanning three major categories (i.e., climate change, acid rain, and ozone depletion) are investigated. *(ii)* The present work considerably expands the data universe of previous studies to 163 nations and 36 years, 1976-2011.

In doing so, a number of potentially interesting results are revealed. These are broadly summarized in three points. First, the ratification of IEAs is found to be

and Currency Unions Datasets constructed by José de Sousa (de Sousa, 2012).

a relatively large source of comparative disadvantage for pollution-intensive sectors. Second, different types of IEAs are found to bring about composition and/or scale effects[2]. For example, climate change IEAs involve a strong export composition effect. This kind of IEAs (i.e., the Kyoto protocol) is found to be a rather modest source of comparative disadvantage for pollution-intensive industries but a notable source of comparative advantage for their least polluting peers. Acid rain and ozone depletion IEAs appear to entail export scale effects. In this regard, acid rain IEAs show up as a large source of comparative disadvantage for pollution-intensive industries. It is not clear whether they harm or benefit the least pollution-intensive sectors. Ozone depletion IEAs are found to generate even larger effects. Last but not least, only climate change and acid rain IEAs are found to engender "leakage"[3] effects. Evidence of "leakage" is not found with regards to ozone depletion IEAs. This very last set of results is in line with the international trade rules aimed at reducing "leakage" and included within the ozone depletion accords.

The third essay assesses the effect of the Kyoto protocol on the carbon content of exports. World trade has been growing at unprecedented pace over the past 65 years but, with it, so did the greenhouse gas (GHG) emissions embodied in exports and import flows. Potentially worrisome, these gains are found to be rather large and to increase rapidly (Hertwich and Peters, 2008a; Peters et al., 2011; Sato, 2012). On a related note, the Kyoto protocol is an IEA designed to tackle GHG emissions with the end objective of limiting and reversing climate change. As part of the accord some parties took on quantitative emission reduction or limitation commitments (QERLCs) and pledged to meet these targets by the end of 2012. The third essay evaluates the effect of adopting Kyoto QERLCs on the carbon dioxide (CO_2) content of exports. It also evaluates the commitment effect on exports and their CO_2 intensity. This work complements the literature on the Kyoto protocol and the carbon content of bilateral trade in several ways. *(i)* It extends the scope of Aichele and Felbermayr (2015) by using the relatively new EORA26 dataset. This way, the effect of Kyoto commitment on the carbon content of exports is estimated in a sample comprising 149 nations, observed between 1995 and 2012. It is worth mentioning that Aichele and Felbermayr (2015) benefit from a sample comprising only 40 countries during the 1995-2007 period. The inclusion of the 2008-2012 time frame is of paramount importance as the QERLCs become legally binding during this time span. Also, any long-run effects are most likely masked by disregarding this time window. *(ii)* A year-by-year analysis is used to evaluate any adjustments that may prevail post-ratification. *(iii)* It investigates whether the outcomes of interest (i.e., carbon content of exports, exports, and the CO_2 intensity of exports) are determined by the QERLC type or by whether a party undergoes the process to transition to a market economy. The analysis of QERLC type gains even more importance as parties have committed

[2]The composition effect refers to changes in the export bundle brought about by the adoption of IEAs (e.g., exports from "clean" industries increase whereas those from "dirty" sectors decline). The scale effect refers to the changes (increase/decrease) in overall level of exports.

[3]"Leakage" refers to the situation in which an environmentally committed jurisdiction increases

to future targets that are to be met by 2020. On a secondary note, this work also adds to the literature on IEAs and their competitiveness effects.

The expansion of the data universe leads to a series of novel and interesting results. First, the inclusion of the 2008-2012 time frame brings to light a significant and positive effect of Kyoto commitment on export flows. Meanwhile, the effect recovered by disregarding this time period is virtually null. Furthermore, both the CO_2 intensity of exports and the carbon content of exports are found to decrease notably for committed parties. This set of results points out to an export "clean-up" effect that is attributable to the Kyoto protocol. Second, the time series analysis brings into view an export adjustment process that prevails throughout the post-ratification period. Specifically, exports are found to decline during the first three years, only to rebound thereafter. Of potential importance to policy-makers, this finding suggests that committing under the Kyoto protocol entails only a short spell of competitiveness loss. The CO_2 intensity of exports and the carbon content of exports, on the other hand, are found to decrease continuously after ratification. Third, the ratification effect on the outcomes of interest is larger for parties which pledged to reduce emissions. Additionally, and contrary to prior beliefs, the final set of results suggest that the transition economies significantly reduced both the CO_2 intensity and the carbon content of their exports.

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its imports of pollution-intensive wares.

Chapter 2 Economic Integration and Bilateral Export Concentration: The Case of the Eurozone

2.1 Introduction

Do economic integration agreements (EIAs) always foster bilateral[1] export diversification? As this paper will show, the answer is 'it depends on each EIA type'. To the best of my knowledge there exists only one other study Regolo (2013) which documents the connection between economic integration and bilateral export diversification both theoretically and empirically. Specifically, she finds that exporter-importer economic integration is positively associated with bilateral export diversity. However, this finding is to some extent incomplete. Theoretically, this is due to the omission of horizontal foreign direct investment (FDI) costs as determinants of export diversification. Empirically, the finding originates in the use of an aggregate bilateral integration measure[2] which implies that all EIAs have the same effect on bilateral export diversification. Ultimately, this ends up masking important dynamics concerning the concentration pattern of bilateral commerce flows. In this regard, I show that economic integration in the form of regional trade agreements (RTAs) fosters export diversification, just as in Regolo (2013). However, the formation of economic and monetary unions such as the Eurozone (EZ)[3] accomplishes the opposite.

I start by theoretically documenting that the effect of international EIAs on bilateral export concentration is a function of not only trade Regolo (2013) but horizontal FDI costs as well. In this context, an EIA which leads to a relative drop in trade costs should promote bilateral export diversification. At the same time, the exact opposite is true for an EIA which entails a relative decline in horizontal FDI costs[4]. As a consequence, each EIA may have a different impact on the diversification pattern of bilateral exports. Although novel, this key theoretical insight should not be at all surprising given that horizontal FDI is often regarded as a substitute for trade (Brainard, 1997; Yeaple, 2003; Helpman, 2006). Despite this, horizontal FDI costs as potential determinants of export diversification have been overlooked by previous

[1] The term "bilateral" is key in differentiating the current work from the rest of the literature. Most of the work regarding the link between economic integration and export diversification has been focusing on a "country year" instead of a "country-pair year" analysis. The current study is aimed at filling this gap. Note that studies on the intensive or extensive margins of trade can also be seen as inquiries into bilateral trade concentration/diversification. The current work and that of Regolo (2013) differ from these in that the dependent variable is an index of bilateral export concentration which simultaneously comprises both the extensive and intensive margins of trade.

[2] This variable ranges from 0 to 6 and represents a collection of EIAs. Level 0 signals no integration whatsoever whereas level 6 denotes participation in economic and monetary unions; in this case the Eurozone.

[3] European Economic and Monetary Union, adopting the euro, Eurozone or simply EZ are used interchangeably throughout

[4] See Flam (2009); Coeurdacier et al. (2009)) for empirical evidence regarding such asymmetries.

studies.

According to the theoretical model developed in this paper, an EIA which generates a relatively larger decline in horizontal FDI costs should induce bilateral export concentration; not diversification. One economic integration agreement that seems to fit this profile is the European Economic and Monetary Union. Studies by Petroulas (2006); Schiavo (2007); Dinga and Dingova (2011); de Sousa and Lochard (2011) emphasize a positive and statistically significant impact of adopting the euro on intra-Eurozone FDI flows[5]. Moreover, Coeurdacier et al. (2009) uncover a sizable, positive, and statistically significant effect of switching to the euro on bilateral horizontal FDI flows. These estimates are substantially larger than those found within studies aimed at quantifying the Eurozone effect on bilateral trade (Flam, 2009). A possible explanation for these findings is that joining the Eurozone generated a relatively larger drop in horizontal FDI costs as opposed to trade costs. If this is the case, does joining the Eurozone lead to bilateral export concentration; as the theoretical model points out?

The current work answers the above question by using the recently updated Economic Integration Agreement Dataset; a newer version of the one used in Regolo (2013)[6]. Empirically, I find that the European Economic and Monetary Union had a positive effect on bilateral export concentration. Specifically, exports between Eurozone members are on average 4.2%-7.5% more concentrated than those among countries which do not share the euro. Conversely, joint membership within regional trade agreements leads to more diverse exports. This evidence suggests that bilateral export concentration responds differently to the EIA type under consideration, and that a separate assessment of EIAs goes a long way in accurately assessing their impact on export concentration patterns.

The present work adds to the international trade literature in two major ways. First, to the best of my knowledge, this represents the only study which quantifies the effect of joining the Eurozone on bilateral export concentration. Contrary to the common belief that economic integration stimulates export diversity, the current essay finds that joint Eurozone participation accomplishes the exact opposite. Second, I theoretically show that, in addition to trade costs the concentration of bilateral exports also depends on horizontal FDI costs. In this regard, the empirical results discussed above can be explained by the substitutability between exports and horizontal FDI as means of serving foreign markets. I am not aware of any other work that considers this trade-off when analyzing export concentration patterns. Along these lines, EIAs which lead to a relatively larger drop in horizontal investment costs, such as the European Economic and Monetary Union, are expected to generate export concentration. The empirical and theoretical results outlined above complement the study of Regolo (2013). Specifically, these suggest that EIAs should be considered separately, rather than bundled, when assessing their effect on bilateral export concentration and that bilateral export concentration is a function of both trade and

[5]These studies do not distinguish between horizontal and vertical FDI.

[6]This dataset is assembled by Jeffrey Bergstrand as part of the NSF-Kellogg Institute Database

horizontal FDI costs.

Analyzing how EIAs shape export concentration patterns is important for several reasons. Nations are becoming more integrated from an economic perspective and this pace has accelerated during the past two decades[7]. Since 1999, when the first 11 European Union (EU) members adopted the euro, an additional 8 countries joined the economic and monetary union and others are likely to follow in the near future. The primary goals of these transnational arrangements are underlined by reductions in both international trade and investment costs. In the light of the above, there is no doubt that national economies have become more integrated over the past 20 years. And, with these trends set to continue, it is of prime importance to further scrutinize the effects of integration on economic activity. The importance of diversification has been emphasized by the modern portfolio theory and is nested within the idea that "placing all eggs into one basket is risky". Economists and policymakers alike adopted the idea in order to emphasize the benefits of a diversified export base. Evidence linking export concentration with lower growth prospects and increased output volatility is discussed by Kalemli-Ozcan et al. (2003) and Cadot et al. (2013). According to Samen (2010), employment, price stability, capital flows and foreign exchange reserves may also be adversely affected by the lack of export diversification. A United Nations Development Programme (2011) report identifies trade links as the primary shock propagation channel with the degree of export concentration governing its amplitude. From this perspective, export diversification should be regarded as a defensive buffer against such imbalances. A concentrated export structure would accomplish the exact opposite Haddad et al. (2013). The topic has even deeper implications for the Eurozone as a whole, mainly due to its design. Should members be asymmetrically exposed to economic shocks, the European Central Bank's monetary policy would be significantly harder if not impossible to implement on an equitable and equidistant basis.

Traditionally, the connection between economic integration and export concentration has been analyzed at the country rather than country-pair level. Rose and Engel (2002) analyzed the connection between common currencies and country-level export concentration and concluded that members of currency unions are not more specialized in comparison to non-members. Since their dataset spans the period between 1970 and 1995 no inferences can be made with regards to the Eurozone. Furthermore, Agosin et al. (2012) underline economic remoteness, trade openness and distance as key determinants of export concentration. Using trade-weighted tariffs as a measure of trade integration between Canada and the U.S., Beine and Coulombe (2007) uncover an inverse relationship between trade costs and export diversification. Making use of a similar approach, Crabbe and Beine (2009) reach a rather different conclusion

on Economic Integration Agreements Project and available at www3.nd.edu/ jbergstr/ The dataset was updated on September 30^{th}, 2015 to include the 2006-2012 period. It was previously available for the 1950-2005 interval. A complete description of this dataset is provided in section A.1.2.

[7] Between 1958 and 2015, 263 international trade agreements have entered into force. 83% of these have been implemented since 1995. Even more bilateral investment agreements were enforced over the same period. Out of the 2,270 agreements that entered into force, 90% did so during

when investigating a set of Central and Eastern European nations between 1989 and 2000. More specifically, a 1% decline in tariffs is linked with a 1.3% increase in export concentration in the long run. In contrast, this paper studies the effect of EIAs on export concentration at the country-pair rather than country level. This is important because trade is a bilateral rather than a unilateral process for which country-pair and importer characteristics matter just as much as those of the exporter. Understanding the overall export concentration/diversification pattern of a nation requires knowledge about the concentration/diversification of its bilateral exports.

Other studies have focused on export diversification as defined by variations of the intensive or extensive trade margins. Amurgo-Pacheco and Pierola (2008) analyze the topic of diversification by decomposing trade flows into combinations of new/old products and new/old destination markets. Along these dimensions, trade activity seems to be notably shaped by trade costs and destination's market size. Beverelli et al. (2015) provide similar results by emphasizing that trade facilitation exhibits a positive effect on the extensive margin of trade and thus on diversification. Following a similar methodology, Dennis and Shepherd (2011) reach comparable results[8]. According to their findings, export diversification is influenced negatively by market entry costs, exporting fixed costs, and distance. Conversely, sectoral demand and supply capacities as well as per capita GDP within the origin and destination countries positively affect the diversity of outflows. More specifically, they found that a reduction of exporting costs by 10% leads to 3-4% more diverse exports. The direction of this effect is also in line with the findings of Cadot et al. (2013) who survey a positive link between trade liberalization and export diversification. This paper however focuses on concentration indexes[9] as opposed to either the intensive or extensive margin of trade, as the primary objective consists in analyzing overall diversification patterns. From a definitional perspective, bilateral concentration indexes combine the two margins and offer a more complete picture on the concentration pattern of bilateral exports. Disentangling the effect of economic integration on export diversification becomes even more important in the light of Baier et al. (2014) and Soete and Van Hove (2015). Both studies emphasize an asymmetric effect of EIAs on the extensive and intensive margin of trade.

The current essay consists of a theoretical section and its empirical application. Specifically, section 2.2 introduces a theoretical model of bilateral export diversification in the presence of economic integration. The data, empirical methodology, and the results are shown in section 2.3. Section 2.4 is aimed at demonstrating the robustness of these findings while section 2.5 concludes.

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or after 1995 (UNCTAD IIA database; http://investmentpolicyhub.unctad.org/IIA). In 1958, the number of countries sharing a common currency stood at 120. This dropped to 68 by 1983, remained unchanged for the next two decades only to start rising since 1999, when the euro was first introduced. Information on bilateral trade agreements and joint currency union membership were obtained from Jose de Sousa's website (http://jdesousa.univ.free.fr/data.htm).

[8]This study also considers a Hirschmann-Herfindahl index, but does so very briefly.

[9]A consensus on how to accurately measure export concentration has not yet been reached. In order to mitigate this issue Hirschmann-Herfindahl, Theil, and Gini indexes of bilateral export

2.2 Theoretical Framework: Economic Integration, Exporting, and Horizontal FDI

In what follows, a theoretical model of bilateral export concentration is introduced. The purpose of this framework is to place more structure on the link between economic integration and concentration of bilateral trade flows. This is accomplished by emphasizing the substitutability between exports and horizontal foreign direct investment as means of serving external markets[10]. The starting point is the premise that economic integration agreements are likely to lower both trade and horizontal cross border investment costs[11]. This aspect is important because, as shown throughout, a drop in the two cost categories can generate opposite effects on export concentration patterns. Along these lines, an integration agreement which leads to a larger drop in horizontal FDI costs relative to trade costs is expected to entail more concentrated exporter-importer trade flows. Conversely, a larger drop in trade costs is expected to foster export diversification. The theoretical contribution therefore consists in showing that bilateral concentration is a function of not only trade but horizontal FDI costs as well. The proximity-concentration trade-off is then used to explain the impact of economic integration on bilateral export concentration.

In setting up the model I draw on the work of Krugman (1980) and Markusen and Venables (2000). I start by considering two symmetric countries Home (H) and Foreign (F). Additionally, there are two industrial sectors which are assumed to only differ in trade costs (τ) and the fraction of exporting firms (γ). More specifically, I distinguish between sectors characterized by low and high trade costs. Horizontal FDI costs (f) are incorporated in the model such that $\gamma(\tau, f)$[12]. Without the loss of generality, the fraction of exporting firms in the low-τ sector (γ_l) is assumed to be 1[13,14]. Each sector's output is characterized by one differentiated good that is being produced in n varieties using a single factor of production, labor. As it is common for this type of models, within each sector s, each firm produces one unique variety, i. The array of sectoral characteristics introduced above will ultimately determine how the typical firm in each sector decides to serve foreign consumers. On one hand, by engaging in horizontal FDI a firm may duplicate its production activities in a foreign country by incurring a set of fixed costs. Since exporting is a costly activity, this strategy allows the multinational firm to avoid any trade related costs. On the other hand, firms can choose to supply foreign markets by exporting. In this case, the firm is bound to incur the trade costs mentioned above.

concentration are considered. Of course, many other indexes are available but these are the most common. For a survey on concentration/diversification indexes see Palan (2010).

[10]In the literature, this is also known as the proximity-concentration trade-off.

[11]A significant amount of evidence exists in this regard and part of it is discussed in section 2.3.1.

[12]$\frac{\partial \gamma}{\partial \tau} < 0$ and $\frac{\partial \gamma}{\partial f} > 0$. Allowing the fraction of exporting firms to depend on trade and horizontal FDI costs, by explicitly accounting for the latter, is one of the main differences between the current theoretical framework and that of Markusen and Venables (2000).

[13]Parameters associated with the low trade cost sector are denoted by subscript l whereas those pertaining to the high trade cost sector are marked by subscript h, respectively.

[14]Trade costs in the low-τ sector are assumed to be low enough such that every firm in this sector

In the light of the above, the model yields two predictions, both with profound implications regarding the concentration pattern of trade flows between H and F[15]. First, as trade costs between H and F drop, more firms in the high-τ sector will seek to engage in exporting activities. As a result, the share of this particular sector in total exports will rise relative to that of its counterpart. Given that exports within the high-τ sector are relatively low to begin with, this dynamic will lead to a convergence in export shares and, as a result, a more diverse export basket. Second, as horizontal FDI costs drop, the incentive for firms within the high-τ sector to serve external markets this way will increase, while exporting becomes less desirable. Ultimately, this is equivalent to lower sectoral exports and a divergence in sectoral export shares. As a direct consequence, exports flowing from H to F are expected to become more concentrated overall. The decision about how individual firms serve domestic and foreign markets (e.g. exporting or horizontal FDI) is outlined by solving the demand and supply side optimization problems.

2.2.1 Preferences

As it is common, the demand side is underlined by consumers with identical preferences. More specifically, it is represented by a standard upper-tier Cobb-Douglas utility function and a Dixit-Stiglitz, constant elasticity of substitution, sub-utility function. Without the loss of generality, total expenditure shares allotted for each of the two sectors are set at $\frac{1}{2}$. The consumer ends up solving the constrained maximization problem in (2.1) by choosing among a set of varieties $i = \overline{1,n}$ in each sector $s = \{l, h\}$. Intuitively, $q_{i,s}$ represents the quantity of variety i manufactured in sector s whereas $p_{i,s}$ denotes its price. Moreover, given that H and F are symmetric, the utility maximization problem is similar across the two nations.

$$\begin{gathered} Max_{q_l q_h} U = \left\{ \left[\sum_{i=1}^{n(1+\gamma_l)} q_{i,l}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \right\}^{\frac{1}{2}} \left\{ \left[\sum_{i=1}^{n(1+\gamma_h)} q_{i,h}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \right\}^{\frac{1}{2}} \\ s.t. \sum_{i=1}^{n(1+\gamma_l)} p_{i,l} q_{i,l} + \sum_{i=1}^{n(1+\gamma_h)} p_{i,h} q_{i,h} = Y \end{gathered} \tag{2.1}$$

By solving the above for either H and F, the optimal consumption bundle of any given variety *(i,s)* is shown in (2.2). Here, P_s represents the "ideal" price index and can be regarded as the average price across all varieties produced in sector s and consumed within H or F.

$$q_{i,s} = \frac{{p_{i,s}}^{-\sigma} \frac{1}{2} Y}{{P_s}^{1-\sigma}} \tag{2.2}$$

is engaged in exporting activities. For the same reason γ_l does not respond to changes in horizontal FDI costs (i.e., $\frac{\partial \gamma_l}{\partial f} = 0$).

[15] For clarity purposes and without the loss of generality, exports are considered to flow from Home to Foreign and so are horizontal investments. In this regard, trade costs refer to the cost of

For instance, F's optimal demand for any domestically produced variety *(i,s)* is denoted by (2.3)[16]. The price index is detailed in (2.4) where γ_s^H represents the fraction of exporting firms within H's sector s. $n_s^F = n_s^H = n$ represent H's and F's total number of firms activating within sector s. Similarly, the very same demand function holds for F's imported varieties ($q_{i,s}^{H,F}$) with only one difference; the price ($p_{i,s}^{H,F}$) includes trade costs from H to F ($\tau^{H,F}$).

$$q_{i,s}^{F,F} = \frac{p_{i,s}^{F,F^{-\sigma}} \frac{1}{2} Y^F}{P_s^{F^{1-\sigma}}} \tag{2.3}$$

$$P_s^F = \left[n_s^F \left(p_{i,s}^{F,F} \right)^{1-\sigma} + n_s^H \gamma_s^H \left(p_{i,s}^{H,H} \tau_s^{H,F} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{2.4}$$

2.2.2 Production

The production side is characterized by increasing returns to scale within a monopolistic competition framework as in Krugman (1980). The total cost function for any variety *(i,s)* is depicted in (2.5)[17]. Since the model distinguishes between multinationals and exporters, the cost function is discussed separately for each firm type.

$$w l_{i,s} = w(\alpha_{i,s} + \phi_i f) + w \beta \tau_s q_{i,s} \tag{2.5}$$

According to (2.5), the marginal production cost faced by the multinational firm is given by $w^H \beta^H$, for those plants located in H, and $w^F \beta^F$, for those situated in F. However, since H and F are assumed to be symmetric in wages and technology the marginal cost can be rewritten as $w\beta$. This is because multinationals do not engage in any exporting activities and therefore $\tau_s = \tau_s^{H,H} = \tau_s^{F,F} = 1$. In other words, multinationals are not incurring any trade costs. However, the multinational firm experiences additional fixed costs generated by setting up and operating a secondary production plant abroad. For those headquartered in H, this is represented by $f^{H,F}$. Each firm is assumed to offset the cost of engaging in horizontal FDI differently according to the firm-specific parameter $\phi_i \in (0, 1]$. For exporters, goods manufactured in H and shipped to F are subject to iceberg trade costs, $\tau_s = \tau_s^{H,F} > 1$. As a result, the marginal cost faced by an exporter located in H is given by $w\beta\tau_s^{H,F}$.

Pricing by applying a constant mark-up over the marginal cost represents a key feature of models based upon monopolistic competition and CES preferences. In this

exporting from H to F. Similarly, horizontal investment costs denote the costs incurred by a firm in H in order to set up and maintain production in F. This aspect is also important for the empirical and theoretical sections which make use of unidirectional export flows.

[16] Single superscripts are intuitive as they denote country specific variables. Double superscripts such as *H,F* are aimed at emphasizing the idea of direction. For example, one should read $p_{i,s}^{H,F}$ as the price of variety i from sector s that is manufactured in H and sold/consumed in F. Similarly $p_{i,s}^{F,F}$ should read as the price of variety i in sector s that is manufactured in F and sold/consumed in F.

[17] Here w, α and β represent the wage, fixed cost and marginal cost of production whereas ϕ_i is

regard, the firm's optimal pricing rule is shown in (2.6)[18].

$$p_{i,s} = \left[\frac{\sigma}{\sigma - 1}\right] w\beta\tau_s \tag{2.6}$$

2.2.3 Horizontal Foreign Direct Investment or Exporting?

Based on the discussion in subsections 2.2.1 and 2.2.2, calculating the profit stream faced by a multinational firm is intuitive and the result is shown in (2.7). More specifically, this is obtained by summing up the profits generated from producing and supplying variety *(i,s)* locally, in both H and F. Applying a similar rationale, the exporter's profit can be written as in (2.8)[19].

$$\Pi_{i,s}^{FDI} = \frac{1}{\sigma}\left[\frac{p_{i,s}^{H,H}}{P_s^H}\right]^{1-\sigma}\frac{1}{2}Y^H + \frac{1}{\sigma}\left[\frac{p_{i,s}^{F,F}}{P_s^F}\right]^{1-\sigma}\frac{1}{2}Y^F - w^H\alpha_{i,s}^H - w^F(\alpha_{i,s}^F + \phi_i f^{H,F}) \tag{2.7}$$

$$\Pi_{i,s}^{X} = \frac{1}{\sigma}\left[\frac{p_{i,s}^{H,H}}{P_s^H}\right]^{1-\sigma}\frac{1}{2}Y^H + \frac{1}{\sigma}\left[\frac{p_{i,s}^{H,H}\tau_s^{H,F}}{P_s^F}\right]^{1-\sigma}\frac{1}{2}Y^F - w^H\alpha_{i,s}^H \tag{2.8}$$

Intuitively, exporter's profits depend on the relative price of a given variety *(i,s)*, the expenditure on sector s goods in each of the domestic and foreign markets, trade costs between H and F, wages in H, and the fixed cost of production ($\alpha_{i,s}$). In addition to the above, profits for the multinational firm are defined by wages in F, the fixed costs of establishing a plant in F ($f^{H,F}$), and the firm's capacity to offset these costs (ϕ_i). It is worth noting that the profits of the multinational firm are independent of trade costs. In order to decide which strategy to pursue, exporting or horizontal foreign direct investment, a firm compares the payoffs introduced previously. By subtracting (2.8) from (2.7) and rearranging, the firm will decide in favor of horizontal FDI as long as:

$$\Pi_{i,s}^{FDI} - \Pi_{i,s}^{X} = 1 - \left(\tau_s^{H,F}\right)^{1-\sigma} - \frac{w^F(\alpha_{i,s}^F + \phi_i f^{H,F})}{\frac{1}{\sigma}\left[\frac{p_{i,s}^{F,F}}{P_s^F}\right]^{1-\sigma}\frac{1}{2}Y^F} > 0 \tag{2.9}$$

---

firm i's capacity to offset the horizontal FDI costs.

[18] According to this rule, multinationals charge $p_{i,s}^{H,H} = p_{i,s}^{F,F} = \left[\frac{\sigma}{\sigma-1}\right] w\beta$ for those goods produced and sold in H and F respectively. Despite being equal, I keep distinguishing between these prices for clarity and exposition purposes. At the same time, an exporter located in H charges $p_{i,s}^{H,F} = \left[\frac{\sigma}{\sigma-1}\right] w\beta\tau_s^{H,F}$ for each variety exported to F.

[19] Recall that H and F are symmetric in wages and technology and for that matter $w^H = w^F = w$, $\beta^H = \beta^F = \beta$ and $\alpha_{i,s}^H = \alpha_{i,s}^F = \alpha_{i,s}$. I distinguish between country-specific variables for clarity and exposition purposes.

The decision rule depicted in (2.9) is fairly intuitive and similar to the one which could be derived using the payoff functions presented in Markusen and Venables (2000). However, when compared to their profit functions, the explicit inclusion of horizontal investment fixed costs represents the key difference.

$$\frac{\partial\left(\Pi_{i,s}^{FDI}-\Pi_{i,s}^{X}\right)}{\partial\tau_s^{H,F}} = z_1\epsilon_{\tau_s^{H,F}}^{P_s^F}\left[\left(p_{i,s}^{F,F}\right)^{1-\sigma}-\left(p_{i,s}^{H,H}\tau_{i,s}^{H,F}\right)^{1-\sigma}\right]+z_1\frac{1}{\tau_{i,s}^{H,F}}\left(p_{i,s}^{H,H}\tau_{i,s}^{H,F}\right)^{1-\sigma}>0 \tag{2.10}$$

$$\frac{\partial\left(\Pi_{i,s}^{FDI}-\Pi_{i,s}^{X}\right)}{\partial f^{H,F}} = z_2\epsilon_{f^{H,F}}^{P_s^F}\left[p_{i,s}^{F,F\,1-\sigma}-p_{i,s}^{H,H\,1-\sigma}\right]-\phi_i<0 \tag{2.11}$$

where,

$$z_1=\frac{(\sigma-1)\,\frac{1}{2}Y^F}{\sigma\;\tau_s^{H,F}\;P_s^{F\,1-\sigma}}\qquad z_2=\frac{(\sigma-1)\,\frac{1}{2}Y^F}{\sigma\;f^{H,F}\;P_s^{F\,1-\sigma}}$$

The partial derivatives of the profit wedge with respect to trade costs and the cost of engaging in horizontal FDI are shown in (2.10) and (2.11)[20] where both z_1 and z_2 are positive. Intuitively, a drop in cross-border investment costs will incentivize firms to engage in horizontal foreign direct investment. Similarly, as trade costs decrease, firms will seek to engage in exporting activities as means of serving foreign markets.

2.2.4 Economic Integration and Bilateral Export Concentration

Recall that the aim of the current work is to scrutinize how economic integration affects the concentration of bilateral trade flows. Whether or not export flows from H to F are becoming more concentrated or more diversified is measured through a normalized Hirschmann-Herfindahl index (henceforth HHI)[21]. For the two sector model, the index is given by (2.12) where $s_s^{H,F}$ represents the share of industrial sector s=$\{l,h\}$ in total exports from H to F, and is computed as shown in (2.13). Each sector is modeled as discussed in (2.1) through (2.11).

$$HHI^{H,F}=\frac{\sqrt{(s_l^{H,F})^2+(s_h^{H,F})^2}-\sqrt{\frac{1}{2}}}{1-\sqrt{\frac{1}{2}}} \tag{2.12}$$

[20] Given that σ>1 both inequalities are holding with strict inequality as long as $p_s^{H,H}\leq p_s^{F,F}\leq p_s^{H,H}\tau_s^{H,F}$. This latter condition is easily satisfied since $p_s^{H,H}=p_s^{F,F}$ and $\tau_s^{H,F}>1$. As discussed in the appendix the elasticities of the F's price index with respect to $\tau_s^{H,F}$ and $f^{H,F}$ are positive ($\epsilon_{\tau_s^{H,F}}^{P_s^F}>0$ and $\epsilon_{f^{H,F}}^{P_s^F}>0$).

[21] As opposed to the usual Hirschmann-Herfindahl index, the normalized version is constructed such that its values lie between 0 and 1. When the index records a value of 0 the export shares are equally distributed among sectors. Conversely, a value of 1 indicates that outflows are accounted by only one sector.

$$s_s^{H,F} = X_s^{H,F}/(X_l^{H,F} + X_h^{H,F}) \tag{2.13}$$

Considering equations (2.7) and (2.8), in the context of economic integration two types of dynamics are emerging. First, as trade costs between the two countries drop, firms will seek to serve foreign markets through exporting rather than cross-border horizontal investing. In turn, holding everything else constant, this is expected to generate bilateral export diversification. Second, as costs of engaging in horizontal FDI decrease, the payoff of serving external markets this way increases while exporting becomes less desirable. Furthermore, this should lead to more concentrated bilateral exports. Although it has been touted as having little to no theoretical basis (Dennis and Shepherd, 2011) the Hirschmann-Herfindahl index performs well in explaining diversification patterns, under one assumption: the two sectors are assumed to be heterogeneous in trade costs and as a consequence the sector with lower trade costs accounts for a larger share in total exports. Under these conditions, all that is needed for the index to underline diversification is a convergence in export shares. Conversely, a divergence in export shares leads to concentration of outflows. Overall, export diversification is about whether other sectors can catch up with the ones at the top.

Proposition 1. *Export flows between H and F will become less concentrated as trade costs between the two countries, $\tau^{H,F}$, are dropping.*

$$\frac{\partial HHI^{H,F}}{\partial \tau^{H,F}} > 0$$

Proof: *See section A.1.1 of the appendix.*

To form an idea about how trade liberalization[22] affects the concentration of bilateral trade flows, it is important to recognize that the two sectors (e.g. low-τ and high-τ) are impacted differently. This asymmetric effect is generated by existing differences in sectoral trade costs. Equally important is how the fraction of exporters in each sector responds to changes in trade costs. Provided the model assumptions[23], it is sensible to acknowledge that a drop in trade costs will increase the fraction of exporting firms in the sector characterized by high trade costs. At the same time, the fraction of exporting firms within the low-τ sector will remain unaffected. As a consequence, exports originating in high-τ sector are expected to grow relatively more. This way, the associated export shares of the two sectors will converge, leading to increased diversification of exports and a drop in the HHI.

Proposition 2. *Export flows between H and F will become more concentrated as horizontal foreign direct investment costs between the two countries, $f^{H,F}$, are*

[22] Trade liberalization represents an important part of the economic integration process. Here, trade liberalization is equivalent to a symmetric percentage drop in trade costs across both sectors.

[23] Recall that $\frac{\partial \gamma_h}{\partial \tau_h^{H,F}} < 0$ and $\frac{\partial \gamma_l}{\partial \tau_l^{H,F}} = 0$.

dropping.

$$\frac{\partial HHI^{H,F}}{\partial f^{H,F}} < 0$$

Proof: *See section A.1.1 of the appendix.*

Another consequence of economic integration is represented by lower horizontal FDI costs between H and F ($f^{H,F}$). Just like the drop in trade costs, this dynamic also has the potential of altering the concentration of bilateral trade flows as the two types of sectors are likely to respond differently to a change in foreign investment costs. Firms within the high-τ sector will be inclined to substitute exporting activities with horizontal FDI, just as (2.10) predicts. Also, recall that the drop in foreign investment costs has no impact on those firms operating in the low-τ sector, provided that these costs are sufficiently low such that exporting is still regarded as the profitable choice. This leads to reduced exports within the high-τ industry and thus a lower sectoral share in total exports. Combined, these two dynamics entail a divergence in sectoral export shares, and in turn an increased index of bilateral export concentration.

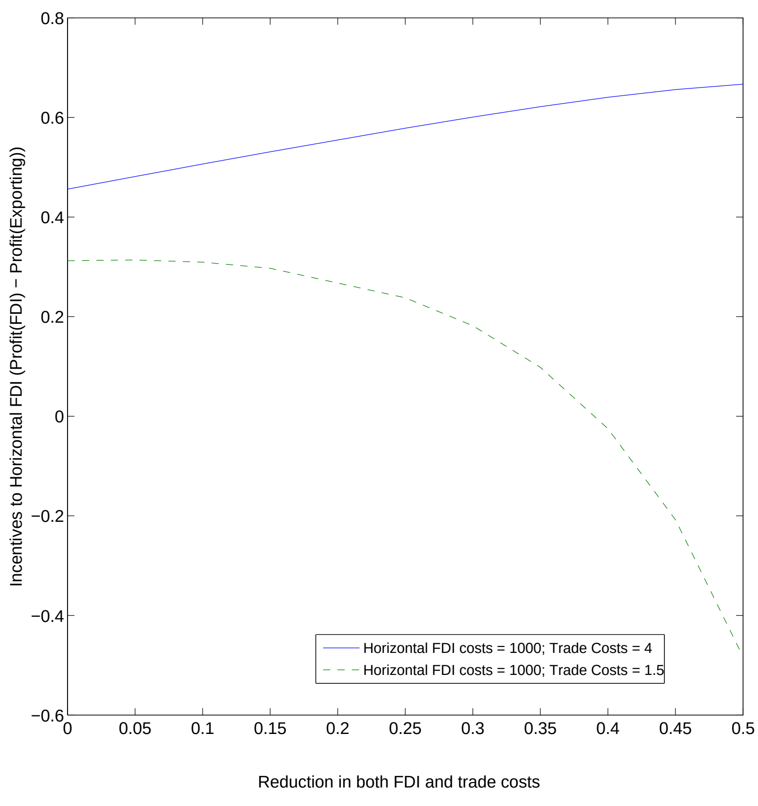

Figure 2.1: FDI vs. Exporting Decision: The Model Prediction

Summarizing, if an economic integration agreement leads to lower horizontal FDI costs relative to those of engaging in trade, firms in the high-τ sector will be inclined to substitute exporting activities with cross border investment as means of serving external markets. This shift entails lower exports and a reduced share of this particular industry in total exports. This implies a divergence in sectoral export shares and, in turn, a larger concentration of bilateral exports. As shown in figure 2.1, the same dynamics prevail even if horizontal FDI and trade are dropping by the same magnitude. Naturally, the incentive to serve foreign nations by engaging in horizontal FDI is larger for those firms within the high-τ industry. This is also depicted in figure 2.4 of the appendix.

This very aspect is at odds with the findings of Regolo (2013) who, empirically, uncovers a negative effect of economic integration on bilateral export concentration. However, the empirical support for these findings may be the result of how economic integration was accounted for. Specifically, the aggregated nature of the integration measure[24] has the potential of masking important dynamics of export concentration patterns within an economic and monetary union, such as the Eurozone. As a takeaway, the effect of economic integration agreements on export diversification should be assessed individually rather than as a sum.

2.3 Empirical Application: The Case of the Eurozone

2.3.1 Trade and FDI Costs within the Eurozone and European Union

The overarching theme of the two propositions outlined in section 2.2.4 is that economic integration may not always foster bilateral export diversification. Just as easy, it can entail trade concentration. As noted previously, the ambiguity originates within the asymmetric effect that each EIA may have on horizontal FDI and international commerce costs at sectoral level. EIAs such as preferential trade agreements, free trade agreements or customs unions are by design aimed at lowering and/or eliminating trade costs. Similarly, common markets such as the European Union (EU) are also contributing to a significant reduction in trade costs and are therefore expected to foster export diversification. Although it contributed to a drop in investment costs as well, the EU effect on FDI seems to have been propagated along the vertical margin Coeurdacier et al. (2009). Since this type of FDI acts as a complement for trade, one can expect membership in the EU (and other similar EIAs) to be accompanied by higher levels of export diversification. Conversely, joining the Eurozone seems to have lowered trade and FDI costs as well. However, it seems that the reduction in FDI costs is much larger and concentrated along the horizontal margin Coeurdacier et al. (2009). At the same time, there are reasons to believe that the reductions in trade costs are small, and concentrated in a fraction of industries[25]. The current section proceeds by discussing the empirical evidence on how economic integration impacted FDI and trade across Europe. The focus is placed on why joining the Eurozone might have contributed to a relatively larger drop in horizontal FDI costs.

[24] For more details consult section A.1.2 within the data appendix.

[25] Regarding the asymmetric Eurozone effect on sectoral-level trade see Flam and Nordstrom

Adhering to the Eurozone is conditional on satisfying the convergence criteria specified in the Maastricht Treaty. These emphasize exchange rate and price stability as well as tractable budget deficits and national debt caps[26]. Members' commitment to these requirements represents a strong signal regarding international cooperation and macroeconomic stability. In turn, this may have the potential of stimulating investors' confidence and thus intra-Eurozone FDI flows. Reductions in FDI costs are believed to be carried out through a series of channels such as harmonization of monetary policies, elimination of exchange rate volatility, increased price transparency, integration of banking and payment systems as well as that of the financial system in general[27]. The positive impact of adopting euro on financial integration has also been documented by Lane (2006); Lane and Wälti (2006). Although episodes of relative currency depreciation in the host country have been shown to foster FDI inflows, the literature on exchange rates and FDI does not provide a clear consensus in this regard (Kiyota and Urata, 2004). Dinga and Dingova (2011) find no significant effect of short term volatility on FDI. However, they find that the impact of long term volatility is economically large, negative, and significant[28]. Additionally, FDI is found to be inversely linked with other types of uncertainty, such as that related to interest rates and inflation (Carruth et al., 2000). As shown in figures 2.2 and 2.3, these two series remained relatively stable after the introduction of the euro in 1999[29]. These developments may have had the potential of rendering investments which were previously risky as feasible ex-post. Furthermore, increased price transparency may have facilitated factor price comparisons thus enhancing the process of decision making with regards to cross border investment. Empirical evidence regarding the positive effect of adopting the euro on intra-Eurozone FDI activity has been uncovered by Petroulas (2006); Schiavo (2007); Dinga and Dingova (2011); de Sousa and Lochard (2011). It is important to note that the above studies do not distinguish between vertical and horizontal FDI. However, the literature emphasizes that the bulk of foreign direct investments is horizontal in nature Flam (2009).

Not only horizontal FDI costs were affected by joining the Eurozone but also the costs of engaging in exporting activities. The reduction in trade costs is believed to stem primarily from the removal of exchange rate volatility, which inevitably generates hedging and other related costs. However, there are reasons to believe that trade costs were marginally affected at best. Before joining the Eurozone, nine out of the initial

(2006); De Nardis et al. (2008); Di Nino (2009); Badinger and Türkcan (2014).

[26]More details can be found within Article 121(1) of the Treaty establishing the European Community.

[27]For example, Kalemli-Ozcan et al. (2010) emphasize that joining the Eurozone promoted financial integration among members through elimination of foreign exchange market risks and legislative harmonization.

[28]Short term volatility is defined as the variance in the ratio of real effective exchange rate indices over a 2 year period. Long term volatility is defined by the variance of the same ratio over a 5 year period.

[29]The pattern vanished for interest rates with the onset of the European sovereign debt crisis in early 2010. Since the latest year available within the dataset is 2011, this aspect is not expected to significantly affect the empirical analysis.

eleven signatory nations were part of the European Monetary System (EMS)[30] or had their currency pegged to the Deutsche Mark or the European Currency Unit (ECU). Given its mechanics, this program significantly dampened exchange rate volatility. Also, there are no solid reasons to believe that hedging opportunities were scarce, inexistent or extremely costly for exporters across the European space. Besides, exchange rate fluctuations can also be managed through contractual terms; a feasible alternative given the European institutional framework. Citing the Commission of European Communities, Beetsma and Giuliodori (2010) note that the costs associated with currency conversion in Europe are small and hover in the vicinity of 0.5%-1% of EU's GDP. Moreover, there seems to be a considerable amount of evidence emphasizing little to no impact of exchange rate volatility on trade flows. First, Tenreyro (2007) finds that nominal exchange rate volatility, which the Eurozone completely eliminates, exhibits no noticeable effect on trade. Broda and Romalis (2011) find evidence of a negligible effect of exchange rate volatility on trade in differentiated goods[31]. A study by (Berger and Nitsch, 2008) emphasizes no effect of joining the Eurozone on trade whatsoever while others, Micco et al. (2003); Faruqee (2004); Baldwin and Taglioni (2006); Bun and Klaassen (2007); Baldwin et al. (2008); Brouwer et al. (2008); Santos Silva and Tenreyro (2010)[32] uncover positive but small effects at best. In the light of this evidence, Eurozone participation is expected to affect trade only slightly.

Surveying both literature strands, Flam (2009) provides evidence of a relatively larger Eurozone effect on bilateral FDI. On aggregate, the effect of European Economic and Monetary Union on intra-Eurozone FDI has been found to situate between 16% and 200%. At the same time, the effect on bilateral trade was concluded to lay between 10% and 30%. Based on this evidence, the Eurozone seems to have promoted bilateral FDI more than trade. It is also important to note that joint membership in the EU also affects bilateral FDI as well as trade flows[33]. However, Coeurdacier et al. (2009) emphasize a key difference between the EU and the Eurozone effects on bilateral FDI activity. Using sectoral data on mergers and acquisitions they estimate that joint EU membership promoted more investment across sectors whereas the Eurozone stimulated investment within sectors[34]. Much of the same results are uncovered by Herger and McCorriston (2014). This evidence lines up well with the theory on verti-

[30] EMS required participation in the Exchange Rate Mechanism (ERM). This was designed to limit exchange rate volatility against the European Currency Unit (ECU) which was defined by a basket of participating members' currencies. ERM specified upper and lower bands in which partaking currencies were allowed to fluctuate relative to the ECU. National Central Banks were then committed to keep their currencies within the specified interval. See De Grauwe (2012). After 1999 the ERM was replaced with ERM II and the ECU was replaced with the euro. Prospective countries are now required to take part in ERM II for at least two years prior to joining the Eurozone.

[31] "A doubling of real exchange rate volatility reduces trade in differentiated products by 2 percent."

[32] All estimates range between 2% and 10%.

[33] Regarding FDI see Flam and Nordstrom (2008b). As for trade, most studies reveal a positive and statistically significant effect.

[34] Coeurdacier et al. (2009) use data on mergers and acquisitions (M&As) in the manufacturing

cal foreign direct investment. Since the EU encompasses a relatively more diverse set of countries in terms of factor endowments and factor prices, it is expected to foster more vertical investment. Also in line with the theory, joining the Eurozone is expected to encourage more cross-border investment of the horizontal type, which was shown to occur mainly between similarly endowed nations (Markusen and Venables, 1996).

As per the above, separately assessing the effect of joint Eurozone membership on bilateral export concentration pattern seems imperative. An empirical framework that allows for this distinction is introduced within the next subsection.

2.3.2 Data and Variable Construction

The dataset covers all European Union (EU) members as of 2011 from 1995 to 2011[35]. The typical observation describes an exporter-importer pair at a given point in time. With 27 countries considered, there are 702 of such pairs. The dependent variable is the Hirschmann-Herfindahl index of bilateral export concentration. In theory, this index's lower and upper bounds are 0 and 1 respectively. Larger values denote higher degrees of bilateral export concentration.

Traditional trade theory points out to differences in factor endowments as being responsible for determining the pattern of trade across countries. From a country-level perspective, Cadot et al. (2013) also emphasize the importance of factor abundance in governing the diversification aspect of country-specific export structures. From a country-pair point of view, Regolo (2013) shows that the degree of bilateral export concentration is to a large extent shaped by differences in factor endowments. The larger these differences are, the higher the degree of export concentration. Following her work, exporter-importer differences in factor endowments are constructed as shown in section A.1.2 of the data appendix. These are given by absolute differences in the natural logarithms of physical capital to labor ratios ($d_{K/L,x,m}$), human capital ($d_{H/L,x,m}$) and land capital to labor ratios ($d_{A/L,x,m}$)[36].

Often underlining asymmetries in preferences, exporter-importer differences in GDP per capita ($d_{GDPpc,x,m}$) have the potential of molding export diversification patterns. Fajgelbaum et al. (2011) found that wealthier countries are net-exporters of high quality goods and net-importers of lower quality wares. For exporter-importer pairs comprising nations of similar per capita income (North-North/South-South) this is suggestive of lower export diversification. Based on the same logic, higher export diversification should characterize North-South/South-North pairs. Empirical

sector. Nevertheless, their study is relevant to the current analysis because M&As account for 70-80% of foreign direct investment within the OECD according to Head and Ries (2008). Furthermore, mergers within sectors are characterized as horizontal whereas mergers across sectors are seen as vertical in nature.

[35] Baldwin and Di Nino (2006) underline that the Eurozone effects on trade may be better investigated within a sample of European Union countries. I follow their reasoning for analyzing export diversification.

[36] Cadot et al. (2011) and Agosin et al. (2012) also emphasize the importance of human capital

evidence in this regard is outlined by Amurgo-Pacheco and Pierola (2008) and Regolo (2013). Jaimovich and Merella (2012) found that wealthier importers tend to consume goods for which they do not possess comparative advantage. Since comparative advantage is shaped by a nation's development stage along with many other factors (e.g. factor endowments), this would also indicate less diversified exports within North-North/South-South origin-destination pairs. The impact of productivity differentials on country-pair export diversification is emphasized empirically by Regolo (2013). Larger exporter-importer productivity differences, $d_{TFP,x,m}$, are consistent with higher degrees of bilateral trade concentration. Exporter-importer GDP per capita and productivity differentials are constructed as shown in A.1.2.

Trade costs are also found to determine the degree of international commerce concentration. Regolo (2013), Amurgo-Pacheco and Pierola (2008), Dennis and Shepherd (2011) and Beverelli et al. (2015) clearly emphasize a negative association between the degree of bilateral export diversification and trade costs. Perhaps not surprisingly, these measures are the very same as those used within the gravity model of international trade. Among the most common, one can count the exporter-importer distance and whether or not the origin and destination share a common border as well as a common language. Here, the coefficient associated with distance is expected to carry a positive sign whereas those attached to the contiguity and common language variables are expected to be negative. The argument regarding the sign of coefficients is as follows. Trade between neighboring countries or among nations which share a common language, is less costly and as a result commerce flows are expected to be more diversified; along both the extensive and intensive margin. Conversely, as the distance between the origin and the destination becomes larger, international commerce costs are also becoming larger. There is a clear consensus throughout the literature that distant partners are trading less in both monetary terms and number of varieties/sectors. It thus follows that exports among them should be more concentrated. In sum, trade costs are expected to impede trade and lead to more concentrated export flows. An extended discussion on EIAs and their effect on trade and horizontal FDI costs follows.

2.3.3 Empirical Model

The effect of joint Eurozone (EZ) membership on bilateral export concentration is analyzed by modifying the empirical framework advanced by Regolo (2013). The specification obtained is depicted in (2.14), where (x,m,t) denotes an exporter-importer pair at a given point in time, t. Here, $S_{x,m,t}$ represents the pair-specific index of bilateral export concentration. Following the theoretical setup presented in section 2.2, the index of choice is the Hirschmann-Herfindahl index[37]. $D_{x,m,t}$ represents a 5×1 column vector which contains pair specific differences in per worker physical

as a determinant of export diversification.

[37]When this index equates unity, bilateral exports are concentrated in one, 3 digit SITC Rev. 3, industrial sector. Conversely, a value of zero indicates that exports from x to m are equally spread across industries. Provided the lack of consensus with regards to the appropriate concentration

and land capital, human capital, GDP per capita and total factor productivity. In their above order, these are denoted by $d_{K/L,x,m,t}$, $d_{A/L,x,m,t}$, $d_{H/L,x,m,t}$, $d_{GDPpc,x,m,t}$, and $d_{TFP,x,m,t}$ respectively. $Z_{x,m}$ represents a 3×1 vector of trade costs which consists of pair characteristics such as distance, whether or not the two nations share a common official language, and geographic contiguity. These variables do not exhibit any time variation and in consequence the associated time subscripts are omitted. Finally, $\mu_{x,m,t}$ represents the error term.

$$ln(S_{x,m,t}) = \alpha' D_{x,m,t} + \beta' Z_{x,m} + \gamma_1 RTA_{x,m,t} + \gamma_2 EZ11_{x,m,t} + \mu_{x,m,t} \tag{2.14}$$

How exporter-importer economic integration is accounted for, represents the key difference between the empirical specification shown above and that of Regolo (2013). Recall that the integration measure used in her study represents a collection of EIAs[38]. In contrast, I define bilateral integration in terms of dual membership within a regional trade agreement and joint participation within an economic and monetary union; in this case the Eurozone. Within the international trade literature, these are by far the most commonly used economic integration indicators. And jointly, both are valid candidates for capturing the degree of integration between nations within a given exporter-importer pair. The added benefit of measuring integration this way is the possibility of separately estimating their impact on bilateral export concentration.

Joint affiliation within the same trade agreement generates a decline in bilateral trade costs, mainly through the phase-out or the removal of tariffs. According to the first proposition, more diverse export flows are expected between nations which are part of the same trade agreement. This country-pair characteristic is captured by $RTA_{x,m,t}$. This is constructed based on the NSF-Kellogg Institute Economic Integration Agreements (EIA) Database[39]. Specifically, $RTA_{x,m,t}$ takes values between 0 and 5 according to the type of integration agreement in which the exporter and importer find themselves at time t[40].

Joint membership within an economic and monetary union represents another determinant of trade costs. However, the only economic and monetary union considered here is the Eurozone, and whether or not the exporter and importer are sharing the

measure, S will also be defined as a Theil or Gini index. The results obtained this way are discussed within section 2.4.5.

[38]See variable TA within section A.1.2 of the data appendix.

[39]Refer to section A.1.2 of the data appendix for more details.

[40]This variable is referred to as regional trade agreements for simplicity purposes only. This is due to the fact that besides trade agreements it also includes customs unions as well as common markets. A correct way of referring to these integration stages would be as shallow (stages 1 through 4) and deep (stages 5 and 6) integration Frankel et al. (2012). For example, levels of 1 through 5 indicate that x and m at time t are jointly part of the same non-reciprocal preferential trade agreement, preferential trade arrangement, free trade agreement, customs union or common market respectively. Splitting the $RTA_{x,m,t}$ variable two-way, into joint membership in common markets (e.g. the European Union) and other regional trade agreements, does not alter the results quantitatively or qualitatively.

euro is accounted for by $EZ11_{x,m,t}$[41,42]. This binary variable equals unity as long as pair members share the euro and 0 otherwise. Despite the renewed attention it received since Rose (1999), formation of currency unions, and more specifically the Eurozone, received little to no consideration as a determinant of bilateral export concentration[43].

Joint enrollment within the Eurozone may reduce not only trade costs but horizontal FDI costs as well. Based on the evidence discussed in section 2.3.1, the reduction seems to be relatively larger for the latter category of costs. Should this be the case, according to the second proposition sharing the euro is expected to entail bilateral export concentration rather than diversification. This follows naturally as this particular type of economic integration may induce exporters, especially those within sectors characterized by high trade costs, to substitute cross border trade with horizontal FDI. This dynamic was discussed within section 2.2 where bilateral horizontal FDI costs were shown to be a key determinant of bilateral export diversification.

By taking into account the two propositions outlined earlier, and allowing the empirical model to separately account for joint Eurozone membership and joint enrollment within regional trade agreements, one should expect that EIAs do not necessarily lead to export diversification. On the contrary, sometimes they may generate more concentrated flows. In Regolo (2013), the coefficient attached to the aggregate integration measure exhibits a negative sign. In turn, this is indicative of an inverse relationship between bilateral export concentration and economic integration. However, by including *RTA* and *EZ11* variables separately, only γ_1 is expected to display the negative sign while γ_2, the coefficient of interest, should be positive. The mechanics of these effects have been extensively discussed within the previous sections.

2.3.4 Estimation Approach

Specification (2.14) is similar to the gravity models often used to analyze bilateral trade flows. In this regard, it is worth paying attention to the empirical issues (and their associated fixes) which surfaced within this strand of literature, since they may

[41] For completeness purposes five definitions of joint Eurozone membership are considered. EZ11 comprises the initial euro adopters. EZ12 adds Greece. EZ13 counts in Slovenia whereas EZ15 includes Malta and Cyprus. Finally, EZ16 incorporates Slovakia. See table 2.1 for more details. Experimenting with these definitions does not change the direction of the Eurozone effect. However, the coefficients on EZ12-EZ16 are less robust and decline in magnitude; but remain positive. Nevertheless, this outcome is expected, since countries that joined after 1999 are small and therefore less attractive to horizontal FDI (Head and Ries, 2004). Estimations conducted while including exporter and importer GDP figures yield positive and statistically significant coefficients on four out of the five Eurozone definitions. Results are shown in table 2.9. This very dynamic also emerges from equation 2.9. Interactions between Eurozone binary indicators and importer's GDP also point out the importance of destination's market size. In the light of these aspects, only estimations involving EZ11 are presented.

[42] For more details, see section A.1.2 within the data appendix.

[43] Studies related to evaluating the Eurozone effect on bilateral export concentration are those analyzing its effect on the intensive or extensive margins of trade. Nonetheless, the current study differs from these, in that the dependent variable simultaneously captures both the extensive and

easily apply here. First on the list is the issue of unobserved heterogeneity which left uncorrected leads to biased and inconsistent estimates. Concerning the gravity models of trade, Baldwin and Taglioni (2006) as well as Head and Mayer (2013) suggest the use of importer-year, $d_{m,t}$, and exporter-year, $d_{x,t}$, effects[44]. Regolo (2013) follows suit and applies this technique for analyzing bilateral export diversification. However, the inclusion of time-varying origin and destination effects may soak up some of the explanatory power of the two integration measures considered here. Instead, I include exporter, d_x, and importer, d_m, fixed effects. In addition to these, year fixed effects, d_t, are included to capture unobserved, time specific characteristics. The error term is thus modeled as $\mu_{x,m,t} = d_x + d_m + d_t + \nu_{x,m,t}$ where $\nu_{x,m,t}$ is assumed to be well behaved. The current study also shares common ground with those analyzing the effect of EIAs on the extensive margin of trade. Among these, Baldwin and Di Nino (2006), Flam and Nordstrom (2008a), Amurgo-Pacheco and Pierola (2008), Di Nino (2009) also implement the exporter and importer fixed effects approach depicted above. Remaining unobserved heterogeneity issues are addressed in section 2.4.1.

Given the nature of the analysis and the structure of the dataset, it seems reasonable to call into question the issues of heteroskedasticity and cross-sectional dependence in addition to that of residual serial correlation. Note that the presence of these issues does not imply any biases on the estimated coefficients. However, by addressing these concerns, standard errors and the validity of statistical inference would be greatly improved. In this regard, two estimation techniques are employed. An initial set of results is delivered using ordinary least squares. A secondary set of estimates is obtained by using generalized least squares with panel corrected standard errors. This approach has the added virtue of adjusting the standard errors for within panel AR(1) residual correlation, in addition to heteroskedasticity and spatial dependence. Hoechle (2007) emphasizes feasibility concerns that are associated with this particular estimator. This issue occurs when standard errors are adjusted for cross-sectional dependence while the ratio of panels to time periods is small as it is the case here. Nonetheless, specifying an independent panel structure and allowing any cross-sectional dependence to be absorbed by the year dummies will yield consistent standard errors.

2.3.5 Empirical Results

The current study crosses paths with those estimating the Eurozone effect on the extensive margin of trade. For example, Flam and Nordstrom (2007); Baldwin et al. (2008); Di Nino (2009); Badinger and Türkcan (2014) emphasize a positive overall effect of joining the Eurozone on the extensive margin of trade. However, by performing a similar analysis I observe an opposite effect. Results are shown in table 2.3[45] and are quite indicative with regards to the Eurozone effect on bilateral export

intensive margins.

[44] An alternative estimation technique is considered in section 2.4.1.

[45] Here, the dependent variable is the origin's number of, SITC 3 Rev. 3, sectors characterized by non-zero export flows to destination.

concentration.

The results in columns *1* and *2* are obtained by estimating a standard gravity model where the dependent variable is the number of industrial sectors which export from origin to destination. Provided the nature of the outcome variable, negative binomial and Poisson PML estimators are used. The evidence presented in table 2.3 suggests that Eurozone exporter-importer pairs are, on average, characterized by fewer exporting sectors. After controlling for an array of other determinants, joining the Eurozone is equivalent to a 7% drop in the number of exporting industries[46]. Conversely, pairs of nations which are concomitantly part of the same regional trade agreement should see an increase in the number of origin's exporting sectors. It is also important to note that all other factors such as distance, common border, and origin together with destination GDPs are correctly signed and statistically significant. By augmenting the standard gravity specifications in columns *1* and *2* with differences in factor endowments, GDP per capita, and total factor productivity, the coefficients on joint Eurozone membership drop but remain negative, statistically meaningful and in the vicinity of 5%.

Recall that the integration measure used in Regolo (2013), *TA*, represents a collection of EIAs[47]. The results obtained by estimating (2.14) while replacing *RTA* and *EZ11* with *TA*, as a sole measure of economic integration, underline a clear and negative relationship between the latter and export concentration. This outcome is presented in columns *1* and *2* of table 2.4. However, provided the asymmetric effect that each EIA type may have on horizontal FDI and international trade costs, it is important to analyze this determinant in a more disaggregated fashion. The results shown in table 2.3 are also supporting the disaggregation thesis.

Results central to the current work are obtained by estimating (2.14) and are reported in columns *3* and *4* of table 2.4. The estimates presented here line up well with the two propositions outlined in subsection 2.2.4. Recall that dual participation within the same trade agreement is expected to generate more diversified exports. At the same time, joint membership in the Eurozone should accomplish the opposite. Both coefficients attached to the variables of interest, *RTA* and *EZ11*, exhibit the expected signs and are significant from a statistical point of view. Sharing the euro is linked to bilateral export flows which are on average 4.2%-7.5% more concentrated. Conversely, joint affiliation within the same trade agreement entails exports which are on average more diversified. Both sets of results follow naturally as long as joining the Eurozone is equivalent to relatively lower horizontal FDI costs. This outcome emerges partly due to the substitutability between exporting and horizontal FDI and partly because of trade cost heterogeneity across origin's industrial base. Since trade cost asymmetry involves disparity in terms of sectoral exporting shares, a further divergence of these shares is expected as a result of joint membership in the Eurozone. The exact opposite prevails with regards to the common adoption of regional trade

[46]The formula needed to quantify this effect is $(e^{\gamma} - 1) * 100$, where γ represents the estimated coefficient.

[47]Details regarding this measure are discussed within section A.1.2 of the data appendix.

agreements.

According to the decision rule shown in (2.9), horizontal investing should be more prevalent for country pairs with large destination markets. To test this, I include the *EZ11×log Importer's GDP* interaction term when estimating (2.14). The last two columns of table 2.4 report the results. The estimates presented here line up well with this prediction. In this regard, Eurozone pairs with larger importers tend to be characterized by higher degrees of export concentration. Remaining coefficients are statistically significant, economically meaningful, and in line with the findings of Regolo (2013) and those of other studies listing trade costs as an impediment to export diversity[48]. Specifically, larger exporter-importer differences in factor endowments and productivity as well as higher bilateral trade costs lead to more concentrated bilateral export flows. Conversely, a larger GDP per capita differential represents a catalyst for more diversity.

The key point delivered by the results in tables 2.3 and 2.4 is that joint membership in the Eurozone leads to more concentrated bilateral exports. This happens due to two reasons. First, as shown in section 2.2, in addition to trade costs export concentration is also a function of horizontal cross-border investment costs. Second, as noted in section 2.3.1, different international EIAs may have different effects on horizontal FDI and trade costs. As a consequence, an integration agreement which leads to a relatively larger drop in horizontal FDI costs, such as the European Economic and Monetary Union, is expected to entail more concentrated bilateral exports. Conversely, a larger decline in trade costs, achieved by joint membership within the same trade agreement, is expected to foster export diversification. Equally important, analyzing the effect of international EIAs on export diversification separately, rather than combined, matters. Bundling the two categories into one variable, aimed at capturing the overall degree of bilateral integration, ends up masking the positive Eurozone effect on the concentration of bilateral export flows.

2.4 Robustness Checks

2.4.1 Possible Endogeneity Issues and the Importance of Unobserved Trade and Horizontal FDI Costs

Recall the empirical specification shown in (2.14) and the error structure proposed in section 2.3.4, $\mu_{x,m,t} = d_x + d_m + d_t + \nu_{x,m,t}$. Because trade and horizontal FDI costs vary over time, this error structure may not be suited to generate unbiased coefficients on *RTA* and *EZ11* variables (Baldwin and Taglioni, 2006; Head and Mayer, 2013)[49]. While any exporter and importer-specific time-invariant trade and FDI determinants are accounted for by using the above error structure, their time-variant counterparts, not captured by year dummies, remain. As a result $E(\mathit{EZ11}_{x,m,t}\tilde{\tau}_{x,m,t}) \neq 0$ and

[48]The one exception is the coefficient on human capital differential. However, given the sample at hand, the statistical meaningless of this result is not striking. It is well-known that European Union members are similar with respect to this particular type of endowment.

[49]Their discussion is aimed at bilateral trade costs but it can easily be extended to bilateral

$E(EZ11_{x,m,t}\tilde{f}_{x,m,t}) \neq 0$. Here $\tilde{\tau}_{x,m,t}$ and $\tilde{f}_{x,m,t}$ represent the unobserved, time-variant components of trade and horizontal FDI costs which are contained in $\nu_{x,m,t}$. A similar argument can be made for the *RTA* variable. As a fix, the above two studies suggest the use of time-varying exporter and importer effects. Estimating (2.14) this way still yields correctly signed coefficients on *EZ11* and *RTA* variables. However, the one attached to the Eurozone variable is statistically not different from zero. Nevertheless, since the use of time-varying exporter and importer effects soaks up much of the explanatory power associated with this pair-specific, binary, variable, this finding is not at all surprising.

Baier and Bergstrand (2009) provide a theory consistent way to approximate these unobserved components, also known as multilateral resistance terms (MRTs)[50]. This approach represents an alternative to the inclusion of exporter and importer time-varying effects. However, while MRTs have been empirically and theoretically well documented for trade costs not the same can be mentioned with regards to horizontal FDI costs. Nonetheless, given the theoretical similarities between trade and FDI gravity frameworks, the rationale which applies to trade costs can easily be extended to horizontal FDI costs[51]. Following Baier and Bergstrand (2009), investment-specific multilateral resistance terms are generated[52]. The results are shown in column *1* of table 2.5 and 2.6 respectively. The coefficients attached to the variables of interest, *RTA* and *EZ11*, hardly change. Despite the slight drop in magnitude the coefficients remain statistically significant and bear the expected signs.

2.4.2 The Importance of Market Size and Development Level

Amurgo-Pacheco and Pierola (2008), Dennis and Shepherd (2011) and Beverelli et al. (2015) emphasize exporter's economic mass as a determinant of export diversification. In this regard, larger exporters are characterized by more diverse outflows. Also, import baskets seem to be more diverse for larger destinations. The results obtained by estimating (2.14) while including these measures are shown in column *2* of tables 2.5 and 2.6. Contrary to the above, the coefficient on the destination's GDP is statistically insignificant within the OLS setup. The GLS estimates are in line with the three studies outlined previously and point to a negative impact of exporter and importer GDPs on bilateral export concentration. Based on these one can conclude that exports flowing between large origin and destination markets are more diverse. Nevertheless, the coefficients associated with joint membership in the Eurozone and trade agreements are robust to the inclusion of exporter and importer GDPs.

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horizontal FDI costs.

[50]The multilateral resistance terms associated with an exporter-importer pair, *(x,m)* are given by $MR_{\omega} = \left(\sum_{i=1}^{N}\theta_i ln\omega_{x,i}\right) + \left(\sum_{j=1}^{N}\theta_j ln\omega_{j,m}\right) - \left(\sum_{i=1}^{N}\sum_{j=1}^{N}\theta_i\theta_j ln\omega_{i,j}\right)$ where θ_k represents the share of country k's GDP in world GDP and $\omega \in$ {distance, common language, contiguity, common legal origin, exchange rate}.

[51]Determinants of bilateral trade flows often included in gravity regressions are also checking the list of factors which shape the pattern of foreign direct investments Brakman et al. (2010).

[52]In calculating these terms, the investment component of country k's GDP is used instead of its

As noted in section 2.3.2, export diversity may be a function of origin and destination development levels. Results obtained by incorporating GDP per capita terms within (2.14) are shown in column *3* of tables 2.5 and 2.6 respectively. Although lower in magnitude, coefficients on *RTA* and *EZ11* are similar to those in columns *1* and *2* and are significant from a statistical viewpoint.

Imbs and Wacziarg (2003) and Koren and Tenreyro (2007) find a clear, non-monotonic relationship between production diversification and development. As they develop, nations tend to diversify in terms of production only to start re-concentrating again after a certain income per head threshold is passed. Cadot et al. (2011) find a similar pattern for exports, although with a higher turning point. To this extent, accounting for exporter's GDP per capita and its squared counterpart becomes imperative. The results are shown in column *4* of tables 2.5 and 2.6. The non-monotonic relationship between exporter's income per head and bilateral export concentration is clear and in line with the one emphasized by the studies above. In this regard, it is worth mentioning that Cadot et al. (2011) are analyzing the impact of income per head on export concentration in a country rather than country-pair context. Along these lines, the present findings can be viewed as a contribution to this particular strand of literature. The coefficient associated with joint membership in the Eurozone is robust to the specification employed only in the OLS setup. It is difficult, however, to explain why the effect becomes statistically zero when using the alternative estimation approach.

2.4.3 The Effect of Trade and Financial Openness

According to the traditional theory of trade, countries become more specialized as they open to trade. Since Eurozone members are, on average, characterized by larger degrees of trade openness, it is essential to account for this factor when estimating the Eurozone effect on bilateral trade diversification[53]. The results obtained this way are presented in column *5* of tables 2.5 and 2.6 respectively. Coefficients attached to *EZ11* and *RTA* variables are statistically significant and exhibit signs which are in line with the two propositions outlined earlier. Not surprisingly, importers more open to trade are receiving a more diverse export basket. At the same time, exporter's trade openness does not seem to influence the concentration of bilateral exports.

Cappiello et al. (2006) and Lane and Wälti (2006) found that joining the Eurozone positively influenced the degree of financial openness across members. However, financial integration and financial openness in general, have been found to facilitate industrial/production specialization Kalemli-Ozcan et al. (2003) and Bos et al. (2011) which, in turn, may lead to less diverse exports. The results obtained by incorporating a measure of financial openness[54] within (2.14) are shown in column *6* of tables 2.5 and 2.6. The coefficients associated with joint membership in the Eurozone and

GDP.

[53]Trade openness is measured as the ratio of exports and imports to GDP. Over 1995-2011, the average trade openness is 1.09 for EZ11 nations and 0.87 for non-members.

[54]See section A.1.2 of data appendix for details regarding this variable.

regional trade agreements remain significant and maintain the expected signs. Estimates also underline that exports originating in financially more open economies are more diversified while importer's financial openness does not seem to affect the diversity of these flows. The sign on exporter's financial openness seems to be at odds with the findings of the studies introduced above, but this may easily be due to the sample of countries included in the analysis.

2.4.4 The Concentration of National Production Structures

Since exports are a "product" of national industrial structures, the current work shares common ground with the literature on production specialization. In this regard, Krugman (1993) and Krugman and Venables (1996)[55] document a positive relationship between economic integration and the specialization of national production. In turn, more concentrated industrial structures may lead to less diverse exports. Omitting this particular factor from the empirical specification may therefore lead to biased results. A nation-specific export concentration measure is therefore used as a measure of production structure diversity[56]. The results obtained this way are shown in column *7* of tables 2.5 and 2.6. As expected, the attached coefficient carries a positive sign, itself emphasizing the direct link between nation and pair specific measures of export concentration. The coefficient on joint Eurozone membership is robust to the addition of this variable. Similarly, the coefficient associated with dual participation within the same trade agreement is also robust while all other coefficients are displaying theory consistent signs.

2.4.5 The Choice of Concentration Index

It can be argued that the results obtained thus far may be the artifact of the index choice. In order to address this, Gini and Theil indexes of bilateral export concentration are constructed and used as dependent variables[57]. Both measures are strongly and positively correlated with the Hirschmann-Herfindahl index. The correlation coefficients are 0.77 for the Gini and 0.96 for the Theil index, respectively. Table 2.7 presents the results obtained by estimating (2.14) when using Gini and Theil indexes as outcome variables. From here one can clearly observe that estimates are robust to the index choice under the GLS setup. Two issues appear in columns *1* and *2*, where Theil and Gini indexes are used as the dependent variables. In this case, the coefficient attached to *EZ11* is still positive but statistically not different from zero. In the latter case, this should not be surprising since Gini indexes are often found to display very small degrees of variability.

[55]Both studies point to geographical concentration of sectoral production as the degree of economic integration becomes large enough.

[56]For more details on this variable see data appendix section A.1.2.

[57]See section A.1.2 of the data appendix for more details on the construction methodology.

2.4.6 The Bounded Nature of the Concentration Indexes

Unlike the Theil index, Hirschmann-Herfindahl and Gini indexes are reaching their respective ceilings at 1. The 0/1 bounded nature of the HH and Gini indexes calls for an additional step in order to insure analytical robustness. I thus follow Baum (2008) who proposes a logistic transformation of such censored variables. The results obtained this way are presented in table 2.8. Note that all coefficients, including those on *EZ11* and *RTA*, are robust to this particular transformation of the dependent variable. A relatively small caveat prevails when transforming the data this way as the logistic transformation is not defined for indexes equal to 0 or 1. While index values of 0 are not present within the dataset values of 1 do exist. However, these account for only 0.016% of observations.

2.5 Conclusions

International trade literature suggests that economic integration leads to export diversification. Similarly, Regolo (2013) finds that this argument holds for bilateral export diversification as well. Both of these outcomes originate in the idea that economic integration lowers trade costs which in turn fosters export diversification at the country and country-pair level. However, the current paper shows, theoretically and empirically, that the latter finding is, to some extent, incomplete.

To start, I theoretically document that bilateral export diversification does not depend only on trade costs but on horizontal FDI costs as well. The reason for which export diversification is a function of both cost types is underlined by the substitutability between exporting and horizontal investment, as means of serving foreign markets. In this regard, the model suggests that a relative decline in trade costs generates bilateral export diversification, just as emphasized by Regolo (2013). However, the exact opposite holds with respect to a relative drop in horizontal FDI costs. Since economic integration agreements (EIAs) may have asymmetric effects on horizontal FDI and trade costs, integration may not always foster bilateral export diversification. For example, an EIA which leads to a relatively larger decline in horizontal FDI costs entails bilateral export concentration, not diversification.

I then empirically show that this is exactly the case by considering two of the most common EIA types. More specifically, I show that joint membership within trade agreements does indeed deliver a more diversified export bundle. However, joint membership within the European Economic and Monetary Union accomplishes the exact opposite. The results are robust to the concentration index choice and the inclusion of other potential factors which may govern export diversity at the country-pair level. It is also worth pointing out that these dynamics are more noticeable for Eurozone exporter-importer pairs which are characterized by large destinations. In this regard, the results carry a policy flavor. Let's consider, for instance, the case of Poland and Romania, both large, European Union, members which are likely to join the Eurozone in the future. Should this be the case, imports from other Eurozone members (e.g. Portugal) are expected to become more concentrated. However, not the same can be said with regards to Bulgaria, a smaller European Union member and also a candidate to joining the Eurozone.

The evidence presented here underlines that bilateral export diversification is a function of horizontal FDI costs just as much as it is a function of trade costs. Given the asymmetric effect of various EIAs on these types of costs, some integration arrangements may not always lead to export diversification. Moreover, the effect of EIAs on bilateral export diversification should be analyzed separately, by considering each agreement type in part. In doing so, the current study finds that, despite being more integrated, Eurozone exporter-importer pairs are characterized by more concentrated, rather than more diverse, export flows.

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Figure 2.2: Inflation Rates for EZ11 Members

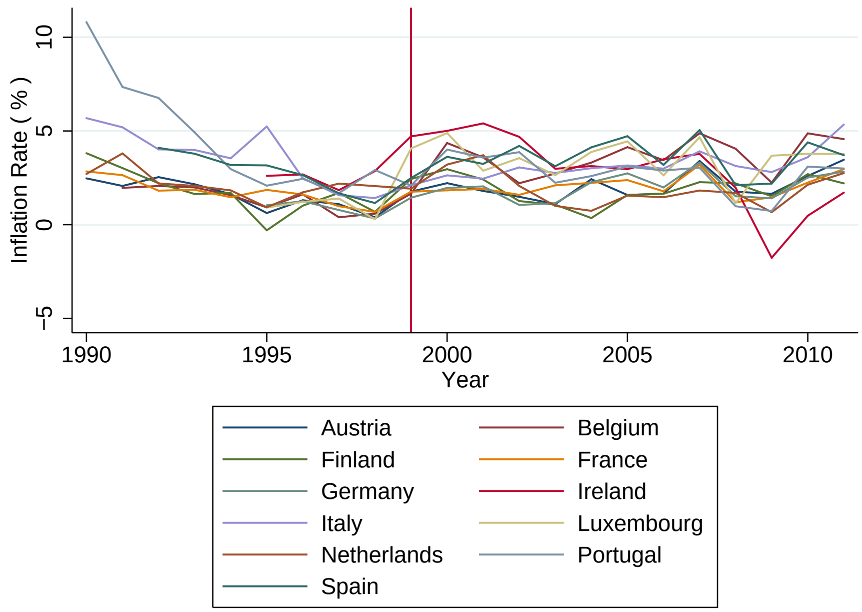

Figure 2.3: Long Term Interest Rates for EZ11 Members

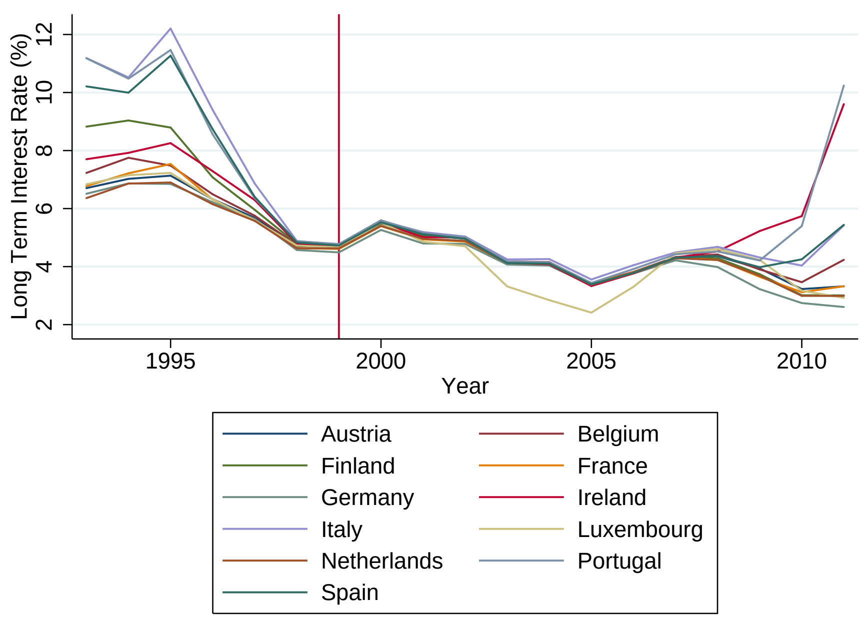

Figure 2.4: FDI vs Exporting Decision

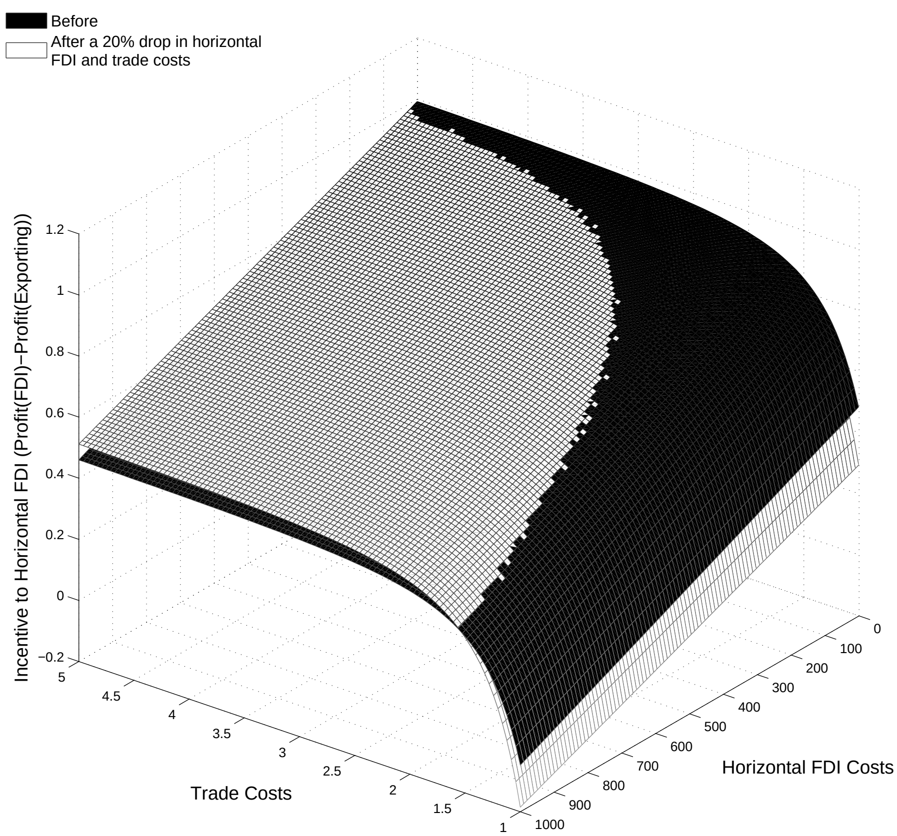

Figure 2.5: Total Bilateral FDI and Trade Flows for EZ11 Members

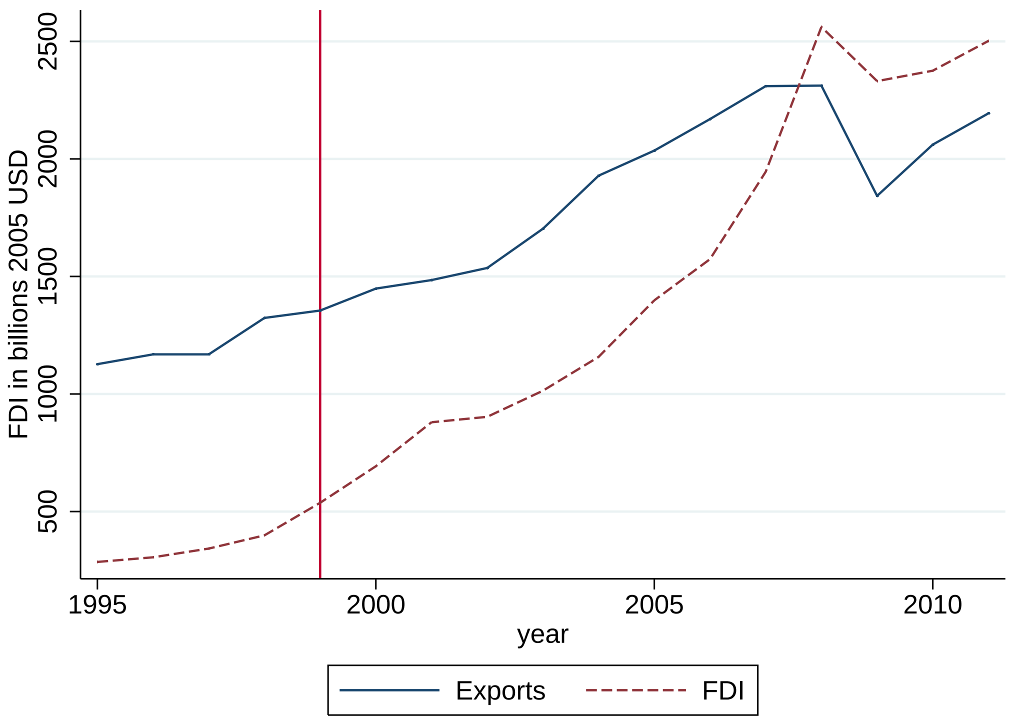

Table 2.1: European Union (EU) and Eurozone (EZ) Membership Timetable

Country	Year joined EU	Year joined EZ
Austria	1995	1999
Belgium	Founder	1999
Bulgaria	2007	
Cyprus	2004	2008
Czech Republic	2004	
Denmark	1973	
Estonia	2004	2011
Finland	1995	1999
France	Founder	1999
Germany	Founder	1999
Greece	1981	2001
Hungary	2004	
Ireland	1973	1999
Italy	Founder	1999
Latvia	2004	2014
Lithuania	2004	2015
Luxembourg	Founder	1999
Malta	2004	2008
Netherlands	Founder	1999
Poland	2004	
Portugal	1986	1999
Romania	2007	
Slovakia	2004	2009
Slovenia	2004	2007
Spain	1986	1999
Sweden	1995	
United Kingdom	1973	

Note: For completeness purposes, it is worth noting that Latvia and Lithuania joined the European economic and monetary union in 2014 and 2015 respectively. However, since these events took place after 2011, the latest year available within the dataset, these countries are not regarded as Eurozone members.

Table 2.2: Summary Statistics

	Obs.	Mean	Std. Dev.	Min.	Max.
HH index of bilateral export concentration	11927	0.24	0.17	0.04	1.00
Theil index of bilateral export concentration	11927	2.15	0.94	0.64	5.54
Gini index of bilateral export concentration	11927	0.86	0.09	0.59	1.00
Capital stock (bil. USD)	11934	1510.69	2304.31	14.47	10405.76
Avg. years of schooling	11934	10.08	1.06	6.98	12.75
Arable land area (mil. ha.)	11934	4148.98	4799.63	8.00	18517.00
Persons employed (mil.)	11934	7.96	9.98	0.15	41.38
Real GDP (bil. USD)	11934	455.63	658.19	4.56	2840.95
Real GDP per capita	11934	23436.31	10682.13	5524.77	65123.80
Total factor productivity index (USA=1)	11934	0.80	0.20	0.33	1.54
Distance (km.)	11934	1431.65	745.64	59.62	3766.31
Contiguity (=1 if x and m share land border)	11934	0.10	0.30	0.00	1.00
Common language (=1 if x and m share official language)	11934	0.04	0.20	0.00	1.00
TA (Integration measure of Regolo (2013))	11934	4.16	1.62	0.00	6.00
RTA	11934	3.98	1.45	0.00	5.00
EZ (=1 if x and m share the euro)	11934	0.18	0.38	0.00	1.00
Trade openness	11934	0.91	0.46	0.21	2.77
Financial openness	11934	5.38	17.40	0.22	119.94
Origin's export concentration index	11934	0.13	0.07	0.04	0.53

Note: Capital stock, real GDP per capita and real GDP figures are expressed in constant 2005 USD at current PPPs. Given the country-pair setup of the dataset, the descriptive statistics pertaining to the exporter are also valid for the importer.

Table 2.3: The Average Eurozone Effect on the Number of Exporting Sectors

Specification:	(1)	(2)	(3)	(4)
log Distance	-0.356***		-0.336***	
	(0.065)		(0.066)	
Common Border	1.412***		2.014***	
	(0.258)		(0.385)	
Common Language	0.108		0.126	
	(0.210)		(0.233)	
RTA	0.052***	0.049***	0.045***	0.043***
	(0.002)	(0.005)	(0.002)	(0.004)
EZ11	-0.067***	-0.071***	-0.047***	-0.044***
	(0.006)	(0.011)	(0.006)	(0.010)
log. Exporter's GDP	0.643***	0.554***	0.639***	0.545***
	(0.013)	(0.047)	(0.014)	(0.046)
log. Importer's GDP	0.413***	0.368***	0.391***	0.332***
	(0.012)	(0.040)	(0.013)	(0.042)
diff. GDPpc			-0.033*	-0.053
			(0.017)	(0.041)
diff. TFP			-0.143***	-0.147***
			(0.015)	(0.041)
diff. K/L			-0.021**	-0.003
			(0.008)	(0.022)
diff. HC			0.003	0.047
			(0.013)	(0.039)
diff. A/L			0.114***	0.123***
			(0.010)	(0.023)
Obs.	11,927	11,927	11,927	11,927

Note: The dependent variable is the number of SITC 3 Rev. 3 sectors in which the origin ticks positive export values towards the destination. Coefficients in columns (1) and (3) are estimated by using the conditional, fixed effects negative binomial estimator. Coefficients in columns (2) and (4) are estimated using the fixed effects Poisson PML estimator. Standard errors are shown in parentheses and clustered at the country-pair level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Specifications within the first two columns represent simple gravity equations. The last two columns include differences in factor endowments, productivity and GDP per capita as in Regolo (2013).

Table 2.4: The Average Eurozone Effect on Hirschmann-Herfindahl Index of Bilateral Export Concentration

Specification:	(1)	(2)	(3)	(4)	(5)	(6)
diff. K/L	0.088**	0.106***	0.106***	0.106***	0.108***	0.085***
	(0.034)	(0.026)	(0.035)	(0.026)	(0.035)	(0.030)
diff. HC	-0.152	-0.097	-0.152	-0.112	-0.158	-0.099
	(0.126)	(0.105)	(0.126)	(0.106)	(0.126)	(0.102)
diff. A/L	0.049**	0.047**	0.049**	0.048**	0.048**	0.035**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.016)
log Distance	0.180***	0.202***	0.184***	0.205***	0.184***	0.185***
	(0.028)	(0.021)	(0.028)	(0.022)	(0.028)	(0.020)
Common Border	-0.217***	-0.227***	-0.215***	-0.227***	-0.222***	-0.215***
	(0.050)	(0.022)	(0.049)	(0.023)	(0.049)	(0.024)
Common Language	-0.148*	-0.132***	-0.158*	-0.136***	-0.151*	-0.152***
	(0.085)	(0.039)	(0.084)	(0.039)	(0.084)	(0.033)
diff. GDPpc	-0.228***	-0.269***	-0.224***	-0.253***	-0.228***	-0.183***
	(0.056)	(0.039)	(0.056)	(0.039)	(0.056)	(0.041)
diff. TFP	0.180**	0.245***	0.176**	0.234***	0.178**	0.166***
	(0.078)	(0.047)	(0.078)	(0.048)	(0.078)	(0.049)
TA	-0.035***	-0.014***				
	(0.007)	(0.004)				
RTA			-0.036***	-0.016***	-0.035***	-0.018***
			(0.007)	(0.004)	(0.007)	(0.005)
EZ11			0.072**	0.041**	-0.577**	-0.248*
			(0.034)	(0.018)	(0.273)	(0.139)
EZ11 x log Importer's GDP					0.050**	0.023**
					(0.021)	(0.011)
log Importer's GDP					-0.050	-0.102
					(0.070)	(0.066)
Obs.	11,927	11,927	11,927	11,927	11,927	11,927
R-Squared	0.656	0.762	0.657	0.758	0.658	0.479

Note: The dependent variable is the natural logarithm of the Hirschmann-Herfindahl index of bilateral export concentration. Results within columns (1), (3), and (5) are obtained by using OLS. Standard errors are shown in parentheses and clustered at the country-pair level. Estimates in columns (2), (4), and (6) are obtained by using generalized least squares. Standard errors are corrected for panel specific heteroskedasticity, cross sectional dependence, together with serial correlation and are shown in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Exporter, importer, and year effects are included but not reported.

Table 2.5: Robustness Checks (OLS)

Specification:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
diff. K/L	0.109***	0.108***	0.111***	0.111***	0.109***	0.106***	0.104***
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
diff. HC	-0.180	-0.158	-0.152	-0.147	-0.151	-0.155	-0.152
	(0.127)	(0.126)	(0.126)	(0.126)	(0.126)	(0.127)	(0.126)
diff. A/L	0.050**	0.049**	0.049**	0.049**	0.049**	0.049**	0.052**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
diff. GDPpc	-0.231***	-0.227***	-0.233***	-0.229***	-0.226***	-0.226***	-0.222***
	(0.057)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)
diff. TFP	0.181**	0.172**	0.169**	0.155*	0.170**	0.182**	0.167**
	(0.079)	(0.079)	(0.079)	(0.080)	(0.079)	(0.079)	(0.078)
log Distance	0.185***	0.185***	0.186***	0.186***	0.185***	0.184***	0.184***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Common Border	-0.216***	-0.217***	-0.217***	-0.217***	-0.216***	-0.216***	-0.216***
	(0.050)	(0.050)	(0.050)	(0.050)	(0.049)	(0.049)	(0.049)
Common Language	-0.157*	-0.158*	-0.158*	-0.158*	-0.158*	-0.158*	-0.158*
	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)
RTA	-0.033***	-0.029***	-0.025***	-0.025***	-0.034***	-0.035***	-0.039***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)
EZ11	0.070**	0.073**	0.066*	0.059*	0.068**	0.074**	0.074**
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
log Exp.'s GDP		-0.416***					
		(0.065)					
log Imp.'s GDP		-0.106					
		(0.069)					
log Exp.'s GDPpc			-0.413***	-1.831***			
			(0.063)	(0.611)			
log Imp.'s GDPpc			-0.127*				
			(0.067)				
log Exp.'s GDPpc sq.				0.077**			
				(0.032)			
log Exp.'s trade open.					-0.010		
					(0.036)		
log Imp.'s trade open.					-0.076**		
					(0.038)		
log Exp.'s fin. open.						-0.050*	
						(0.030)	
log Imp.'s fin. open.						0.005	
						(0.034)	
logistic Exp.'s HHI exp.							0.197***
							(0.024)
Obs.	11,927	11,927	11,927	11,927	11,927	11,927	11,927
R-Squared	0.660	0.660	0.660	0.660	0.658	0.657	0.661

Note: The dependent variable is the natural logarithm of the Hirschmann-Herfindahl index of bilateral export concentration. Coefficients are estimated using ordinary least squares. Exporter, importer, and year effects are included but not reported. Standard errors are shown in parentheses and clustered at the country-pair level. *** p<0.01, ** p<0.05, * p<0.1. (1) Multilateral trade and investment resistance terms as in Baier and Bergstrand (2009) w.r.t. country-pair characteristics (e.g. distance, contiguity, common language, exchange rates, and common legal system) are included but not reported. Exporter and importer real GDP is included in (2). Per capita real GDP figures for exporter and importer are included in (3). Exporter real GDP per head and it's squared counterpart are included in (4). In (5), exporter and importer trade openness are added whereas financial openness is controlled for in (6). Overall exporter's concentration of exports is accounted for in (7).

Table 2.6: Robustness Checks (GLS)

Specification:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
diff. K/L	0.109***	0.112***	0.116***	0.117***	0.108***	0.105***	0.104***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
diff. HC	-0.141	-0.124	-0.115	-0.097	-0.102	-0.119	-0.109
	(0.107)	(0.106)	(0.107)	(0.107)	(0.106)	(0.106)	(0.105)
diff. A/L	0.051**	0.048**	0.047**	0.048**	0.047**	0.048**	0.052**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)
diff. GDPpc	-0.253***	-0.272***	-0.278***	-0.273***	-0.254***	-0.258***	-0.249***
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.038)
diff. TFP	0.222***	0.235***	0.227***	0.208***	0.229***	0.248***	0.227***
	(0.049)	(0.048)	(0.048)	(0.047)	(0.048)	(0.049)	(0.048)
log Distance	0.206***	0.207***	0.209***	0.208***	0.206***	0.205***	0.207***
	(0.022)	(0.022)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Common Border	-0.229***	-0.230***	-0.231***	-0.229***	-0.228***	-0.227***	-0.227***
	(0.024)	(0.024)	(0.024)	(0.022)	(0.022)	(0.023)	(0.023)
Common Language	-0.147***	-0.150***	-0.145***	-0.143***	-0.131***	-0.136***	-0.138***
	(0.039)	(0.038)	(0.037)	(0.037)	(0.039)	(0.039)	(0.039)
RTA	-0.015***	-0.013***	-0.011***	-0.011***	-0.015***	-0.015***	-0.017***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
EZ11	0.040**	0.047**	0.040**	0.029	0.039**	0.045**	0.044***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.017)	(0.018)	(0.017)
log Exp.'s GDP		-0.314***					
		(0.057)					
log Imp.'s GDP		-0.159***					
		(0.054)					
log Exp.'s GDPpc			-0.324***	-1.833***			
			(0.055)	(0.631)			
log Imp.'s GDPpc			-0.192***				
			(0.054)				
log Exp.'s GDPpc sq.				0.080**			
				(0.033)			
log Exp.'s trade open.					0.020		
					(0.035)		
log Imp.'s trade open.					-0.077***		
					(0.028)		
log Exp.'s fin. open.						-0.078***	
						(0.028)	
log Imp.'s fin. open.						-0.015	
						(0.023)	
logistic Exp.'s HHI exp.							0.129***
							(0.018)
Obs.	11,927	11,927	11,927	11,927	11,927	11,927	11,927
R-Squared	0.754	0.755	0.757	0.758	0.760	0.759	0.759

Note: The dependent variable is the natural logarithm of the Hirschmann-Herfindahl index of bilateral export concentration. Estimates are obtained using generalized least squares. Standard errors are corrected for heteroskedasticity, cross sectional dependence, together with serial correlation and shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Exporter, importer, and year effects are included but not reported. (1) Multilateral trade and investment resistance terms as in Baier and Bergstrand (2009) w.r.t. country-pair characteristics (e.g. distance, contiguity, common language, exchange rates, and common legal system) are included but not reported. Exporter and importer real GDP is included in (2). Per capita real GDP figures for exporter and importer are included in (3). Exporter real GDP per head and it's squared counterpart are included in (4). In (5), exporter and importer trade openness are added whereas financial openness is controlled for in (6). Overall exporter's concentration of exports is accounted for in (7).

Table 2.7: Controlling For Index Choice

Specification:	(1)	(2)	(3)	(4)
diff. K/L	0.072***	0.011**	0.062***	0.009***
	(0.021)	(0.005)	(0.013)	(0.003)
diff. HC	-0.019	0.016	-0.006	0.019**
	(0.073)	(0.017)	(0.044)	(0.008)
diff. A/L	0.025**	0.000	0.023**	0.001
	(0.012)	(0.003)	(0.011)	(0.002)
diff. GDPpc	-0.140***	-0.021***	-0.125***	-0.015***
	(0.032)	(0.008)	(0.020)	(0.004)
diff. TFP	0.144***	0.037***	0.146***	0.028***
	(0.046)	(0.011)	(0.026)	(0.005)
log Distance	0.168***	0.045***	0.164***	0.045***
	(0.017)	(0.004)	(0.013)	(0.003)
Common Border	-0.164***	-0.061***	-0.201***	-0.064***
	(0.030)	(0.008)	(0.016)	(0.004)
Common Language	-0.090*	-0.014	-0.068***	-0.016***
	(0.053)	(0.013)	(0.021)	(0.005)
RTA	-0.026***	-0.005***	-0.011***	-0.001***
	(0.004)	(0.001)	(0.002)	(0.000)
EZ11	0.028	0.000	0.022**	0.003*
	(0.019)	(0.004)	(0.009)	(0.002)
Obs.	11,927	11,927	11,927	11,927
R-Squared	0.791	0.851	0.848	0.828

Note: The dependent variables are the natural logarithm of the Theil index in columns (1) and (3) and Gini index in (2) and (4). Coefficients in columns (1) and (2) are estimated using ordinary least squares. Standard errors are shown in parentheses and clustered at the country-pair level. Estimates in columns (3) and (4) are obtained using generalized least squares. Standard errors are corrected for panel specific heteroskedasticity, cross sectional dependence, together with serial correlation and are shown in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Exporter, importer, and year effects are included but not reported.

Table 2.8: Controlling For Index Boundness

Specification:	(1)	(2)	(3)	(4)
diff. K/L	0.201***	0.226***	0.200***	0.182***
	(0.055)	(0.051)	(0.046)	(0.031)
diff. HC	-0.299*	0.015	-0.236	0.037
	(0.180)	(0.149)	(0.170)	(0.100)
diff. A/L	0.115***	0.094***	0.103***	0.061***
	(0.031)	(0.026)	(0.038)	(0.022)
diff. GDPpc	-0.360***	-0.380***	-0.362***	-0.280***
	(0.082)	(0.069)	(0.072)	(0.050)
diff. TFP	0.195*	0.318***	0.220**	0.267***
	(0.114)	(0.100)	(0.089)	(0.063)
log Distance	0.252***	0.427***	0.270***	0.437***
	(0.038)	(0.033)	(0.037)	(0.030)
Common Border	-0.209***	-0.158**	-0.235***	-0.190***
	(0.066)	(0.064)	(0.044)	(0.039)
Common Language	-0.275**	-0.233**	-0.222***	-0.247***
	(0.121)	(0.115)	(0.062)	(0.059)
RTA	-0.074***	-0.080***	-0.044***	-0.035***
	(0.014)	(0.011)	(0.010)	(0.006)
EZ11	0.117**	0.086**	0.063**	0.057***
	(0.049)	(0.040)	(0.028)	(0.018)
Obs.	11,925	11,925	11,925	11,925
R-Squared	0.599	0.808	0.473	0.899

Note: The dependent variables are the logistic transformation (Baum, 2008) of the Hirschmann-Herfindahl index in columns (1) and (3) and Gini index in (2) and (4). Coefficients in columns (1) and (2) are estimated using ordinary least squares. Standard errors are shown in parentheses and clustered at the country-pair level. Estimates in columns (3) and (4) are obtained using generalized least squares. Standard errors are corrected for panel specific heteroskedasticity, cross sectional dependence, together with serial correlation and are shown in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Exporter, importer, and year effects are included but not reported.

Table 2.9: Controlling For The Economy Size

Specification:	(1)	(2)	(3)	(4)	(5)
diff. K/L	0.112***	0.112***	0.112***	0.112***	0.111***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
diff. H/L	-0.124	-0.117	-0.116	-0.116	-0.115
	(0.106)	(0.106)	(0.105)	(0.105)	(0.105)
diff. A/L	0.048**	0.048**	0.048**	0.050**	0.049**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
diff. GDPpc	-0.272***	-0.277***	-0.279***	-0.279***	-0.281***
	(0.039)	(0.040)	(0.040)	(0.039)	(0.039)
diff. TFP	0.235***	0.238***	0.239***	0.238***	0.241***
	(0.048)	(0.048)	(0.048)	(0.048)	(0.048)
log Distance	0.207***	0.206***	0.206***	0.206***	0.205***
	(0.022)	(0.021)	(0.021)	(0.021)	(0.021)
Common Border	-0.230***	-0.229***	-0.230***	-0.230***	-0.231***
	(0.024)	(0.023)	(0.023)	(0.024)	(0.023)
Common Language	-0.150***	-0.144***	-0.142***	-0.142***	-0.140***
	(0.038)	(0.037)	(0.037)	(0.037)	(0.037)
RTA	-0.013***	-0.013***	-0.013***	-0.013***	-0.014***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
EZ11	0.047**				
	(0.018)				
EZ12		0.031*			
		(0.017)			
EZ13			0.025*		
			(0.015)		
EZ15				0.032**	
				(0.015)	
EZ16					0.017
					(0.014)
log Exporter's GDP	-0.314***	-0.313***	-0.313***	-0.314***	-0.314***
	(0.057)	(0.056)	(0.057)	(0.056)	(0.057)
log Importer's GDP	-0.159***	-0.159***	-0.157***	-0.159***	-0.159***
	(0.054)	(0.055)	(0.055)	(0.054)	(0.055)
Obs.	11,927	11,927	11,927	11,927	11,927
R-Squared	0.755	0.758	0.758	0.758	0.758

Note: Dependent variable is the natural logarithm of the Hirschmann-Herfindahl index of bilateral export concentration. Estimates are obtained using generalized least squares. Standard errors are corrected for heteroskedasticity, cross sectional dependence, and serial correlation and shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Five definitions of the Eurozone dummies are employed. First, EZ11 takes a value of 1 for the exporter-importer pairs formed by the initial euro adopters and 0 otherwise. EZ12 adds Greece to the group of 11 initial adopters. EZ13 comprises Slovenia while EZ15 adds Malta and Cyprus. Finally, EZ16 adds in Slovakia. Exporter, importer, and year effects are included but not reported.

Chapter 3 The Effect of International Environmental Agreements on Trade: An Industry Level Approach

3.1 Introduction

Since the early 1970s national governments have engaged in an array of international environmental agreements (IEAs). The IEAs are diverse in their scope, means of achieving the outlined objectives, and the substances targeted. Time and again, national engagement in IEAs is met with distaste by the supply side of the market, as these were, and still are, a perceived source of additional production costs and an inhibitor of competitiveness. For example, the environmental regulation brought about in the 1970s is believed by some to have contributed to the deterioration of the United States trade balance (Jaffe et al., 1995). Thus, it should not be surprising that firms and sometimes entire industrial sectors oppose this kind of international commitment. But, are IEAs a source of comparative disadvantage and an inhibitor of competitiveness? Starting from the premise that nations trade based on comparative advantage differences, and that environmental regulation may represent a source of comparative disadvantage (at least for "dirty" industries[1,2]), this essay seeks to provide an answer to the above question by analyzing the effect of IEAs' adoption on industry-level exports[3]. The rationale behind testing this hypothesis within the context of international trade is simple. If sovereign enrollment in IEAs is indeed a source of additional production expenditures, such costs should be then passed along to consumers in the form of higher prices which, in turn, should generate lower exports. Of course, the degree to which exports respond to price changes depends on an array of factors such as the degree of market competition, the elasticity of substitution (i.e., product homogeneity), or transportation costs that prevail within a given sector. However, given the scope of this analysis these factors are not explicitly addressed here.

In a broader context, the current work belongs to the literature strand on the Ricardian and Heckscher-Ohlin theories of trade which postulate that international trade patterns are driven by comparative advantage differences. Comparative advantage differentials may arise along the lines of geography, endowments of production factors, productivity, financial and economic development, institutional attributes,

[1]Industries defined as "dirty" display a high ratio of emissions to output. This ratio is referenced throughout as "emission intensity". Refer to table 3.10 for sectoral rankings by emission intensity. For the ease of exposition, I classify industries into "dirty" and "clean" using the 75^{th} percentile cut-off relevant to the CO_2 emission intensity distribution. As a result, the following sectors are identified as "dirty": other non-metallic minerals, coke, refined petroleum and nuclear fuel, basic metals and fabricated metal, and chemicals and chemical products. This split is consistent with previous studies (Jänicke et al., 1997; Mani and Wheeler, 1998; Ederington et al., 2005; Kellenberg, 2009; Grether et al., 2012).

[2]Refer to figures 3.6, 3.7, and 3.8 for unconditional trends.

[3]The analyzed IEAs span three major categories: climate change, acid rain, and ozone deple-

and quality of contract and property rights enforcement[4]. Since the 1970s, environmental regulation has been added to the list, but as a source of comparative disadvantage rather than advantage[5]. Differences in environmental regulation, across nations, can arise from differences in the demand for, and supply of, environmental quality. The former is found to be shaped by differences in per capita income levels (Grossman and Krueger, 1991; Antweiler et al., 2001) while the latter may be influenced by factors such as population density (Frankel, 2009) or pollution dispersion capabilities (Broner et al., 2012). More narrowly, this essay adds to the literature on the pollution haven effect (PHE) and its special case of "leakage". The PHE hypothesizes the loss of comparative advantage (and thus exports) in "dirty" industries to jurisdictions with laxer environmental standards. Meanwhile, "leakage" denotes the displacement of domestic production by relatively cheaper imports originating within jurisdictions characterized by more lenient environmental rules.

For the most part, studies linking the environmental policy choice with comparative advantage losses focused on regulation such as enforcement stringency, pollution abatement costs, or fuel standards (Kalt, 1985; Tobey, 1990; Grossman and Krueger, 1991; Ederington and Minier, 2003; Ederington et al., 2005; Levinson and Taylor, 2008; Kellenberg, 2009; Broner et al., 2012). This paper contributes to this literature strand by directing attention onto the adoption of IEAs and their effects on industry-level comparative advantage patterns. The analysis conducted here is comparable to those in De Santis (2012) and Aichele and Felbermayr (2015)[6]. It differs, however, from these along two important margins. First, the focus is placed on the stock of adopted IEAs rather than on a single IEA at a time. This study considers 13 air pollution agreements, therefore broadening the scope of previous studies. Second, the present work benefits from a much larger data universe which encompasses 163 nations and 36 years, 1976-2011[7]. In line with the recommendations of Head and Mayer (2013)[8], and similar to the approach of Aichele and Felbermayr (2015), I account for the non-random selection into IEAs by including exporter, and importer,

tion. Refer to section 3.3 for details. Unless otherwise specified the term "IEAs" refers to all three categories.

[4]Refer to Helpman et al. (2004); Romalis (2004); Costinot (2005); Bernard et al. (2007) for theoretical discussions on comparative advantage at the country, industry, and firm levels. For empirical evidence see Chor (2010); Chor and Manova (2012); Jaimovich and Merella (2012); Levchenko (2004); Manova (2008, 2012); Nunn (2007); Regolo (2013); Fajgelbaum et al. (2011). The negative impact on geographic remoteness on international commerce is underlined by virtually every study that uses the gravity model of trade. Refer to Head and Mayer (2013) for a survey of estimates. Nunn and Puga (2012) also discuss the role of geography in determining trade patterns.

[5]Refer to Pethig (1976); Robison (1988); McGuire (1982) for early theoretical discussions regarding environmental regulation as a source of comparative disadvantage.

[6]De Santis (2012) considers the United Nations Framework Convention on Climate Change (UNFCCC) along with its Kyoto protocol, and the Montreal protocol to the Vienna Convention for the Protection of the Ozone Layer (VCPOL). Aichele and Felbermayr (2015) assess the Kyoto protocol.

[7]De Santis (2012) observes 24 countries between 1988-2008. Aichele and Felbermayr (2015) examine a total of 40 countries from 1995-2007.

[8]The discussion pertains to the choice of trade integration agreements, but it equally applies here.

time-varying effects in all empirical specifications. This setup presents itself as a relatively simple alternative to the instrumental variable techniques, previously used to tackle the endogenous nature of environmental policy choice. Although some studies have managed the task, finding the "correct" and relevant instrument can often be difficult[9].

The evidence brought forward by the current essay can be summarized in three points. First, the ratification of IEAs is found to be a source of comparative disadvantage for pollution-intensive sectors. For example, the adoption of an additional IEA by the exporter lowers outflows from sectors categorized as "dirty" by about 3%. Exports from "clean" sectors are found to decrease by 1%. Furthermore, exports of non-metallic minerals (the most CO_2-intensive industry in the sample)[10] are lowered by 3.6% while exports of leather and footwear (the least CO_2-intensive industry in the sample) decline by only 0.5%.

Second, different types of IEAs seem to entail different composition and/or scale effects[11]. Climate change IEAs involve a strong export composition effect. This kind of IEAs, namely the Kyoto protocol, seem to be a modest source of comparative disadvantage for pollution-intensive industries and a notable source of comparative advantage for their least polluting peers. For sectors marked as "dirty" the ratification of Kyoto protocol entails an export decline below 1%. The exports from "clean" sectors, however, are estimated to increase by as much as 5.8%. Moreover, for the non-metallic minerals industry, the export decline brought about by joining the protocol is 3%. Conversely, exports of leather and footwear are estimated to increase by 5%. Acid rain and ozone depletion IEAs imply export scale effects. In contrast to climate change IEAs, acid rain agreements appear as a large source of comparative disadvantage for pollution-intensive industries. It is debatable, however, to what extent they harm or benefit the least pollution-intensive industries. For example, the ratification of an additional acid rain IEA is equivalent to an export decline of about 1% for sectors classified as "clean", and 5% for those tagged as "dirty". Moreover, for coke, refined petroleum, and nuclear fuel sector (the most SO_x-intensive industry in the sample)[12] the ratification of an extra acid rain IEA carries a 3.2% decline in outflows. At the opposite end, exports of leather and footwear (the least SO_x-intensive industry in the sample) are negligibly, but positively, impacted. The average effect of joining ozone depletion IEAs is even larger, bringing about an approximate export drop of 2.2% in

[9]For example, Broner et al. (2012) use the air pollution dispersal potential as an instrument for IEA ratification. This nation-specific trait is elegantly constructed as a function of various geographical and meteorological characteristics. Aichele and Felbermayr (2015) use the ratification of Statuses of the International Criminal Court to instrument the ratification of IEAs.

[10]CO_2 stands for carbon dioxide. This greenhouse gas is a by-product of virtually any industrial activity and it is specifically targeted under the Kyoto protocol. However, due to emissions overlap (e.g. CO_2 may be released into the atmosphere along with other substances), it may be indirectly targeted by other IEAs.

[11]The composition effect refers to changes in the export bundle brought about by the adoption of IEAs (e.g., exports of non-metallic minerals decrease while exports of leather and footwear increase). The scale effect refers to the changes (increase/decrease) in the overall volume of exports.

[12]SO_x stands for sulfur oxides. Figuring as a target for three out of the seven acid rain IEAs

"clean", and 7.5% in "dirty" sectors, respectively.

Third, only climate change and acid rain IEAs are found to engender "leakage" effects. The effects appear to be stronger for the first category. For climate change IEAs, the marginal effects of ratification on "dirty" exports and imports hover in the vicinity of -3% and 4%, respectively[13]. Concerning acid rain IEAs, the effects situate at -4.5% for exports and 2% for imports. Evidence of "leakage" is not found with regards to ozone depletion IEAs. For this category, negative effects are found on both "dirty" exports (i.e., -7%) and imports (i.e., -1%). This last set of findings is in line with the international trade provisions aimed at reducing "leakage" and included within this latter type of IEAs.

This essay is organized as follows. Section 3.2 provides an overview of the relevant literature and elaborates on the contribution of this essay. Section 3.3 discusses the framework for IEA adoption and describes the three agreement types introduced earlier (i.e., climate change, acid rain, and ozone depletion). Section 3.4 discusses the data and the construction of the covariates. Section 3.5 details the empirical analysis and critically assesses the results. Finally, section 3.6 concludes.

3.2 Literature Review

There are two ways in which environmental regulation may affect international trade patterns. First, a tougher environmental stance may alter comparative advantage differentials by increasing production costs and leading to a loss of exports to jurisdictions with less stringent environmental rules. This outcome is known as the pollution heaven effect (PHE)[14]. A special case of the pollution heaven effect is known as "leakage"; the scenario under which domestic production, which becomes costlier due to increased environmental regulation, is substituted with imports from environmentally lax nations (Copeland and Taylor, 2005). Second, Porter and van der Linde (1995) argue for the case in which environmental regulation acts as a catalyst for further research, innovation and efficiency gains. Ultimately, this outcome is expected to translate into increased competitiveness both domestically and internationally. This is known in the literature as the "Porter hypothesis". In support of this view, Morgenstern et al. (2001) outline the existence of an overlap between production and environmental activities. Thus, increased environmental regulation may induce additional economies of scope, improvements of production processes, or the recovery of valuable byproducts through increased recycling. In summary, aside from the "Porter hypothesis" scenario, environmental regulation is expected to adversely impact export flows.

Early studies have analyzed the consequences of increased environmental strin-

considered, it is by far the most targeted chemical compound under the acid rain IEA category.

[13]These effects are relative to the corresponding flows in the "clean" sectors. For example, due to the adoption of Kyoto protocol, exports from sectors categorized as "dirty" decrease by 3% relative to exports from sectors regarded as "clean".

[14]Refer to Copeland and Taylor (1994, 2005). For an early theoretical discussion regarding the locational choice of industries in the presence of environmental regulation and regulation in general

gency on international trade with little success in providing evidence for PHE[15]. In a survey, Levinson (1995) concludes that the apparent lack of evidence can give itself to an array of factors ranging from empirical misspecifications to various motives for which firms and sectors would not be impacted by a tougher environmental stance (i.e., firms prefer to operate in line with the most stringent standards to achieve efficiency gains, or multinationals are more able to cope with the higher costs brought about by regulation). Levinson (1996) advances the idea that industries with the highest pollution abatement costs (PACs) may also be the least mobile (i.e., the least footloose), and thus unlikely to relocate in "pollution havens". This may provide an explanation for why early studies (which focused on PACs as measures of environmental stringency) found little PHE evidence. Another drawback of earlier studies is the failure to address the endogenous nature of the environmental policy stance. Left unaccounted, this issue is likely to bias estimates away from PHE consistent figures (Levinson and Taylor, 2008). In fact, studies that fall into this category, often invoke arguments along the lines of the "Porter hypothesis".

More recent studies tackled the above issues and provided evidence in favor of the pollution haven effect. Millimet and List (2004) do so by taking into account the heterogeneous nature of environmental controls across industries and space. They also emphasize the issue of aggregation which has the potential of masking idiosyncratic responses to regulation across sectors. Ederington and Minier (2003) assess environmental stringency at the industry-level as the share of PACs in total costs. By taking into account the endogenous nature of this ratio, they estimate a positive and significant effect of environmental stringency on net sectoral imports for the United States. Ederington et al. (2005) discuss the importance of accounting for sectoral characteristics and the development level of the trading partner. In doing so, they provide evidence in favor of the PHE for footloose sectors. Their study also points out to an increase in the United States' imports from low-income nations in response to incremental environmental regulation. No such evidence is found for inflows originating within OECD countries. Levinson and Taylor (2008) circumvent the endogenous nature of sectoral PACs by using an instrumental variable (IV) approach and find significant PHE supporting evidence. Specifically, a 1% increase in PACs is equivalent to a 0.4% increase in net imports from Mexico. A similar change in PACs entails a 0.6% increase in net inflows from Canada. Kellenberg (2009) seems to be the first study to provide evidence for the pollution heaven effect within a cross-sectional data environment. Their identification strategy is based on a game-theoretical approach to policy determination. This framework identifies two channels, and therefore two sets of instruments, through which manufacturing costs, and environmental and trade policies are determined. By using a first-differenced instrumental variable estimation setup and the ratification of Kyoto protocol as treatment, Aichele and Felbermayr (2012) provide support for the pollution haven effect of IEAs. For parties which ratified the protocol with a binding emission cap, their estimates underline a 14% increase

refer to McGuire (1982).

[15]Refer to Kalt (1985), Robison (1988), Tobey (1990), Grossman and Krueger (1991), Hettige

in the ratio of imported to domestic emissions. Broner et al. (2012) use meteorological factors to construct regional pollution dispersal potentials. They then make the argument that regions/nations with low dispersal potentials are more likely to pursue stricter environmental regulation. Using this as an instrument, the authors underline a deleterious effect of environmental regulation on comparative advantage and exports. As for the size of the PHE, the estimates are difficult to compare. Recall that the studies discussed above use different measures of environmental stringency (share of PACs in total costs, or value added, joining diverse IEAs) and various outcomes of interest (imports, exports, their "net" counterparts, or births of plants)[16].

The current work is concerned with IEAs as a source of comparative disadvantage, and whether their impact is larger for pollution-intensive sectors. This angle contrasts with previous studies which focused mainly on production abatement costs as a measure of environmental stringency. Two channels may be at play should IEAs engender a loss of competitiveness for "dirty" industries. First, Heckscher-Ohlin, general equilibrium effects underline the possibility of environmental regulation benefiting the "clean" sectors while harming their "dirty" counterparts. The underlying mechanism is simple: some resources employed within the "dirty" sectors, which shrink as a result of regulation, are freed up and can be cheaply employed within the "clean" sectors which, in turn, expand. In this scenario, IEA engagement implies a compositional shift in a nation's production and exporting clusters, with "clean" sectors accounting for a larger share of output and outflows. Conversely, increased environmental regulation may negatively impact "clean" industries as well. This follows naturally as industries are heavily inter-connected through upstream and downstream linkages. In this case, the rise of production costs within the pollution-intensive sectors may spill over into the least polluting ones through more costlier inputs (e.g., energy) or transportation[17]. According to this second scenario, the ratification of IEAs implies competitiveness losses and lower exports across the board, regardless of sectoral pollution-intensity.

This study complements those employing the gravity model of international trade

et al. (1992), Mani and Wheeler (1998), and Kahn (2000) among others.

[16]For example, Levinson and Taylor (2008) estimate elasticities of the United States' gross imports from Mexico and Canada to share of PACs in value added at 0.49 in both cases. Regarding net import penetration (from non-OECD countries) and environmental costs (as share of PACs in total costs), Ederington et al. (2005) estimate an elasticity of 0.2.

[17]Based on World Input Output Tables (WIOT) data (Timmer et al., 2012; Dietzenbacher et al., 2013; Timmer et al., 2015), for the 14 manufacturing industries considered here, the sector-specific share of domestically sourced intermediate inputs in gross output is 28.60%. The share excludes inputs sourced within the same industry (i.e., from transport equipment by transport equipment). Also, the average ratio of "dirty" and domestically sourced intermediate inputs to "clean" gross output is 5.4%. The ratio is calculated using the binary pollution-intensity measure outlined earlier (i.e., based on 75^{th} percentile of the CO_2 intensity distribution). The WIOT data is available for 40 nations (all 27 European Union members (in 2011) plus 13 other nations: Australia, Brazil, Canada, China, India, Indonesia, Japan, South Korea, Mexico, Russia, Turkey, Taiwan, and the United States) from 1995 to 2009.

to analyze the effects of environmental policy on trade flows[18]. Perhaps the most relevant, Aichele and Felbermayr (2015) analyze the effect of ratifying one IEA, the Kyoto protocol[19], on imports, carbon dioxide (CO_2) intensity of imports, and the CO_2 content of imports. Taking into account the bilateral structure of their dataset, they address the non-random selection into the protocol through the inclusion of exporter and importer time-varying "fixed" effects. Their estimates are robust to the use of ratification of Statuses of the International Criminal Court as an instrument for adopting the Kyoto protocol. Aichele and Felbermayr (2015) provide strong evidence in favor of the pollution haven effect. The result most relevant to the current study is the effect of Kyoto ratification on imports. Specifically, an importer which ratifies the protocol with a binding emission cap sees its inflows increasing by 5%. Given the bilateral and balanced nature of their dataset, the exact opposite can be inferred for exports (i.e., that they decrease by 5%). These declines are larger in more pollution-intensive industries such as basic metals (i.e., -20%). For relatively "cleaner" sectors, such as textiles and leather, there is evidence of increased exports of 12%. For a number of sectors, such as chemicals and petrochemicals, Kyoto ratification appears to have had a rather small (i.e., 2%) and statistically insignificant effect on outflows. This evidence is in line with the two general equilibrium channels identified above. First, in the wake of Kyoto ratification, some "clean" industries seem to expand at the expense of their "dirty" counterparts; possibly through the employment of production factors released from pollution-intensive sectors. Second, some other industries seem to shrink, perhaps due to spillover effects (i.e., rising costs, and prices) within industries from which intermediate inputs are acquired. Aichele and Felbermayr (2013) use matching techniques to account for self-commitment to the Kyoto protocol. In doing so, they find that adopting a binding emission cap under the protocol entails a decline in exports of about 15%. Further, the authors uncover that among the most impacted are energy intensive sectors such as iron and steel, non-ferrous metals and chemicals, as well as machinery and equipment.

3.3 International Environmental Agreements at a Glance

The design of most IEAs follows a well-established pattern. Initially, participating nations adopt a *framework convention* which outlines the rules, special provisions, objectives, and other fundamental principles under which subsequent arrangements, known as a *protocols*, are mediated. As part of protocols to the framework convention, parties negotiate consumption and production reduction targets as well as emission caps for one or more substances. Means of achieving the proposed targets, such as the promotion of research and development, the exchange of information, the

[18] Aichele and Felbermayr (2015); De Santis (2012); Grether and De Melo (2003); Grether et al. (2012); Jug and Mirza (2005) provide evidence for the PHE. Cagatay and Mihci (2006); van Beers and van den Bergh (1997) find some evidence of a negative effect of environmental regulation on exports. Others, Xu (2000); van Beers and van den Bergh (2000); Harris et al. (2002); Kee et al. (2010) do not find evidence for the PHE.

[19] In their study, only the countries which ratified the Kyoto protocol with a binding emission

sharing of technology among parties, and/or product standards are also discussed. Sometimes protocols are accompanied by one or more *amendments*. Often, these incorporate additional phase-out schedules, emission targets, and/or ways of achieving such targets that were not previously included within the protocol. Just as with the framework convention and the associated protocols, amendments also follow the same three-step, adoption process: signature, ratification, and entry into force. The IEAs considered span three major categories, each briefly described in what follows. The descriptions are based on the treaty texts provided by the International Environmental Agreements Database Project (Mitchell (2016)) and are not meant to be exhaustive. Instead, they are aimed at providing the reader with a broad overview of the IEAs considered and the manufacturing sectors which they are likely to impact. An IEA adoption time-line is presented in table 3.5.

3.3.1 Acid Rain IEAs

IEA's designed to tackle the issue of air pollution and its transboundary effects were adopted as part of the 1979 Geneva Convention on Long Range Transboundary Air Pollution (LRTAP). The signatory and enforcing parties are, to a large extent, represented by Canada, present members of the European Union, Norway, Russia, Switzerland, and the United States.

The first accompanying protocol, Helsinki (1985), mandates the parties to an immediate, or by 1993 at the latest, 30% reduction in sulphur emissions. The 1980 emission levels were used as a basis for the calculation of reduction targets. The protocol also encouraged parties to reduce sulphur emissions beyond the initial mark of 30%. Addressing the same pollutant, the Oslo (1994) protocol introduced party-specific reduction targets[20]. Under this protocol, parties were also mandated to increase energy efficiency. This included the application of national standards with regards to the sulphur content of gasoline, jet kerosene, diesel, marine diesel, or fuel oil. The major sources of sulphur emissions include the combustion processes in the power generating, basic and fabricated metal, and coke, refined petroleum and nuclear fuel sectors. Industries which process titanium dioxide, such as chemicals and chemical products, other non-metallic minerals, and pulp, paper, printing and publishing sectors were also identified as major emitters of sulphur[21].

Under the 1988 Sofia protocol, parties pledged to bring nitrogen oxide (NO_x) emissions to their 1987 levels by 1995. Parties also agreed to negotiate further discharge reductions, and introduced emission standards as well as controls for major emission sources. Under the auspices of the same protocol, participating nations agreed to make unleaded fuel "sufficiently" available no later than two years after the protocol entered into force. Among the sectors affected by the enforcement of Sofia (1988) pro-

cap are regarded as de-facto ratifiers. These are known as Annex II countries and are also listed in table 3.6.

[20]These are inscribed in Annex II of the protocol. For year 2000, the reduction targets range from 11% for Croatia to 83% for Germany. 1980 is considered as the base year.

[21]In a 2006 Intergovernmental Panel on Climate Change (IPCC) report (Sanz Sánchez et al.

tocol one can count the machinery, transport equipment, and the electricity/power generating sectors[22]. Also impacted were the non-metallic minerals[23], basic metals and fabricated metal products, as well as coke, refined petroleum products and nuclear fuel industries. Adding to these, pulp production is also associated with high emissions of nitrogen oxides.

The 1991 Geneva protocol to LRTAP was geared towards reducing emissions of volatile organic compounds (VOCs). Specifically, parties agreed to decrease their emissions of VOCs by at least 30% by 1999. 1988 levels were used as base for reduction calculations. However, if the emissions were transboundary in nature, the offending party had to ensure that, by 1999, these fluxes were decreased by 30% while also bringing its domestic VOC emissions below their 1988 levels. Given the VOC emission reduction guidelines included in the protocol, industries such as petroleum, chemical and chemical products, food and beverages, fabricated metal, and agriculture are more likely to be impacted. Other sectors, such as transport equipment, in which degreasing agents, paints, inks, and glues were heavily used, are also expected to have been affected by the protocol ratification.

The Aarhus (1994) protocol mandated reductions for discharges of heavy metals (cadmium, lead, and mercury). Although no specific targets were introduced for annual emission levels, the protocol did emphasize concrete emission caps for major discharge sources. For new stationary sources, these limits were mandated to be achieved in two years after the protocol's entry into force[24]. For existing sources, eight years were awarded. Most of these sources were identified as various combustion processes employed across an array of industrial sectors. Among these one can count coke, refined petroleum and nuclear fuel, basic metals and fabricated metal, and other non-metallic minerals[25]. In addition, the protocol provided very detailed guidance regarding the instruments and mechanisms through which heavy metal emissions can be contained, reduced, or virtually eliminated[26]. The Aarhus protocol also mandated parties to set standards on the lead content of fuel used by on-the-road vehicles[27].

Under the Aarhus protocol of 1998, parties were mandated to cease the production and use of persistent organic pollutants (POPs) in accordance to their specific timetables. However, some exemptions regarding the use of POPs were allowed[28]. The

(2006)), titanium dioxide is identified as "the most important white pigment".

[22]According to the emission reduction guidelines included in the protocol manufacturers may be mandated to equip vehicles with catalytic converters, more efficient engines, or injection systems.

[23]The cement as well as glass production processes are notoriously NO_x-intensive. See table 3.10.

[24]A new stationary source is defined as any source "of which the construction or substantial modification is commenced after the expiry of two years from the date of entry into force of: (i) the protocol [...]".

[25]This includes the production of glass and cement. For example lead was identified as an intermediate input in the production of crystal glass and cathode ray tubes.

[26]For example, protocol's annex III discusses an array of heavy metal emission control techniques. It also provides data on the performance of dust cleaning devices such as filters, and scrubbers.

[27]Under the protocol, an upper limit of 0.013 grams of lead per liter of unleaded fuel was mandated for introduction no later than six months after the protocol entered into force.

[28]The use of DDT, a pesticide, was permitted only in cases of absolute necessity (i.e., malaria

protocol also mandated environmentally sound strategies for recycling, destruction, and disposal of POPs. Similar to the 1994 Aarhus protocol, the current agreement also included a list of specific emission caps applicable to different stationary sources. The time allowance for meeting these limitations was also conditional on the source status (i.e., new or existing). In accordance with the identified discharge sources, some of the affected industrial branches include energy production, basic metals and fabricated metals, chemicals and chemical products, and agriculture[29].

Finally, the 1999 Gothenburg protocol was aimed at targeting discharges associated with all of the previously introduced pollutants plus ammonia. In addition to the provisions introduced as part of previous arrangements, the protocol added party-specific, emission reduction targets for sulphur compounds (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and non-methane volatile organic compounds (NMVOC)[30]. Further, emission caps for major stationary discharge sources were introduced, or updated if previous figures were already present. In accordance with provided time tables, the Gothenburg protocol also introduced tailpipe emission limits for passenger cars, light and heavy-duty vehicles, motorcycles, and mopeds as well as non-road vehicles and machinery. New standards for marketed fuels were also added under the same agreement.

It is worth noting that all of the above protocols include extensive technical annexes which provided detailed information on readily available, emission reducing technologies by pollutant and emission source, as well as data on costs, and guidelines regarding means of implementation. The central idea behind the provision of such information was to facilitate and expedite the emission reduction process for participating members.

3.3.2 Ozone Depletion IEAs

IEAs aimed at reducing and controlling the emission of substances with ozone altering and depletion characteristics were adopted under the auspices of the 1985 Vienna Convention for the Protection of the Ozone Layer (VCPOL). These comprise the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer and its subsequent amendments, London (1990), Copenhagen (1992), Montreal (1997), and Beijing (1999). Broadly, the Montreal protocol was centered around limiting the consumption and production of chlorofluorocarbons (CFCs) and bromofluorocarbons (BFCs) relative to their calculated 1986 levels[31]. In addition, it also introduced

and encephalitis outbreaks) and for only one year after its production was stopped.

[29] After-crop incineration was identified as an important source of POP emissions.

[30] Emission reduction targets refer to 2010 relative to their 1990 levels. Across all four pollutants these range between 0% and 90%. For example, in the case of NO_2, Armenia, Croatia, and Greece faced a 0% target whereas Czech Republic and Germany committed to a 61% and 60% discharge drop.

[31] Calculated levels are obtained in a two-step process. First, the annual production of each controlled substance is multiplied by its ozone depleting potential. Second, the obtained figures are aggregated across all substances within a given category (consumption and production). For CFCs and BFCs, the average ozone depleting potentials are 0.88 and 6.33, respectively.

a phase-out timetable for the substances noted above. For example, by 1990, the annual production and consumption of CFCs should not have exceeded the 1986 calculated levels. A similar stipulation, but with 1993 as a deadline, was made for BFCs. By 1994, the annual consumption and production of CFCs was subjected to a 20% reduction. By 1999, these counts were marked for a 50% decrease. Under the protocol, developing countries were granted preferential treatment. Specifically, they were allowed to delay, by as much as 10 years, their compliance with the above timetable; as long as their consumption of controlled substances did not exceed certain levels. Regarding production, and for most substances, developing countries were allowed to exceed the reduction limits noted above by no more than 10 percentage points.

Subsequent amendments to the Montreal protocol targeted new substances with ozone altering or depleting features. These also introduced phase-out schedules, for both the newly added and already targeted compounds. For example, the 1990 London amendment expanded the list of initial CFCs. Relative to their 1989 calculated levels, the amendment mandated a 20% reduction by 1993, 85% by 1997, and a complete elimination by 2000. BFCs were also commissioned for a complete phase-out by year 2000. The amendment also added two solvents, carbon tetrachloride and methyl chloroform, to the list of controlled substances. Both substances were scheduled for outright withdrawal by 2000, and 2005, respectively[32]. Hydrochlorfluorocarbons (HCFCs), also known as transitional substances, were developed as alternatives to CFCs but these compounds also display ozone depletion characteristics, albeit much lower than that of CFCs. HCFCs were placed in the bin of controlled substances under the 1992 Copenhagen amendment. This class of compounds is scheduled for an outright displacement by 2030[33]. The Copenhagen amendment also mandated the phase-out of hydrobromofluorocarbons (HBFCs) by 1996. In addition, it expedited the complete exclusion of CFCs, BFCs, and carbon tetrachloride from consumption and production by 1995, 1993, and 1995, respectively. The 1997 Montreal amendment introduced a timetable for limiting the use and production of methyl bromide. Specifically, it emphasized a reduction of 25% by 1999, 50% by 2001, and 70% by 2003. A complete phase-out was mandated by 2005. Critical use conditions and exemptions pertaining to the use of this substance were also included in the amendment. The 1999 Beijing amendment mandated a complete phase-out of bromochloromethane by 2002. Additionally, it imposed significant consumption and production limitations on HCFCs, thus accelerating their phase-out process. Thus, each participating nation was required to commit itself to a 2.8% cap relative to the 1989 calculated levels.

The ordinary IEA is centered on setting production standards which apply only to ratifying parties. In addition, the VCPOL agreements also impose product stan-

[32]Carbon tetrachloride consumption and production were mandated for an 85% and 100% reduction by 1995 and 2000, respectively. Similarly, methyl chloroform followed a similar phase out schedule; 0%, 30%, 70%, and 100% by 1993, 1995, 2000, and 2005. The reductions are relative to the 1989 levels.

[33]Relative to their aggregate 1989 level, the phase-out schedule for these substances was set at 0%, 35%, 65%, 90%, 95%, and 100% by 1996, 2004, 2010, 2015, 2020, and 2030, respectively.

dards which also affect non-ratifying nations. It is, therefore, of crucial importance to acknowledge that the Montreal protocol and its subsequent amendments deviate from the typical IEA structure, as they include special provisions regarding international trade with non-members. This way, the possibility of leakage is significantly reduced. Specifically, parties were required to ban imports of controlled substances from non-participating parties starting 1990. Beginning 1992, parties were also mandated to elaborate an annex of products containing the controlled substances and ban their imports from non-members one year after the annex becomes effective. A similar treatment was outlined for wares produced with, but not containing, the substances targeted under the protocol. Parties were also discouraged from exporting to non-members any technology that may be used for the production of controlled substances. However, the parties were encouraged to export any technologies that facilitate the development of substitute substances, as well as the containment, capturing, recycling, or destruction of controlled substances.

According to a report published by the Intergovernmental Panel on Climate Change (Sanz Sánchez et al. (2006)), the substances targeted by the Montreal protocol were used in diverse industrial processes across several manufacturing industries. These include electronics and optical equipment where the substances served as cleaning and degreasing agents for circuit boards, and machinery n.e.c. where the substances aided as refrigerants for household and industrial air conditioning units, refrigerators, or freezers. The controlled substances were also used as aerosol propellants in the chemical and pharmaceutical sectors, or as solvents for the dry cleaning services. The compounds addressed under the protocol were also used for the manufacturing of insulating foams, or as refrigerants in mobile air conditioning units, both of which were passed downstream to the transport equipment sector.

3.3.3 Climate Change IEAs

Climate change IEAs were adopted as part of the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Their end objective focuses on limiting and curbing anthropogenic emissions of all greenhouse gases (GHGs) not covered by the Montreal protocol[34].

Concrete GHG emission reduction targets were introduced as part of the Kyoto (1997) protocol to the UNFCCC. These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). The principal provisions of the protocol are centered around the reduction of aggregate GHG emissions[35] rather than the reduction of discharges for each GHG in part. Both the UNFCCC convention and the Kyoto protocol argued for "common but differentiated" responsibilities among parties. In this regard, some adopters pledged to reduce, keep unchanged, or increase by a limited amount their

[34] "Anthropogenic emissions" refer to emissions that are the result, direct or indirect, of human activity.

[35] Emissions of various GHGs can be packaged together using specific global warming potentials (GWPs), calculated for a given period of time. For Kyoto purposes, a 100 year period was chosen.

aggregate emissions relative to 1990 levels[36]. Targets for the 2013 - 2020 window were added as part of the Doha (2012) amendment to the Kyoto protocol. These are not detailed here given the time frame of the analysis. Aside from adopting quantitative reduction or limitation commitments (QERLCs), developed parties[37] were also designated to spearhead, through domestic policies and other instruments, the effort of achieving significant reductions of GHG discharges by 2005. Additional dispositions, such as the provision of financial assistance and transfer of technologies towards the developing parties, were also included. A key difference between the Kyoto protocol and other international environmental accords (i.e., the protocols to the Convention on Long Range Transboundary Air Pollution or the Montreal Protocol to the Vienna Convention for the Protection of Ozone Layer) is the lesser degree of technical detail with regards to the means of bringing emissions down to their pre-1990 levels. Under the Kyoto protocol, parties were awarded significant flexibility for tackling the emissions issue through various market based strategies (i.e., emission trading between Annex I parties, Joint Implementation, and Clean Development Mechanism[38]) (Grubb, 2003).

Given the GHGs falling under the jurisdiction of the protocol, all industrial sectors are expected to be impacted since CO_2 discharges are characteristic to the entire spectrum of industrial processes. However, the effects are expected to be relatively larger in those sectors where emissions of carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, pentafluorocarbons, and sulfur hexafluoride are particularly high. Some of these sectors, such as energy production and transportation, rely heavily on fuel combustion. Additionally, industrial processes in sectors such as coke, refined petroleum and nuclear fuel, chemicals and chemical products, other non-metallic minerals, as well as electronics and electrical equipment generate significant emissions of the GHGs outlined above (Sanz Sánchez et al., 2006).

3.4 Data and Variable Construction

The data universe is represented by 163 countries, observed as exporters and importers across 14, ISIC 2 Rev. 3, manufacturing sectors between 1976 and 2011[39]. Data on sectoral export flows is obtained from COMTRADE. These were further re-classified from SITC Rev. 2 into ISIC. Rev. 3.

GWPs for the GHGs covered are 1, 21, and 310 for $CO2_2$, CH_4, and N_2O, respectively. For HFCs, PFCs, and SF_6 these vary from 140 to 23,900. GWP figures are from (Albritton et al., 1995).

[36]These are referred to as Annex I countries. Parties also have the option of choosing to reduce emissions jointly. This is the case of European Union members which together pledged an 8% reduction in GHG discharges. However, EU members also adopted individual targets. Refer to table 3.6 for details.

[37]These are referred to as Annex II countries. See table 3.6.

[38]This strategy emphasizes investment projects aimed at lowering GHG emissions in developing countries.

[39]Refer to tables 3.7, and 3.4 for details.

3.4.1 IEA Membership

Information on each nation's IEA membership is gathered from the International Environmental Agreements Database Project (Mitchell (2016)). It is important to note that only protocols and amendments are considered as IEAs[40]. In addition, only the ratified protocols and amendments are used. As it is standard in the literature, the ratification year is preferred to that of signature or entry into force as the official treatment date[41]. Often times, the signature of IEAs is just a formality, with no immediate implications for the parties nor on their future ratification decision. For example, the United States signed the Kyoto protocol in 1998 but failed to ratify as it did not gather the required domestic support. Also, by choosing the treatment year as that of entry into force, one rules out the possibility of capturing any anticipatory effects that do occur.

As in Slechten and Verardi (2014), this work focuses on the count of international environmental agreements (IEAs) as a measure of environmental commitment. Slechten and Verardi (2014) emphasize a clear and significant degree of overlap between IEAs. For instance, IEAs aimed at reducing sulphur oxide (SO_x) emissions could also lead to a reduction in carbon dioxide (CO_2) emissions, as these pollutants are often spewed into the atmosphere together, as part of the same industrial processes. This point is further supported by the sectoral emission intensity rankings shown in table 3.10.

However, the bundling of an entire spectrum of IEAs (i.e., climate change, acid rain, and ozone depletion) may be too strong of an assumption; since this particular approach implies analogous effects for each agreement added to the bundle, regardless of type. In line with the previously mentioned study, the IEAs under scrutiny will be divided into three major categories: acid rain (AR), ozone depletion (OD), and climate change (CC)[42]. The rationale behind the split is simple and revolves around the idea that IEAs belonging to the same convention are more likely to have a homogeneous effect on a certain pollutant, or group of pollutants. For instance, the use of closed-loop catalysts in gas powered passenger cars, initially aimed at reducing emissions of nitrogen oxides (NO_x), may also lead to significant declines in emissions of volatile organic compounds (VOC). Also, alternative techniques for reducing (NO_x) emissions may also result in lower sulphur dioxide (SO_2) emissions. Reductions in NO_x emissions were mandated under the 1988 Sofia Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution (LRTAP). Similarly, reductions in VOC, and SO_2 emissions were targeted as part of the Geneva (1991), Helsinki (1985)

[40] The framework conventions are not included. As it is often the case, this type of agreements only sketch the rules under which the protocols and agreements are negotiated and/or provides guidelines regarding the institutional or funding mechanisms; without including any specific emission targets or phase-out schedules. This kind of agreement is expected to have negligible effects on firms, sectors, and exports.

[41] Slechten and Verardi (2014) and Aichele and Felbermayr (2015) are just two studies, among many others, considering ratification rather than signature or entry into force as the treatment date.

[42] The only climate change IEA is the Kyoto protocol. The two terms will be used interchangeably throughout.

and Oslo (1994) protocols to the same LRTAP Convention.

A number of studies highlighted the endogenous nature of IEA membership (Aichele and Felbermayr, 2015, 2013, 2012; Antweiler et al., 2001; Copeland and Taylor, 1995; Grether and De Melo, 2003; Ederington and Minier, 2003; Kellenberg, 2009; Kellenberg and Levinson, 2014; Levinson and Taylor, 2008). Analyzing the effect of IEAs on trade, using a gravity framework and a panel dataset, is highly desirable in addressing this issue. Specifically, this setup allows for the inclusion of exporter and importer time-varying "fixed" effects which, in turn, tend to successfully account for the endogenous selection into IEAs. This feature is present in all econometric specifications used in the current analysis.

3.4.2 Sectoral Pollution

Continuous Pollution Measures

Data on sectoral emissions and output are from the Environmental and Socio-Economic Accounts of the World Input Output Database (Genty et al., 2012)[43]. In accordance with Hettige et al. (1992), Hettige et al. (1995), Aichele and Felbermayr (2015) and Broner et al. (2012), I first define sectoral "dirtiness" as annual emissions relative to annual output. This ratio is further referred to as emission intensity[44]. Data on sectoral emissions is available only for a subsample of 40 countries between 1995 and 2009; a time frame that is significantly narrower than the 1976-2011 time horizon on which the current study focuses[45]. Nevertheless, since the current analysis is not concerned with the technique effects of IEAs[46], this limitation is of limited importance. Given that emission intensity rankings tend to be correlated across time and countries[47] (Grether and De Melo, 2003; Grether et al., 2012; Hettige et al., 1995), sectoral averages from the WIOD subsample are used as "dirtiness" proxies for the entire sample period[48].

[43]Emission data is available for carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), sulphur oxides (SO_x), nitrous oxide (N_2O), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), and ammonia (NH_3).

[44]Sectoral emission intensities are expressed in kilograms per $1,000 of output at 2005 prices. Sectoral output is deflated using sector specific price indexes.

[45]An extension of this work focuses entirely on the 40 country and 15 year subsample outlined above.

[46]As per the logic of Grossman and Krueger (1991), and Antweiler et al. (2001) the technique effect denotes the changes in sectoral emission intensities brought about by the ratification of IEAs.

[47]Own correlation analyses of emission intensities, calculated for the WIOD subsample but not reported here, emphasize that sectoral "dirtiness" rankings are indeed correlated across time and countries. For example, an industry which was "dirty" in 1995 (i.e., basic metals and fabricated metal) is likely to be "dirty" in 2009. For the 8 pollutants considered, the average correlation coefficient hovers around 0.5. Additionally, an industry which is classified as "dirty" within one country (i.e., chemicals and chemical products) is very likely to be classified as "dirty" in another country. Regarding this latter dimension, average correlation coefficients situate around 0.95.

[48]For example, the average CO_2 intensity for the basic metals and fabricated metal sector from the WIOD subsample (e.g., 675 kg/$1,000) will be assigned to all rows pertaining to this industry, regardless of time, exporter, or importer. Refer to table 3.10 for more details.

Binary Pollution Measures

For the ease of interpretation, I also consider binary measures of sectoral pollution intensity. I follow previous studies (Kahn, 2000; Broner et al., 2012) and assign sectors into "clean" and "dirty" bins based on the properties of the associated CO_2 emission intensity distribution. Mean and 75^{th} percentile cut-offs are similar and identify other non-metallic minerals, coke, refined petroleum and nuclear fuel, basic metals and fabricated metal, and chemicals and chemical products as "dirty" sectors. A cut-off level set at the 50^{th} percentile adds pulp, paper, printing and publishing to the list of emission-intensive sectors. The bins are, to a large extent, preserved across pollutants. Also, the most CO_2-intensive sectors are topping the emission intensity rankings for pollutants targeted by acid rain IEAs (i.e., SO_x, NO_x, NMVOC, and NH_3). Interestingly, the 75^{th} percentile-based "dirty" bins are similar to those of other related studies. Some of these have used pollution abatement costs per unit of value added (output, or total costs) or capital intensity to quantify sectoral "dirtiness"[49]. Unless specified otherwise, the 75^{th} percentile measure is considered throughout.

IEA-Specific Pollution Measures

At this point, it is worth recalling the eight pollutants considered and the IEA types addressing them. Climate change agreements are aimed at emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O) while acid rain IEAs are angled at emissions of sulphur oxides (SO_x), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), and ammonia (NH_3). Directly, none of these pollutants are the focus of ozone depletion IEAs. Given the multitude of substances addressed by each IEA type, the ideal "dirtiness" measure should include the maximum amount of information on all relevant emission intensities. A "close to ideal" pollution-intensity measure can be constructed using a principal component analysis.

Initially, I am considering the emission intensity measures for all eight pollutants. This first PC analysis is detailed in table 3.1 and figure 3.9. The PC analysis yields three principal components which, between them, account for 99% of the variance in the eight emission intensity measures. Usually, all principal components with an eigenvalue higher or equal to 1 are relevant. However, provided the current objective (i.e., including principal components as covariates for "dirtiness" accounting), only the first, PC1, is retained as the only component with positive loadings on all emissions. By itself, PC1 embodies roughly 60% of the information incorporated in the emission intensities. This principal component is used just as a regular covariate for estimation purposes. Second, table 3.2 and figure 3.10 showcase the PC analysis for emission intensities of climate change pollutants. Here, the first principal component (PC1 CC) accounts for 56% of the variance displayed by the CO_2, CH_4, and N_2O intensity measures. Third, the PC analysis for acid rain pollutants is shown in table 3.3 and figure 3.11. Similar to the previous two, the first principal component (PC1 AR) accounts for 58% of the variance characterizing emission intensities for SO_x, NO_x,

[49] Jänicke et al. (1997), Mani and Wheeler (1998), Ederington et al. (2005), Kellenberg (2009),

NMVOC, and NH_3. Given the unavailability of data, no PC analysis is conducted for substances with ozone depletion characteristics.

As noted earlier, data on emissions for substances targeted under the Montreal protocol (i.e., CFCs and HCFCs) is not available. Further, this lack of information renders the process of calculating sectoral emission intensities impossible. Instead, I make use of the data provided within a 2006 IPCC report (Sanz Sánchez et al., 2006) about industrial processes which result in HCFC and HFC emissions, across a range of ISIC Rev. 3 manufacturing sectors. The report also lists a number of products in which HFCs and HCFCs are used as production inputs[50]. I augment these insights with data from the EORA MRIO Project (Lenzen et al., 2012, 2013). Using information on HFC emissions and sectoral output, I find that transport equipment and textiles and wearing apparel are leading other sectors in terms of HFC emission intensity by a notable margin. Based on the above, the following sectors are identified as "dirty" from the perspective of Montreal protocol and its subsequent amendments: transport equipment, electrical and optical equipment, machinery n.e.c., textiles and textile products, together with leather and footwear.

3.5 Empirics

The covariates of interest are constructed using the count of ratified IEAs. First, a linear, relative measure of environmental stringency, for a given pair *(x,m)* at time t, is constructed as the difference between the number of agreements ratified by the exporter ($IEAs_{x,t}$), and by the importer ($IEAs_{m,t}$).

$$d(IEA)_{x,m,t} = IEAs_{x,t} - IEAs_{m,t} \tag{3.1}$$

In addition to this, a second measure of relative stringency is built as shown in (3.2). The added virtue of this variable consists in its non-linearity, a characteristic which makes identification possible when unobserved heterogeneity is more rigorously accounted for. This non-linear feature also implies, perhaps realistically, diminishing marginal effects to IEAs ratification[51]. The correlation between the linear relative environmental stringency difference and its non-linear counterpart is 0.844.

$$d(IEA)^2_{x,m,t} = \frac{IEAs^2_{x,t} - IEAs^2_{m,t}}{(IEAs_{x,t}+1)(IEAs_{m,t}+1)} \tag{3.2}$$

Grether et al. (2012)

[50]CFCs and HCFCs were heavily used as refrigerants in stationary and mobile air conditioning units. These substances were also used for the manufacturing of various foams, or solvents used for high precision cleaning. It is worth pointing out that starting in the early 1990s these substances were replaced/substituted by HFCs. HFCs fall under the jurisdiction of Kyoto protocol.

[51]For $IEA_{x,t} > 0$ and $IEA_{m,t} > 0$ it can be shown that:

$$(i)\ \frac{\partial d(IEA)^2_{x,m,t}}{\partial IEA_{x,t}} = \frac{IEA_{x,t}(IEA_{x,t}+2) + IEA^2_{m,t}}{(IEA_{x,t}+1)^2(IEA_{m,t}+1)} > 0; (ii)\ \frac{\partial^2 d(IEA)^2_{x,m,t}}{\partial^2 IEA_{x,t}} = -\frac{2(IEA_{m,t}-1)}{(IEA_{x,t}+1)^3} \leq 0$$

The third and fourth covariates of interest are the exporter and importer-specific counts of ratified IEAs, $IEAs_{x,t}$, and $IEAs_{m,t}$. The conventional discussion regarding the expected signs on the attached coefficients, for these four measures, is provided within the relevant section below.

Besides accounting for any omitted trade determinants, the empirical strategies outlined in this section are also designed to address the crucial issue of endogenous selection into IEAs. For example, one could reasonably argue, that trade and selection into IEAs are simultaneously determined. Specifically, larger degrees of trade openness are positively correlated with national wealth which, in turn, is correlated with an increased likelihood of ratifying IEAs. This dynamic is clearly emphasized in figures 3.1 and 3.6 through 3.8. Also, the endogenous selection of nations in IEAs has been extensively discussed within the literature. Often, an approach to this issue is the use of various instrumental variables (Aichele and Felbermayr, 2015, 2013; Broner et al., 2012; Kellenberg, 2009; Levinson and Taylor, 2008; Jug and Mirza, 2005; Ederington and Minier, 2003). But, the endogeneity of IEAs is very similar to that of economic integration agreements (EIAs). And, unlike the former category of agreements, EIAs have been largely analyzed by using gravity-type frameworks (Baldwin and Taglioni, 2006; Regolo, 2013; Baier and Bergstrand, 2007; Baier et al., 2014; Soete and Van Hove, 2015). Hence the solution of including exporter and importer time-varying effects for capturing any unobserved factors that might determine the adoption of EIAs and IEAs.

3.5.1 Non-Linear Relative Environmental Stringency

Empirical Model

The effect of relative environmental stringency on international trade flows is analyzed within a standard gravity framework. The benchmark results are produced using the non-linear environmental differential. The first specification is depicted in (3.3), where (x,m,t) denotes an exporter-importer pair at a given point in time, t. $T_{x,m,s,t}$ denotes export flows from exporter x to importer m in sector s during a given year, t. The variable of interest, $d(IEA)^2_{x,m,t}$, denotes the non-linear difference in the stocks of ratified IEAs between the exporter and importer whereas D_s represents a measure of sectoral pollution-intensity. D_s is defined as in section 3.4.2, either as a continuous[52], principal component-based, or binary measure; nevertheless it is time invariant in all three cases. Under the assumption of "IEAs as source of comparative disadvantage", the expected sign on β_1 is ambiguous for the two reasons already outlined in section 3.2[53]. However, a negative sign is expected on the coefficient attached

[52] The natural logarithm transformation is used in this case.

[53] β_1 could be positive. Lower output within pollution-intensive sectors, and therefore unemployment of production factors, may arise as a result of IEA adoption. One potential general equilibrium effect outlines the expansion of less pollution-intensive sectors through the employment of these idle factors. β_1 could also be negative. This effect may arise if increases in production costs within the pollution-intensive sectors spill over into the least polluting counterparts through more expensive inputs, transportation alternatives, etc.

to the interaction term $d(IEA)^2_{x,m,t} \times D_s$, β_2. In other words, the more environmentally committed the exporter becomes and the higher the sectoral pollution intensity, the lower the export flows. $TA_{x,m,t}$ accounts for the level of economic integration[54] characterizing an exporter-importer pair, (x, m) at time, t. Finally, $\mu_{x,m,s,t}$ represents the error term.

$$lnT_{x,m,s,t} = \beta_1 d(IEA)^2_{x,m,t} + \beta_2 d(IEA)^2_{x,m,t} \times D_s + \gamma TA_{x,m,t} + \mu_{x,m,s,t} \tag{3.3}$$

A discussion regarding the modeling of the error term, $\mu_{x,m,s,t}$, is in line. Trade flows between exporter x and importer m within sector s are determined by an array of time-invariant and time-varying factors. Often, these elements are exporter, importer, sector, and time specific, or any combination of these four dimensions. Broadly, these are referred to as multilateral resistance terms (MRTs). Some of these factors range from geographical, historical, and cultural characteristics to infrastructure and preferences, to the sectoral supply and demand capacities of both the exporter and importer[55]. Within a gravity-type setup, the standard procedure of accounting for this type of unobserved heterogeneity is the inclusion of exporter×industry×year, (x, s, t), and importer×industry×year, (m, s, t), effects along with their exporter-importer, (x, m), peers (Head and Mayer, 2013).[56] In line with the above, the error term is initially modeled as shown in (3.4). It is worth pointing out that a term $\beta_3 D_s$ should be included in specification (3.3). However, since any variation in D_s is absorbed by the included "fixed" effects, this term is intentionally omitted.

$$\mu_{x,m,s,t} = \nu_{x,s,t} + \nu_{m,s,t} + \nu_{x,m} \tag{3.4}$$

[54]The economic integration variable was compiled by Jeffrey Bergstrand and his collaborators, as part of the NSF - Kellogg Institute Data Base on Economic Integration Agreements Project and is available at http://www3.nd.edu/~jbergstr/. It is measured on a scale from 0 to 6, with the null value indicating no integration whatsoever. $TA_{x,m,t} = 1$ is indicative of a non-reciprocal preferential trade agreement between x and m at time t. Similarly, level 2 denotes joint attendance within a preferential trade arrangement while level 3 indicates joint participation within a free trade agreement. If $TA_{x,m,t} = 4$, x and m are part of a customs union. Level 5 underlines the joint membership within a common market (i.e., the European Union) while level 6 denotes joint membership in an economic union (i.e., the Eurozone).

[55]For example, Baldwin and Taglioni (2006) emphasize the importance of price indexes. Under the assumption that $\mu_{x,m,s,t}$ is well behaved, a proper estimation of the specification in (3.3) implies the deflation of export flows by using exporter and sector-specific price indexes. The inclusion of year dummies (i.e., a time trend) alone would not do justice, as these covariates only capture the common trend in sectoral prices. Within a given year, however, a significant degree of heterogeneity exists among the movement of prices across the industrial spectrum. Information on just this dimension alone is difficult to gather, let alone other trade determinants such as the degree of substitutability between similar goods, the quality of institutions, etc.

[56]Until recently, this particular approach, although simple in principle, was computationally burdensome and time-consuming. This is especially true for the current analysis, which focuses on a total of 210,627 exporter×importer×sector pairs across a 36 years span. In implementing the approach outlined above, the current study significantly benefits from the new *reghdfe* STATA routine (Correia, 2015).

Results

The benchmark results are shown in table 3.11. The first column presents the results recovered by using the binary "dirtiness" measure. The second column shows the results retrieved by using the first principal component, based on all eight pollutants (PC1). Finally, in the last eight columns sectoral "dirtiness" is measured as the emission intensity, in one of the available eight pollutants.

The magnitude of coefficients is addressed next. Given the ease of interpretation brought about by the binary pollution measure, the discussion is centered on the estimates in the first column. Here, β_1 is rather small, but nevertheless negative, thus underlining a potentially negative effect of IEA ratification on "clean" sectors. More importantly, however, the environmental commitment differential exhibits a significant and negative effect on "dirty" exports. Specifically, a 1 unit increase in the IEA stock differential is associated with a 6% drop in outflows originating within sectors classified as "dirty"[57]. From a more intuitive perspective, an additional IEA ratified by the *average* exporter implies a 1.75% drop in "dirty" exports[58] towards the average importer.

I now turn to the non-linear effect of IEA ratification. For illustration purposes, let's first consider a hypothetical country pair consisting of the average importer and an exporter with no IEAs adopted so far[59]. In this first scenario, the marginal effect of IEA ratification on the exporter side is equivalent to a 9.7% fall in "dirty" exports[60]. Now, let's consider a similar pair, barring that the exporter ratified a total of 12 IEAs instead. In this scenario, the enactment of the 13^{th} IEA (the maximum possible given the current sample) generates a 1.4% decline in outflows from sectors classified as "dirty". The effects on "clean" sectors are once again negligible; 0.6% and 0.1% for ratifying the 1^{st} and the 13^{th} IEA, respectively. The diminishing effect of IEA ratification is consistent with the non-linear structure of $d(IEAs)^2$, and is relevant from an economic standpoint[61]. It is not surprising that earlier stages of adjustment to a new regulatory environment are relatively costlier for firms and industries.

The results are robust to the various "dirtiness" measures used (i.e., based on the first principal component (PC1) in column (2) and emission intensity in columns (3)

[57] Refer to section 3.4.2 for details regarding the "dirty"/"clean" split.

[58] The dataset is not symmetric and, in turn, a relatively fewer number of exporters is observed. As a result, the average exporter ratified 4.39 IEAs while the average importer ratified 3.79 agreements. Together these imply a non-linear differential of approximately 0.19. All else constant, the ratification of an additional IEA by the exporter increases this wedge to 0.48. The effect of a 1 unit change in the non-linear differential commitment is equivalent to $\beta_1 + \beta_2 \times D_s$. Following this rationale, a 0.29 differential change is equivalent to a 1.75% drop in "dirty" exports towards the average importer. Unless otherwise specified, all results are discussed in the context of the average exporter-importer pair.

[59] An exporter-importer pair which comes close to matching this average is Romania and the Netherlands in 1992. By this time point, Romania ratified no IEAs while the Netherlands have ratified 4.

[60] Evaluated at the mean, this effect amounts to a decline in "dirty" exports of USD3.38 million. In terms of sectoral output, this translates into a 0.06% decline.

[61] Refer to equation (3.2) for details.

through (10)) and emphasize the detrimental impact of IEA ratification on exports. As expected, pollution-intensive sectors are the most affected. The β_1 coefficient in column (3), however, seems to break this pattern. Two aspects are worth discussing at this point. First, despite the apparently large β_1, a negative effect of IEAs on pollution-intensive sectors still prevails. For a comparative static exercise, involving the above two points, let's consider once more the average exporter-importer pair[62]. If there was an industry for which the CO_2 intensity would be zero, then, an additional IEA ratified by the exporter would increase its exports by 4.1%. However, such industry does not exist. The sector with the least amount of CO_2 emissions per unit of output (80.88 kg. CO_2/\$1,000) is leather and footwear. Based on the estimates in column (3), the marginal effect of IEA ratification would increase exports of leather and footwear by 0.4%. Conversely, for the average CO_2-intensive industry (260.66kg. CO_2/\$1,000), the marginal ratification effect yields a 0.5% decline in exports. A sector close to this CO_2 intensity figure is transport equipment. For the most CO_2-intensive sector, other non-metallic minerals (1862.98kg. CO_2/\$1,000), the ratification effect resembles a notable 2.2% drop in outflows. Second, the (+) and (-) signs on β_1 and β_2 underline a possible compositional shift regarding export flows. In other words, export bundles tend to become cleaner, CO_2-wise, for nations which become more environmentally committed, just as discussed in section 3.2. Recall that a potential general equilibrium effect implies the expansion of "clean" sectors at the expense of their "dirty" counterparts. Seemingly unusual, the estimates in column (3) are quite relevant, and in line with intensity measures in columns (4) through (10). Estimates involving emission intensities for other pollutants paint a similar picture. For the most polluting sectors, the effect of ratifying an additional IEA range from -2.5% (e.g., coke, refined petroleum, and nuclear fuel for SO_x) to -1.2% (e.g., chemicals and petrochemicals for N_2O). For industries displaying average emission intensities, the effects range between -0.46% (for NH_3) to -0.58% for (CO_2). For the least pollution-intensive industries the marginal ratification effects range between -0.1% (e.g., leather and footwear for N_2O) and +0.6% (e.g, leather and footwear for SO_x)[63]. It is worth pointing out that the marginal IEA ratification is equivalent with increases of exports from the least pollution-intensive sectors; regarding six out of the eight pollutants considered[64]. This result emphasizes once more the compositional shift in export flows, which emerges as a consequence of IEA ratification. However, it is worth bearing in mind that the growth in exports appears to be experienced only by the least pollution-intensive sectors. This is by no means the case for the sectors displaying average pollution intensities. The results presented in this section, and throughout

[62]Refer to footnote 58 for details.

[63]This last point may be confusing and an explanation may be in order. The leather and footwear sector is the least polluting in both SO_x, and N_2O (see table 3.10). If sectoral "dirtiness" is assessed using SO_x emission intensity, then, for the average exporter-importer pair, the ratification of an additional IEA by the exporter is equivalent to a 0.1% drop in leather and footwear exports. Similarly, if the sectoral degree of pollution is assessed based on N_2O emissions, ratifying an additional IEA would boost leather and footwear exports by 0.6%.

[64]The sector-pollutant pairs are leather and footwear (CO_2, NO_x, SO_x), textiles and textile

the remainder of this essay, gain in importance given that, on average, the share of outflows in the exporter's gross domestic product (GDP) is approximately 29%.

3.5.2 Linear Relative Environmental Stringency

Empirical Model

There is, however, a drawback associated with the use of exporter×industry×year and importer×industry×year effects. As noted in Head and Mayer (2013), sums, averages, and differences of exporter and importer-specific variables can no longer be identified. This is also the case of $(dIEA)_{x,m,t}$, the linear differential. As a consequence, its non-linear counterpart is used to produce the benchmark results. A trade-off is therefore made between the intuition behind the environmental commitment differential and a comprehensive accounting of any unobserved trade determinants. One way of retaining and identifying the linear environmental commitment differential in (3.1) is through the use of symmetric exporter×importer×year effects along with their exporter×importer×industry counterparts. Additionally, I include industry×year effects to control for any unobserved, industry-specific and time-varying characteristics. This way, the error term will be modeled as shown in (3.6). Under the same assumption of "IEAs as source of comparative disadvantage", an ambiguous sign is expected on β_1'. However, β_2' is expected to carry a negative sign. Despite the methodological differences, this approach also underlines, very clearly, the negative impact of environmental regulation on export flows.

$$lnT_{x,m,s,t} = \beta_1' dIEA_{x,m,t} + \beta_2' dIEA_{x,m,t} \times D_s + \gamma' TA_{x,m,t} + \mu'_{x,m,s,t} \tag{3.5}$$

$$\begin{aligned} \mu'_{x,m,s,t} &= \nu'_{x,m,t} + \nu'_{x,m,s} + \nu'_{s,t} \\ \nu'_{x,m,t} &= \nu'_{m,x,t} \end{aligned} \tag{3.6}$$

Results

The results concerning the linear environmental stringency differential are obtained by estimating (3.5) and presented in table 3.12. The organization of the table is similar to that of table 3.11, discussed earlier.

I proceed by presenting the results in the first column. From here, one can observe that β_1' is negative and statistically significant. This indicates that the marginal effect of IEA adoption by the exporter yields a 1.2% decrease in "clean" export flows. Perhaps more important is the coefficient attached to the interaction term, β_2', which is significant and carries a negative sign. This denotes a negative effect of joining IEAs on "dirty" exports as well. Quantitatively, the ratification of an additional IEA by the exporter yields a 3.1% decrease in outflows from sectors classified as "dirty". However, due to the use of the linear differential, β_1' implies a constant effect of IEA ratification, regardless of whether an exporter ratifies its 1^{st} or its 13^{th} IEA. It is therefore not surprising that this effect lays within the [-9.7%, -1.4%] interval discussed in section 3.5.1. This estimate is of comparable magnitude and direction with the marginal ratification effect characterizing the average exporter-importer pair (i.e., -1.75%) also outlined in section 3.5.1. The wedge between β_1' and β_1 owes itself, most likely, to the use of the linear differential rather than to the modeling of the error term. Note, for instance, that the bilateral measure of economic integration does not vary with the error term structure.

The results presented throughout the rest of table 3.12 emphasize a clear and consistent point. That is, pollution-intensive exports decline as a result of a larger environmental commitment wedge between the exporter and the importer. Ratification of IEAs by the origin country also seems to have an impact on the least pollution-intensive sectors. This effect, however, is close to zero. Depending on the pollution intensity measure, outflows from these sectors may increase or decrease as a result of joining an IEA. For example exports of leather and footwear (the least SO_x-intensive sector) are estimated to increase by about 1% whereas exports of leather and footwear (the least CO_2-intensive) sector are found to decrease by 0.5%. Nevertheless, the export declines are significantly larger for pollution-intensive sectors. The implications are robust across the "dirtiness" measures considered. The only deviation from this pattern seems to appear, once again, in column (3), where the differential commitment, by itself, is positive, large, and statistically significant. However, the earlier discussion regarding this seemingly unusual estimate applies here as well. By taking into account the interaction term, the ratification of an additional agreement by the exporter is equivalent to a 1.6% drop in outflows originating within the "average CO_2-intensive" sector. Also using estimates from column (3), the effect of ratifying an additional IEA on exports within the most polluting industry, other non-metallic minerals, is equivalent to a 3.6% decline in exports. For the cleanest sector, leather and footwear, the effect is of -0.5%[65]. Although higher[66], most probably due to the use of linear differential, the results shown in table 3.12 are painting the same picture as those outlined in the previous section. That is, IEAs seem to be a source of comparative disadvantage, especially for sectors displaying high emission intensity ratios. To put these results into perspective, the average effect of sharing a common border with the importing country is estimated to increase exports by approximately 64%. Similarly, the average effect of joining regional trade agreements is estimated at 60%[67].

The results discussed above are also supported by those in tables 3.13 and 3.14. Here, the environmental differential effect is estimated on a sector-by-sector basis.

products (CH_4, NH_3), and machinery n.e.c. (NMVOC).

[65]The results are calculated for the average exporter-importer pair. Refer to footnote 58 for details. Cleanest and dirtiest sectors are picked based on the CO_2 emission intensity distribution. Refer to table 3.10 for details.

[66]The marginal effect of IEA ratification on "dirty" exports, obtained using the linear differential, is -3.1%. Using the non-linear differential, this effect is -1.75%.

[67]These figures are surveyed by Head and Mayer (2013) from 159 articles. As the authors note,

As expected, the impact of marginal IEA ratification is larger for the sectors at the top of emission intensity rankings, namely other non-metallic minerals. For this industry, the effect of ratifying an additional IEA by the exporter is equivalent to a 6.6% decline in exports. Sectors such as machinery, rubber and plastics, and transport equipment are notably impacted as well. These results are also expected. For example, manufacturing of machinery subsumes, among others, the production of domestic and industrial refrigerators and freezers as well as engines of various kinds. Manufacturing of refrigerators and freezers is expected to have been affected by the phase-out, under the Montreal protocol to the VCPOL, of CFCs and HCFCs. These substances were widely used as cooling agents. The manufacturing of engines in general, but especially that of engines for passenger vehicles, is expected to have been impacted by new standards regarding fuels, combustion processes, efficiency, and emissions; all implemented in response to the ratification of protocols to the LRTAP convention. Under the LRTAP IEAs, efficiency guidelines were also set for stationary emission sources such as industrial ovens, furnaces, and furnace burners; all of which are products of the machinery sector. For some industries, however, the ratification of additional IEAs seems to aid exporting (i.e., leather and footwear, manufacturing n.e.c. and recycling, and wood, and products of wood and cork). According to the rankings presented in table 3.10, leather and footwear, together with manufacturing n.e.c. and recycling sectors are also among the cleanest. Provided the discussions in sections 3.2 and 3.5.1 these results should not surprise. In fact, these estimates emphasize once more the compositional shift towards "cleaner" outflows for exporters which adopt a tougher environmental stance. Recall that the ratification of IEAs hurts exports and most likely production of pollution-intensive sectors. This leads to unemployment of production factors which, in turn, may be employed within the least polluting sectors (i.e., that are impacted the least by the adoption of IEAs). Two additional arguments may be in line with regards to the positive effect of IEA ratification on outflows in the manufacturing n.e.c. and recycling sector. First, increased environmental stringency may incentivize recycling activities. Second, a significant part of this industrial branch is represented by the manufacturing of furniture from any material, including recycled metal and non-metal waste, and scrap.

3.5.3 IEA-Specific Linear Relative Environmental Stringency

Empirical Model

By construction, the linear differential implies a constant effect across all IEAs considered, regardless of their type. As noted earlier, a measure which combines the entire spectrum of IEAs (i.e., climate change, acid rain, and ozone depletion) may be regarded as not rigorous enough. Following Slechten and Verardi (2014), three differential measures will be considered based on the three IEA categories (climate change, acid rain, and ozone depletion) outlined in section 3.3. The logic behind this bundling is simple and postulates that trade effects are more likely to be homogenous

these estimates may be upward biased since the most contemporaneous studies employing the gravity for IEAs belonging to the same category. The specification thus obtained is shown in (3.7). Here k denotes the IEA type; namely climate change (CC), acid rain (AR), and ozone depletion (OD). For this additional specification, the previous discussions apply.

$$lnT_{x,m,s,t} = \sum_{\substack{k\in\{CC,\\AR,OD\}}} \beta''_{1,k} dIEA^k_{x,m,t} + \sum_{\substack{k\in\{CC,\\AR,OD\}}} \beta''_{2,k} dIEA^k_{x,m,t} \times D_s + \gamma'' TA_{x,m,t} + \mu''_{x,m,s,t} \tag{3.7}$$

$$\mu''_{x,m,s,t} = \nu''_{x,m,t} + \nu''_{x,m,s} + \nu''_{s,t} \qquad \nu''_{x,m,t} = \nu''_{m,x,t} \tag{3.8}$$

Results

The results obtained after separating IEAs by their scope into climate change, acid rain, and ozone depletion are presented in table 3.15. The estimates are in line with those discussed earlier. Most importantly, the effects of climate change and acid rain IEAs on pollution-intensive exports are negative, and statistically significant for all pollutants considered. Furthermore, only the ratification of acid rain IEAs seems to adversely affect exports of less pollution-intensive sectors. This dynamic is, most likely, driven by the transmission of negative shocks from "dirty" sectors towards their "clean" peers, perhaps through intermediate inputs or transportation linkages[68]. Given the implied overall reduction in outflows, the adoption of acid rain IEAs is characterized by a negative export scale effect. Conversely, "clean" sectors seem to benefit from the ratification of climate change agreements, namely the Kyoto protocol[69]. This dynamic is in line with the discussions and results presented in sections 3.2, 3.5.1, and 3.5.2; according to which ratification of IEAs engenders a compositional shift towards a "greener" bundle of exports. Let's now turn to column (3) of table 3.15 for a numerical perspective on this last viewpoint. For exports of other non-metallic minerals (the most CO_2-intensive industry in the sample), the estimates in column (3) imply a Kyoto ratification effect of -3%. Meanwhile, outflows of transport equipment (the average CO_2-intensive industry) would experience a 2% increase. Lastly, if the exporter ratifies the Kyoto protocol, exports of leather and footwear (the least CO_2-intensive industry) are estimated to increase by approximately 5%. Moreover, for coke, refined petroleum, and nuclear fuel sector (the most SO_x-intensive industry in the sample)[70] the ratification of an additional acid rain IEA implies a 3.2% decline in outflows. At the opposite end, the marginal ratification effect of an acid rain IEA,

model fail to account for the time-varying nature of trade determinants.

[68]For example, a regulatory shock that results into higher production costs in the coke, refined petroleum, and nuclear fuel industry may spill over into industries such as leather and footwear, or textiles and textile products through higher energy prices.

[69]The next chapter reassesses this result by taking into account the binding emission caps adopted by some Kyoto ratifiers.

[70]Recall that SO_x stands for sulfur oxides and it is by far the most targeted chemical compound

entails a meager 0.02% increase in exports of leather and footwear (the least SO_x-intensive industry in the sample). A version of this weak compositional effect was also observed in the previous sections, when the aggregate stock of IEAs was utilized[71].

The ratification of ozone depletion agreements, however, does not seem to affect "dirty" industries at all. In fact, these opposite is observed. This finding, although counterintuitive, is driven by one important detail. That is, sectors where the use of ozone depletion substances is high display moderate emission intensities in all eight pollutants considered[72]. It is also worth reminding the reader that none of the eight pollutants included is targeted directly by the Montreal protocol and its subsequent amendments. In order to circumvent this problem, I turn to the inclusion of agreement-specific measures of pollution intensity. The results obtained this way are shown in table 3.16. The first column includes the first principal components as IEA-specific measures of sectoral "dirtiness"[73]. No data is available on emissions of ozone depletion substances (i.e., CFC or HCFC). As a consequence, no principal component-based measure of "dirtiness" is obtainable for this kind of IEAs. A binary measure, specific to ozone depletion IEAs, will be used instead. This was introduced and discussed within section 3.4.2. The estimates recovered this way are clear and in line with previous findings. It is important to note that now, as expected, the coefficient attached to the interaction term involving the ozone depletion differential ($\beta''_{2,OD}$) is negative and statistically significant. With the exception of climate change IEAs, which seem to positively affect outflows from "clean" sectors, all coefficients indicate a negative effect of IEAs on exports; regardless of whether the sector is "dirty" or "clean", or more or less polluting.

I now shift the focus to the second column of table 3.16. Here, two binary measures of sectoral pollution intensity are introduced to facilitate the interpretation of ratification effects. These are specific to climate change (CC) and acid rain (AR) IEAs. Both measures are based on the underlying distributions of the PC1 CC and PC1 AR principal components. Sectors with principal component values above the 75^{th} percentile are categorized as "dirty" whereas the rest are marked as "clean".[74] First and foremost, the coefficients attached to the interaction terms $\beta''_{2,CC}$, $\beta''_{2,AR}$,

under the acid rain IEA category.

[71]Unfortunately, the present analysis does not benefit from emission data for ozone depletion substances. It is, therefore, unable to make any inferences on the potential compositional shifts brought about by the ratification of ozone depletion IEAs when using a continuous measure of sectoral "dirtiness".

[72]These sectors are i.e., transport equipment, electrical and optical equipment, machinery, n.e.c., textile and textile products, and leather and footwear. This sectoral trait can also be observed in table 3.10.

[73]The first principal component of emission intensities from carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (NO_x), PC1 CC, is used as a measure of pollution intensity that is specific to climate change IEAs. The first principal component of emission intensities from sulphur oxides (SO_x), nitrogen oxides (NO_x), nitrous oxide (N_2O), non-methane volatile organic compounds (NMVOC), and ammonia (NH_3), PC1 AR, is used as a relevant pollution intensity measure for acid rain IEAs.

[74]Based on PC1 AR, the industries identified as "dirty" are other non-metallic minerals, coke,

and $\beta''_{2,OD}$ are negative and statistically significant, once again highlighting the deleterious effect of IEA ratification on sectors categorized as "dirty". Quantitatively, the ratification of the Kyoto protocol on the exporter side is equivalent to a 0.8% decline in "dirty" exports. Conversely, outflows from sectors tagged as "clean" are expected to increase, in the wake of the Kyoto adoption, by 5.8%. Once more, these results underline the readjustment of the export bundle towards a higher "clean"/"dirty" outflows ratio. Conversely, acid rain IEAs seem to hamper exports regardless of their origin sector. Specifically, the ratification effect of an additional acid rain IEA by the exporter decreases "clean" outflows by about 1%. Similarly, exports from sectors categorized as "dirty" decline by approximately 5%. Ozone depletion IEAs carry an even stronger effect but this result is expected. Recall that the Montreal protocol and its subsequent agreements include strict provisions regarding the banning of *(i)* exports of substances targeted, *(ii)* exports of products incorporating these substances, and *(iii)* exports of goods manufactured with but not containing, the targeted substances. Numerically, outflows from sectors identified as "clean" decline by 2.2% due to the ratification of an additional ozone depletion IEA by the exporter. The decline in "dirty" exports is even larger, situating at about 7.5%. The ratification of any kind of IEA (i.e., climate change, acid rain, and ozone depletion) by the exporter seems to entail a negative effect on outflows from sectors categorized as "dirty". Moreover, acid rain and ozone depletion IEAs appear to have a detrimental effect on exports originating in "clean" industries as well. This evidence underlines the negative scale effects brought about by the adoption of IEAs in these two categories. The effects are considerably larger for ozone depletion IEAs. Conversely, the adoption of Kyoto protocol seems to benefit exporters in "clean" sectors, where outflows are found to increase by as much as 5.8% following the ratification. This result showcases, once more, the compositional shift towards a more "cleaner" export bundle for parties to the Kyoto protocol.

3.5.4 Environmental Stringency by Exporter and Importer

Empirical Model

Another way to estimate the impact of IEA ratification on export flows is to consider exporter and importer-specific measures of environmental commitment. The specification obtained this way is depicted in (3.9), where $IEA^k_{x,t}$ and $IEA^k_{m,t}$ denote the number of ratified IEAs in category k, for the exporter and importer at a given point in time. As noted previously these categories are climate change (CC), acid rain (AR), and ozone depletion (OD). More flexible than the ones used previously, this approach facilitates the decomposition of the IEAs' ratification overall effect into pollution haven (PHE)[75] and "leakage" sub-effects. If IEAs in category k are

refined petroleum and nuclear fuel, chemicals and chemical products, as well as wood and products of wood and cork. Regarding PC1 CC, these are other non-metallic minerals, coke, refined petroleum, and nuclear fuel, together with chemical and chemical products.

[75]Recall that the PHE underlines a loss of comparative advantage for industries which are im-

a source of comparative disadvantage (and thus of PHE) then $\alpha_{1,k}$ is expected to bear a negative sign. Specifically, a more environmentally committed exporter would ship less to its partners. Hence, $\alpha_{1,k} < 0$. If IEAs in category k are to generate "leakage", one would expect $\alpha_{2,k}$ to be positive. Under this scenario, an importer which commits itself more strongly to environmental regulation is expected to import more from non-committed exporters in sectors classified as "dirty". Hence, $\alpha_{2,k} > 0$. Moreover, $\alpha_{1,k} < 0$ and $\alpha_{2,k} = 0$ denote the scenario in which the exports of dirty goods decline in response to IEA ratification without being replaced or substituted with similar goods from abroad. Consequently, support for the "leakage" hypothesis is synonymous with a positive sign on $\alpha_{2,k}$. All other definitions and notations outlined in sections 3.5.1 and 3.5.2 apply here as well.

$$\begin{aligned} lnT_{x,m,s,t} = \sum_{\substack{k \in \{CC, \\ AR, OD\}}} \alpha_{1,k} IEA^{k}_{x,t} \times D_s + \sum_{\substack{k \in \{CC, \\ AR, OD\}}} \alpha_{2,k} IEA^{k}_{m,t} \times D_s \\ + \gamma''' TA_{x,m,t} + \mu'''_{x,m,s,t} \end{aligned} \tag{3.9}$$

$$\mu'''_{x,m,s,t} = \nu'''_{x,t} + \nu'''_{m,t} + \nu'''_{s,t} + \nu'''_{x,m,s} \tag{3.10}$$

In line with the "unobserved heterogeneity" rationale outlined earlier, the error term is modeled as shown in (3.10). This represents a departure from the exporter×industry×year and importer×industry×year structure shown in (3.4) or (3.6). Yet again, the trade-off between a proper accounting of unobserved heterogeneity and the ability of identifying the covariates of interests becomes apparent. Usually, (3.9) should include separate covariates for the exporter's and importer's IEAs ratified. The equation should also contain the pollution intensity covariate. However, given their structure, these are absorbed by the "fixed effects" considered in (3.10), and therefore not identifiable. Additionally, the coefficients obtained by estimating (3.9), can only be used for relative inferences; on a "clean"/"dirty" relative basis.

Results

The results obtained by estimating (3.9) are presented in table 3.17. Here, the exporter and importer stocks of ratified IEAs are used as a measure of environmental commitment. The first column displays coefficients that are in line with expectations, both in terms of sign and magnitude, for climate change and acid rain IEAs. Thus, the ratification of the Kyoto protocol by the exporter implies a relative decline in "dirty" exports of 3.1%. A similar action undertaken by the importer leads to a relative increase in "dirty" imports of 3.4%. Similarly, the ratification of an additional acid rain IEA entails a relative deterioration in "dirty" outflows of 4.4%. On the importer side, a similar enactment is expected to increase "dirty" imports by about 2%. This outcome is indicative of "leakage". Regarding climate change IEAs, the evidence presented here is in line with that of Aichele and Felbermayr (2015). They also provide support in favor of "leakage" effects that are attributable to the ratification of Kyoto protocol. Throughout the remainder of the table, the results are, to a large extent, robust in terms of sign and in line with those discussed in sections 3.5.1, 3.5.2, and 3.5.3. However, not the same can be inferred with regards to their statistical significance. Nonetheless, it is worth noting that $\alpha_{1,CC}$, $\alpha_{2,CC}$, $\alpha_{1,AR}$, and $\alpha_{2,AR}$ display the expected signs and are statistically meaningful when sectoral "dirtiness" is measured using the relevant pollutant (e.g., CO_2 for climate change, or NO_x and SO_x for acid rain).

The results regarding ozone depletion IEAs seem once again counterintuitive. However, bear in mind that, as pointed earlier, the sectors most affected by the ratification of ozone depletion IEAs are not ranking high in any of the above eight pollutants. As a consequence, ozone depletion IEAs are unlikely to impact sectors categorized as "dirty" using the first principal component (PC1), the binary, or the continuous measures[76]. In order to address this difficulty IEA-specific pollution intensity measures are considered once more. The results are depicted in table 3.18. Again, the results underline the importance of agreement-relevant pollution intensity degrees, especially for ozone depletion IEAs.

Turning to column (1), one can observe that the coefficients are in line with the "leakage" hypothesis; both in terms of sign and, to a large extent, in terms of statistical significance. The only exception is the negative sign on $\alpha_{2,OD}$. The absence of "leakage" regarding the ratification of ozone depletion IEAs is, however, expected. As noted in section 3.3.2, imports of ozone depleting substances and products containing these substances from non-members were banned under the Montreal protocol. Column (2) introduces an IEA-specific, binary measure of sectoral pollution-intensity to aid with coefficient interpretation[77]. In doing so, the modest "leakage" effect of acid rain IEAs vanishes; most likely due to the less-flexible nature of the binary "dirtiness" measure. Nevertheless, the "leakage" effects of climate change IEAs line up with expectations. The absence of "leakage" characterizing the build-up of ozone depletion IEAs is consistent with the international trade restrictions included within the Montreal protocol to VCPOL and its subsequent amendments. On the exporter side, the marginal ratification effects of climate change and ozone depletion IEAs are calculated as -5.5%, and -7% respectively. Bear in mind that these figures are relative to comparable flows within the "clean" industries. On the importer side, positive coefficients are estimated for both climate change and acid rain IEAs. For the climate change category, the ratification of an additional agreement is equivalent to a relative increase in "dirty" imports of about 4%. This result is emphasizing, once again, the "leakage" effect induced by joining the Kyoto protocol. For acid rain IEAs, the marginal effect of ratification leads to a small relative increase in imports of 0.4%. In summary, the results outlined by the current section are supportive of the "leakage" hypothesis in the case of climate change IEAs, namely the Kyoto protocol. "Leakage"

pacted by a tougher environmental stance.

[76]Refer to table 3.16 and section 3.4.2 for details.

[77]These are identical to the ones used within the previous section.

also seems to occur for acid rain IEAs but the supporting results are less robust, and lower magnitude-wise. Finally, there is no confirmation of ozone depletion IEAs triggering "leakage" effects.

3.6 Conclusions

Early work provides little evidence on the adverse effect of environmental regulation on exports. In addition, these early studies are plagued by several drawbacks ranging from the unavailability of time-series data to the deficit of taking into account the endogenous nature of environmental policy stance. Recent studies have addressed these issues, and were able to produce concrete evidence on the detrimental effect of environmental regulation on exports. The present work adds to this recent literature strand along three important margins. First, in contrast to most studies, it uses the count of air pollution IEAs as a measure of environmental commitment. Second, it analyzes environmental stringency and trade within a considerably larger sample. Third, it uses a gravity framework along with a panel dataset which, together, allow for a rather simple accounting of unobserved trade determinants and the endogenous selection of the environmental policy regime.

The evidence brought forward by the current essay can be summarized in three points. First, the ratification of IEAs in general is a source of comparative disadvantage for pollution-intensive sectors. Second, the results underline the existence of composition and scale effects, but these differ in accordance to each IEA category. Climate change IEAs (i.e., the Kyoto protocol) are found to be a source of comparative disadvantage for pollution-intensive industries and a source of comparative advantage for their least polluting peers. Hence, the ratification of climate change IEAs suggests a compositional shift towards a "cleaner" (less pollution-intensive) export bundle. Acid rain IEAs seem to be a notable source of comparative disadvantage for pollution-intensive industries. It is uncertain to what extent they aid or harm the least polluting sectors. Ozone depletion IEAs, on the other hand, bring about negative effects on exports regardless of whether the sector is categorized "clean" or "dirty". Hence, acid rain and ozone depletion IEAs call for negative scale effects. Third, climate change and acid rain IEAs involve "leakage" effects, which appear to be stronger for the first category. In line with their international trade provisions, ozone depletion IEAs do not spawn "leakage" effects. On the contrary, they comprise of negative effects on exports and imports alike.

This study contributes to the vast literature on comparative advantage and international trade patterns. Specifically, it causally links the ratification of international environmental agreements (IEAs) with deleterious effects on comparative advantage and exports. The analysis starts from the premise that ratification of IEAs is more likely to impact the pollution-intensive sectors. In order to tease out this effect, the current study relies on both binary and continuous measures of sectoral polluting degrees. First, the adoption of additional IEAs is found to adversely affect exports of not only "dirty" but of "clean" industries as well. Numerically, the marginal effect of ratifying an IEA on "dirty" exports is approximately -3%. For "clean" outflows the implied decline is approximately 1%. Diminishing effects of IEA ratification are also found (i.e., -9.7% for the 1^{st} IEA and -1.4% for the 13^{th} IEA). Second, evidence of a compositional shift in export bundles emerges. More precisely, ratifying parties seem to transition towards a "cleaner" export mix. For sectors exhibiting high emission intensities, the ratification of an additional IEA is found to entail a significant decline in exports. For example, exports of other non-metallic minerals, the most CO_2-intensive sector, are estimated to decrease by 3.6%. For sectors with low emission intensities, the ratification of an additional IEA is found to entail negligible negative effects, or even small gains, on outflows. This depends on the differential (i.e., linear or non-linear) and pollution intensity (i.e., CO_2, SO_x, etc.) measures used. For example, exports of leather and footwear, the least CO_2 intensive sector, are estimated to decrease by 0.5% (when using the preferred linear differential). Sector-by-sector estimates further support this evidence. The most adversely affected sector is that of other non-metallic minerals, for which the marginal IEA ratification entails a 6.6% decline in exports. At the other end of the spectrum one finds leather and footwear as well as machinery n.e.c. and recycling sectors. For these industries, exports are estimated to increase by 1.7%, and 2.8%, respectively, if an extra IEA is ratified by the exporter. A similar picture is painted when the marginal ratification of IEAs is analyzed in accordance with their type. Specifically, ozone depletion IEAs are found to be the most detrimental to export flows. Each additional IEA of this type is found to reduce "dirty" exports by approximately 7.5%. Similarly, "clean" exports are decreased by 2.2%. Acid rain IEAs rank next, with implied effects on "dirty" outflows of -5%. The effect on "clean" exports is about -1%. Climate change IEAs, namely the Kyoto protocol, are different because they entail modest declines (i.e., -0.8%) in exports of pollution-intensive sectors but large gains (i.e., 5.8%) for their least polluting peers. These results suggest that the adoption of climate change IEAs (i.e., the Kyoto protocol) veer the ratifying parties towards a "cleaner" export bundle.

More narrowly, this study adds to the now substantial body of evidence on environmental policy and "leakage". Evidence of "leakage" is presented for both climate change and acid rain IEAs, but found to be more robust for the former. For climate change IEAs, the marginal effect of ratification on relative "dirty" exports range between -5.5% and -3%. In line with the leakage hypothesis, the effect on relative "dirty" imports locates between 3% and 4%. Regarding acid rain IEAs, the effect on relative exports situates around -4.5%. Meanwhile, the marginal ratification effect on relative imports is approximately 2%. Conversely, evidence of "leakage" is not found with regards to ozone depletion agreements. For this IEA category, negative effects are found for both the relative "dirty" exports (i.e., -7%) and imports (i.e., -1%). This result is expected, and in line with the "leakage"-reduction stipulations of the Montreal protocol to VCPOL and its subsequent amendments. Specifically, parties were mandated to ban imports of targeted substances from non-parties shortly after ratification. Imports of products containing such substances and of goods produced with, but not containing, the targeted compounds were also restrained. In other words, these provisions can be regarded as product standards, which non-ratifiers have to comply with in order to penetrate the domestic markets of ratifying parties. The exporting of technology that may be used for the production of controlled substances towards non-members was also restricted. This last set of results may hold some implications regarding the design of future IEAs, which could include international trade provisions in order to achieve the desired emission reductions while reducing "leakage".

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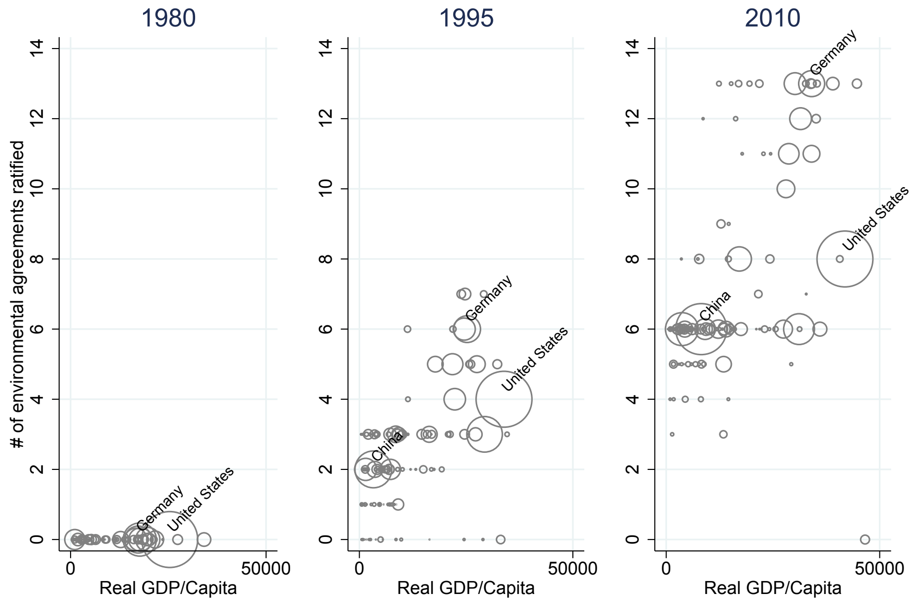
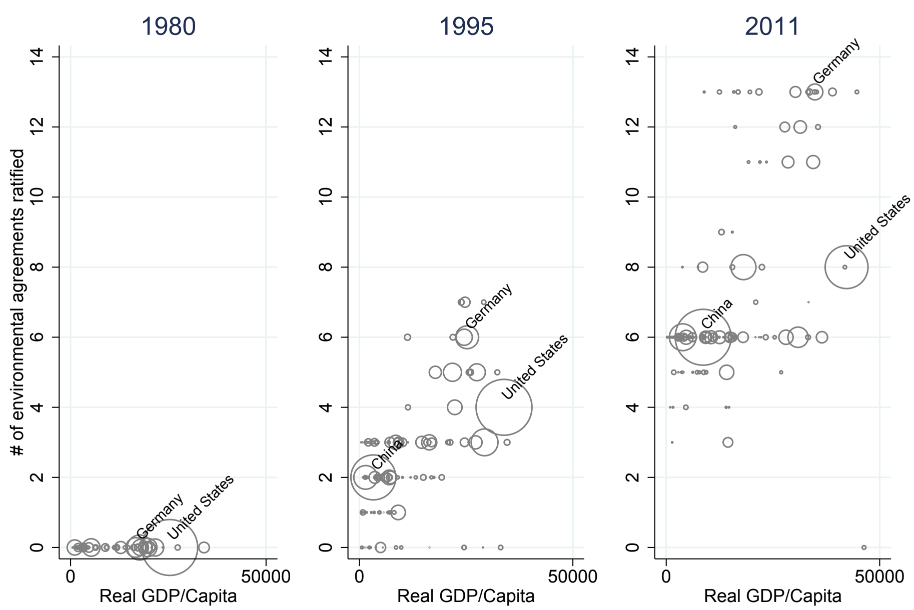
Figure 3.1: Ratification and Real GDP by Real GDP Per Capita



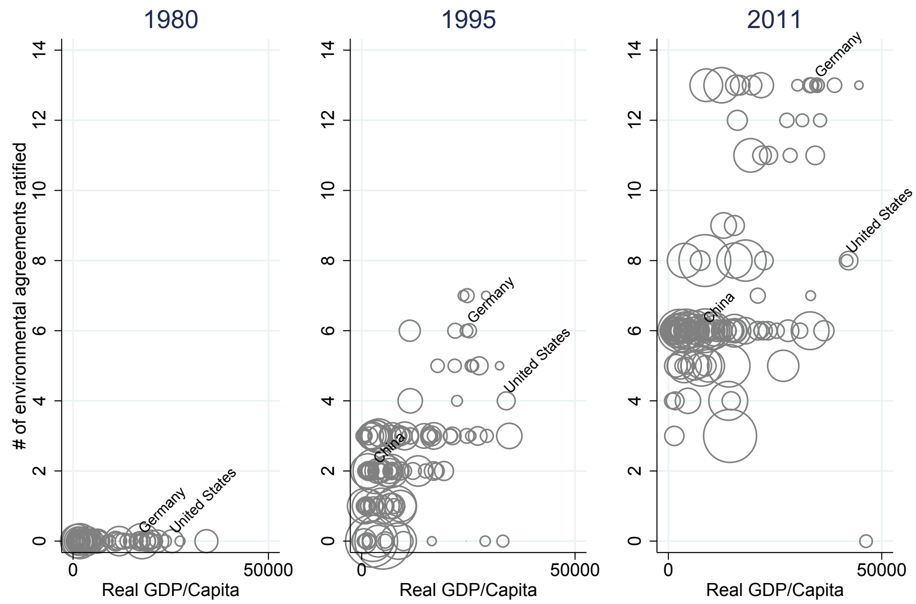
Ratification as function of Real GDP per capita (USD, 2005 prices)

Figure 3.2: Ratification and CO2 Emissions by Real GDP Per Capita



Ratification and CO2 emissions as functions of Real GDP per capita (USD, 2005 prices)

Figure 3.3: Ratification and CO2 Emission Intensity by Real GDP Per Capita



Ratification and CO2 emission intensity as functions of Real GDP per capita (USD, 2005 prices)

Figure 3.4: Average # of Ratified IEAs and Total CO2 Emissions

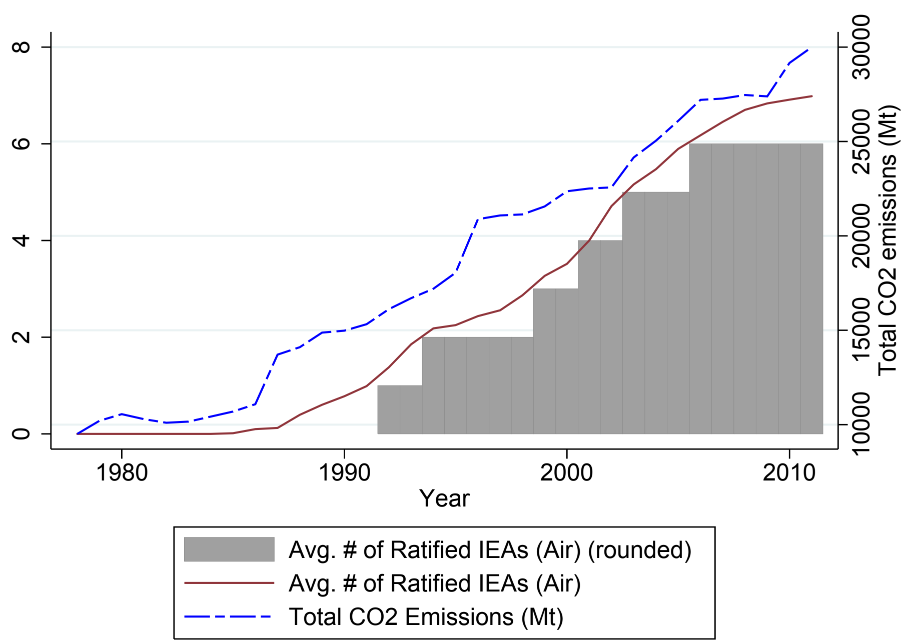


Figure 3.5: Average # of Ratified IEAs and Average CO2 Emission Intensity

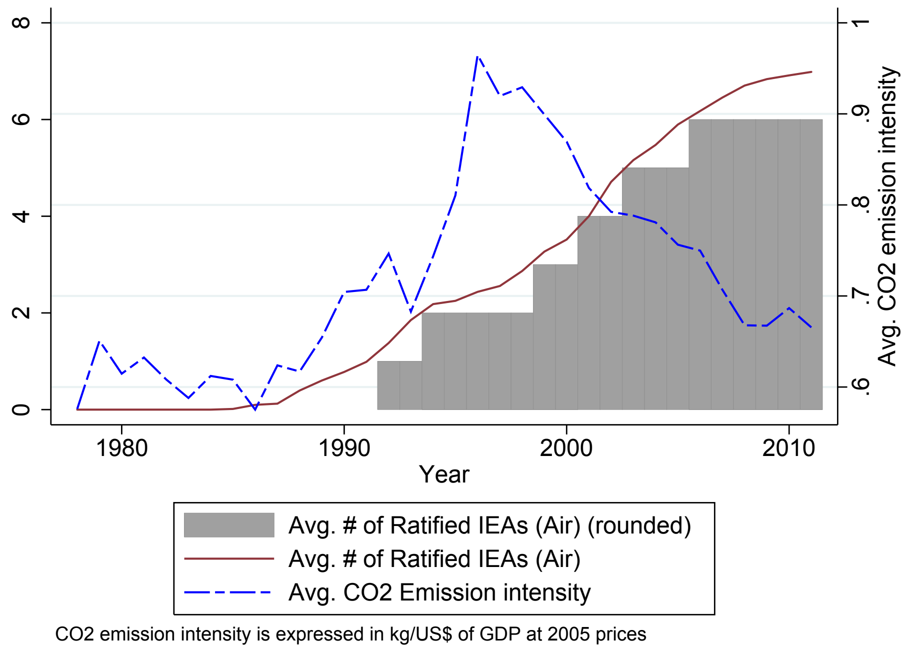


Figure 3.6: Average # of Ratified IEAs and Dirty vs Non-Dirty Exports (Mean)

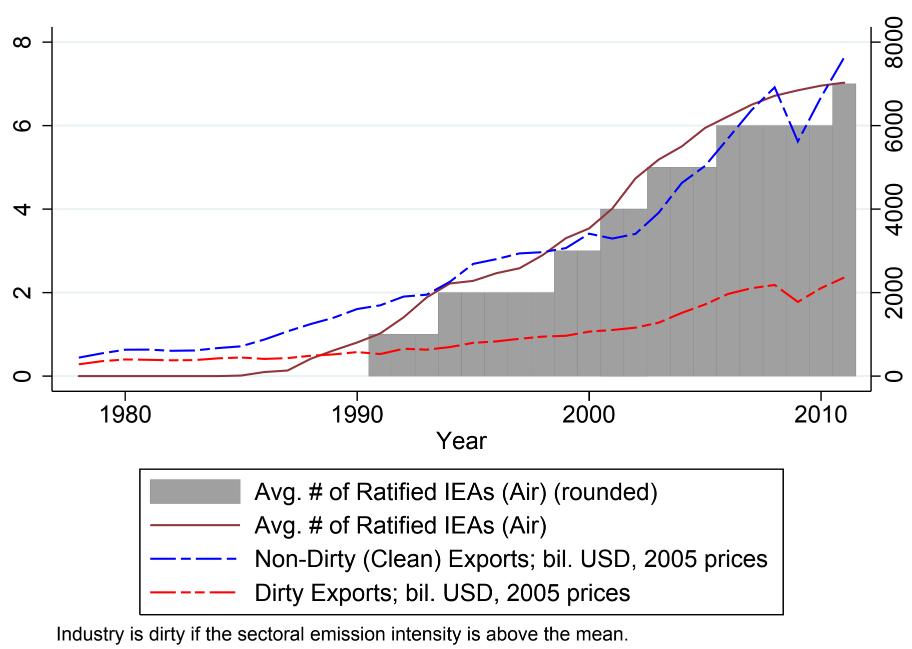


Figure 3.7: Average # of Ratified IEAs and Dirty vs Non-Dirty Exports (50th Percentile)

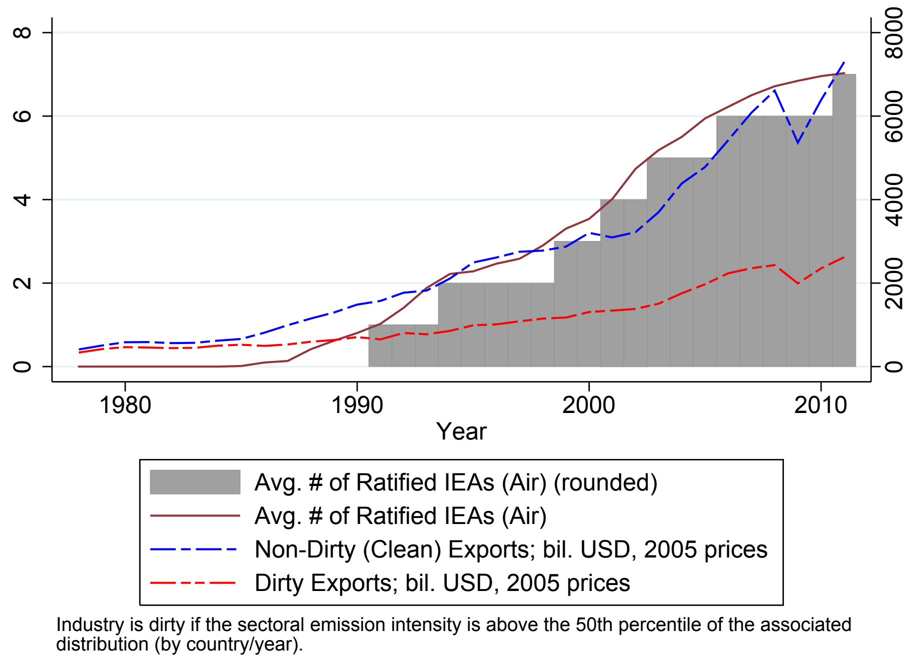


Figure 3.8: Average # of Ratified IEAs and Dirty vs Non-Dirty Exports (75th Percentile)

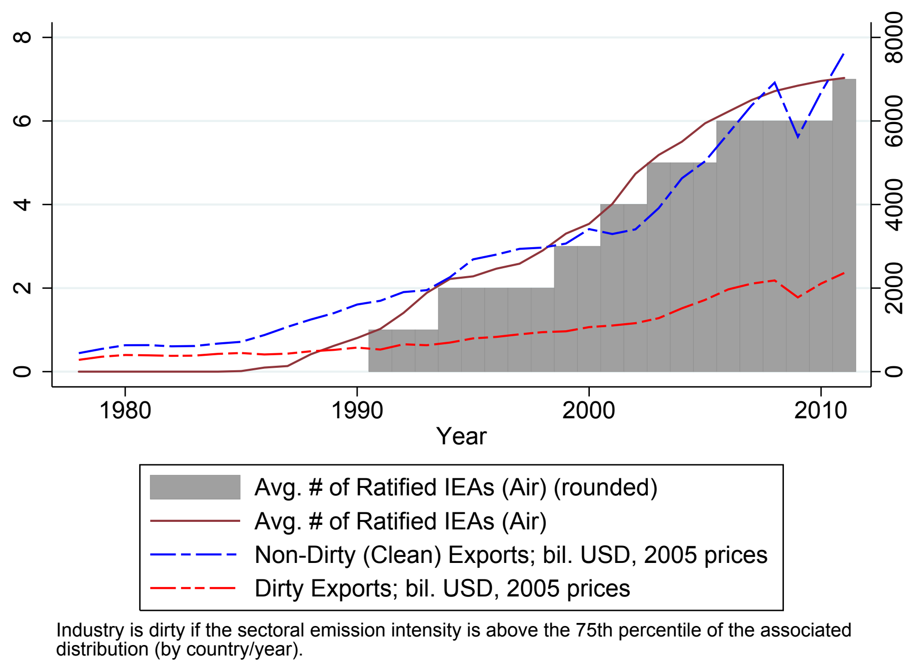


Table 3.1: PC Analysis on Emission Intensities (All Pollutants): Summary

	Eigen-value	Var. Covered	CO2	CH4	N2O	NOX	SOX	CO	NMVOC	NH3
PC1	4.68	0.59	0.40	0.42	0.09	0.28	0.44	0.42	0.44	0.08
PC2	2.05	0.26	0.02	-0.08	0.67	0.17	-0.08	-0.20	-0.04	0.68
PC3	1.10	0.14	0.43	-0.37	-0.19	0.71	0.02	-0.24	-0.24	-0.13

The table displays the factor loadings for those principal components with eigenvalues greater than 1. The proportion of emission intensity variance, across all 8 pollutants, captured by each component, is also displayed.

Figure 3.9: PC Analysis on Emission Intensities (All Pollutants): Screeplot of Component Eigenvalues

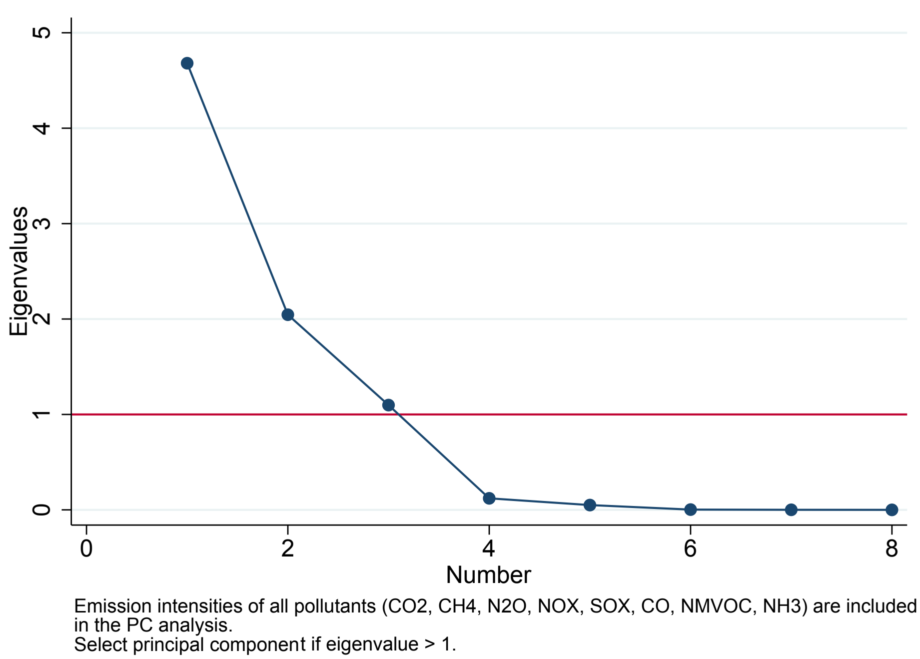
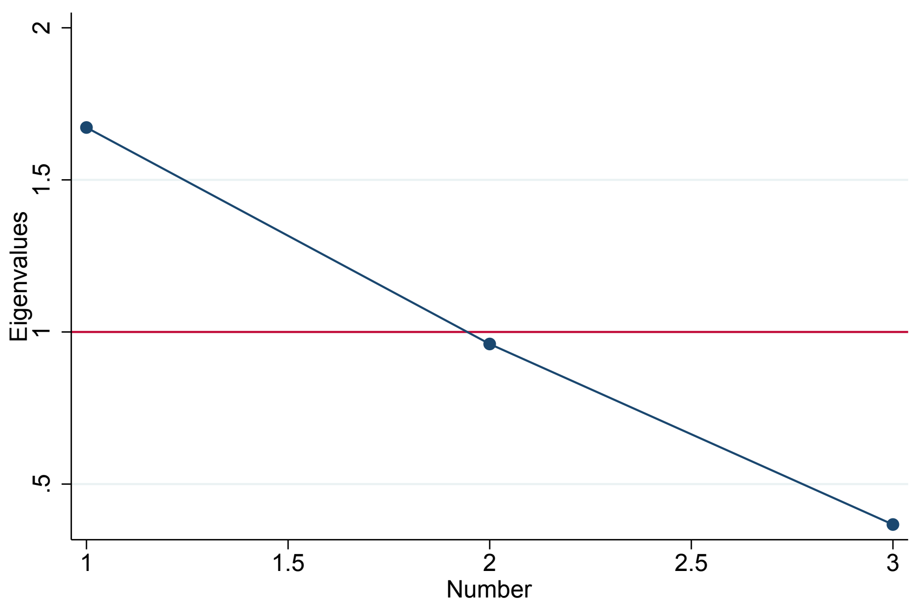


Table 3.2: PC Analysis on Emission Intensities (Climate Change Pollutants): Summary

	Eigen-value	Var. Covered	CO2	CH4	N2O
PC1 CC	1.67	0.56	0.68	0.69	0.24
PC2 CC	0.96	0.32	-0.19	-0.15	0.97

The table displays the factor loadings for those principal components with eigenvalues greater than 1. The proportion of emission intensity variance, across the 3 climate change pollutants, captured by each component, is also displayed.

Figure 3.10: PC Analysis on Emission Intensities (CC Pollutants): Screeplot of Component Eigenvalues



Emission intensities of climate Change pollutants (CO2, CH4, N2O) are included in the PC analysis.
Select principal component if eigenvalue > 1.

Table 3.3: PC Analysis on Emission Intensities (Acid Rain Pollutants): Summary

	Eigenvalue	Var. Covered	NOX	SOX	NMVOC	NH3
PC1 AR	2.32	0.58	0.48	0.62	0.59	0.18
PC2 AR	1.01	0.25	0.22	-0.25	-0.20	0.92

The table displays the factor loadings for those principal components with eigenvalues greater than 1. The proportion of emission intensity variance, across the 4 acid rain pollutants, captured by each component, is also displayed.

Figure 3.11: PC Analysis on Emission Intensities (AR Pollutants): Screeplot of Component Eigenvalues

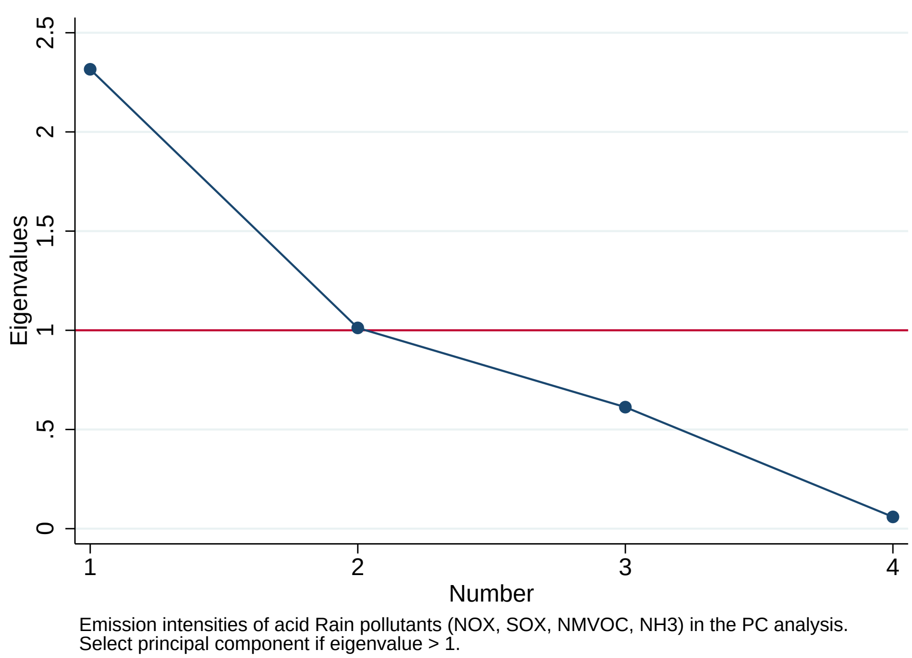


Table 3.4: Exporters and Importers

Country		
Albania	Gabon	Nigeria
Angola	Gambia	Norway
Antigua and Barbuda	Georgia	Oman
Argentina	Germany	Pakistan
Armenia	Ghana	Panama
Australia	Greece	Paraguay
Austria	Grenada	Peru
Azerbaijan	Guatemala	Philippines
Bahamas	Guinea	Poland
Bahrain	Guinea-Bissau	Portugal
Bangladesh	Honduras	Qatar
Barbados	Hong Kong	Romania
Belarus	Hungary	Russian Federation
Belgium and Luxembourg	Iceland	Rwanda
Belize	India	Saint Kitts and Nevis
Benin	Indonesia	Saint Lucia
Bermuda	Iran	Saint Vincent and the Grenadines
Bhutan	Iraq	Sao Tome and Principe
Bolivia	Ireland	Saudi Arabia
Bosnia and Herzegovina	Israel	Senegal
Botswana	Italy	Sierra Leone
Brazil	Jamaica	Singapore
Brunei Darussalam	Japan	Slovakia
Bulgaria	Jordan	Slovenia
Burkina Faso	Kazakstan	South Africa
Burundi	Kenya	Spain
Cambodia	Korea	Sri Lanka
Cameroon	Kuwait	Sudan
Canada	Kyrgyzstan	Suriname
Cape Verde	Lao People's Democratic Republic	Swaziland
Central African Republic	Latvia	Sweden
Chad	Lebanon	Switzerland
Chile	Lesotho	Syrian Arab Republic
China	Liberia	Taiwan
Colombia	Lithuania	Tajikistan
Comoros	Macau	Tanzania, United Rep. of
Congo	Macedonia (the former Yugoslav Rep. of)	Thailand
Costa Rica	Madagascar	Togo
Croatia	Malawi	Trinidad and Tobago
Cyprus	Malaysia	Tunisia
Czech Republic	Maldives	Turkey
Cote d'Ivoire	Mali	Turkmenistan
Denmark	Malta	Uganda
Djibouti	Mauritania	Ukraine
Dominica	Mauritius	United Kingdom
Dominican Republic	Mexico	United States of America
Ecuador	Moldova, Rep. of	Uruguay
Egypt	Mongolia	Uzbekistan
El Salvador	Morocco	Venezuela
Equatorial Guinea	Mozambique	Viet Nam
Estonia	Namibia	Yemen
Ethiopia	Nepal	Zambia
Fiji	Netherlands	Zimbabwe
Finland	New Zealand	
France	Niger	

All countries appear as both exporters and importers with the exception of Chad, Equatorial Guinea, Lao People's Democratic Republic, Macedonia (the former Yugoslav Rep. of), and Uzbekistan. These six nations are only observed as importers.

Table 3.5: International Environmental Agreements

International Environmental Agreements (IEAs)	*First Ratified*	*Ratifiers as of 2011*
Geneva Convention on Long Range Transboundary Air Pollution (LRTAP)		
Helsinki Protocol for Reduction of Sulphur Emissions (1985)	1985	Albania, Austria, Belarus, Belgium and Luxembourg, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany Hungary, Italy, Lithuania, Macedonia (the former Yugoslav Rep. of), Netherlands, Norway, Russia, Slovakia, Sweden, Switzerland, and Ukraine
Sofia Protocol on the Control of Nitrogen Oxides and their Transboundary Fluxes (1988)	1989	All Helsinki ratifiers plus Croatia, Cyprus, Greece, Ireland, Lithuania, Slovenia, Spain, the United Kingdom, and the United States of America
Geneva Protocol on the Control of Volatile Organic Compounds and their Transboundary Fluxes (1991)	1993	Austria, Belgium and Luxembourg, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Lithuania, Macedonia (the former Yugoslav Rep. of), Netherlands, Norway, Slovakia, Spain, Sweden, Switzerland, and the United Kingdom
Oslo Protocol on Further Reduction of Sulphur Emissions (1994)	1995	All Geneva ratifiers plus Canada, Cyprus, Greece, Ireland, and Slovenia; less Estonia, Russia, and the United States of America
Aarhus Protocol on Persistent Organic Pollutants (POP) (1998)	1998	Austria, Belgium and Luxembourg, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Macedonia (the former Yugoslav Rep. of), Moldova, Rep.of, Netherlands, Norway, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom
Aarhus Protocol on Heavy Metals (1998)	1998	All Aarhus POP ratifiers plus the United States of America, less Iceland and Italy
Gothenburg Protocol to Abate Acidification, Euthrophication and Ground Level Ozone (1999)	2002	All Aarhus POP ratifiers plus the United States of America, less Cyprus, Estonia, Iceland and Italy
Vienna Convention for the Protection of the Ozone Layer (VCPOL)		
Montreal Protocol on Substances that Deplete the Ozone Layer (PSDOL) (1987)	1988	Australia, Austria, Azerbaijan, Belarus, Belgium and Luxembourg, Bulgaria, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kazakhstan, Latvia, Lithuania, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Ukraine, the United Kingdom, the United States of America, Uzbekistan
London Amendment to Montreal PSDOL (1990)	1990	All nations in table 3.4 except Angola, Bermuda, Hong Kong, and Macau
Copenhagen Amendment to Montreal PSDOL (1992)	1993	All nations in table 3.4 except Angola, Bermuda, Guinea, Hong Kong, Kazakhstan, Macau, and Nepal
Montreal Amendment to Montreal PSDOL (1997)	1998	All nations in table 3.4 except Angola, Bermuda, Botswana, Cote d'Ivoire, Guinea, Hong Kong, Kazakhstan, Macau, Morocco, Mozambique, Nepal, Saudi Arabia, and Zimbabwe
Beijing Amendment to Montreal PSDOL (1999)	2000	All nations in table 3.4 except Angola, Azerbaijan, Bahrain, Bangladesh, Bermuda, Bolivia, Bosnia and Herzegovina, Botswana, Cape Verde, Chad, Cote d'Ivoire, Djibouti, Ecuador, Georgia, Guinea, Hong Kong, Iran, Kazakhstan, Kenya, Macau, Mauritania, Morocco, Mozambique, Nepal, Peru, Saudi Arabia, Syrian Arab Republic, and Zimbabwe
United Nations Framework Convention on Climate Change (UNFCCC)		
Kyoto Protocol (1997)	1998	All nations except Hong Kong, Macau, Taiwan and the United States of America

Source: International Environmental Agreements Database Project (Mitchell (2016))

Table 3.6: UN Framework Convention on Climate Change: Status of Parties

Country Code	*Country Name*	*Annex II*	*Transition**	*% Kyoto Target (Annex B)*	*% Kyoto Target***
AUS	Australia	YES		108	108
AUT	Austria	YES		92	87
BLR	Belarus		YES		
BEL	Belgium	YES		92	92.5
BGR	Bulgaria		YES	92	92
CAN	Canada	YES		94	94
CYP	Cyprus				
HRV	Croatia		YES	95	95
CZE	Czech Republic		YES	92	92
DNK	Denmark	YES		92	79
EST	Estonia		YES	92	92
FIN	Finland	YES		92	100
FRA	France	YES		92	100
DEU	Germany	YES		92	79
GRC	Greece	YES		92	125
HUN	Hungary		YES	94	94
ISL	Iceland	YES		110	110
IRL	Ireland	YES		92	113
ITA	Italy	YES		92	93.5
JPN	Japan	YES		94	94
LVA	Latvia		YES	92	92
LIE	Liechtenstein	YES		92	92
LTU	Lithuania		YES	92	92
LUX	Luxembourg	YES		92	72
MLT	Malta				
MCO	Monaco	YES		92	92
NLD	Netherlands	YES		92	94
NZL	New Zealand	YES		100	100
NOR	Norway	YES		101	101
POL	Poland		YES	94	94
PRT	Portugal	YES		92	127
ROU	Romania		YES	92	92
RUS	Russian Federation		YES	100	100
SVK	Slovakia		YES	92	92
SVN	Slovenia		YES	92	92
ESP	Spain	YES		92	115
SWE	Sweden	YES		92	104
CHE	Switzerland	YES		92	92
TUR	Turkey				
UKR	Ukraine		YES	100	100
GBR	United Kingdom	YES		92	87.5
USA	United States	YES		93	93

All parties are included in Annex I. Slovakia and Slovenia were added in 1998. Annex I also includes the European Union (EU). Malta and Cyprus were added in 2009, and 2013, respectively. Turkey was removed from Annex II in 2002. *Denotes parties transitioning to a market economy in 1992. **Denotes individual targets of EU members; EU pledged to an 8% overall reduction. In most cases targets are relative to 1990 levels. Targets are for the 2008-2012 period.

Table 3.7: ISIC Rev. 3 Industries

Industry	**Code**
Other Non-Metallic Minerals	26
Coke, Refined Petroleum and Nuclear Fuel	23
Basic Metals and Fabricated Metal	27t28
Chemicals and Chemical Products	24
Transport Equipment	34t35
Pulp, Paper, Printing and Publishing	21t22
Electrical and Optical Equipment	30t33
Manufacturing, n.e.c.; Recycling	36t37
Machinery, n.e.c.	29
Wood and Products of Wood and Cork	20
Rubber and Plastics	25
Food, Beverages and Tobacco	15t16
Textiles and Textile Products	17t18
Leather and Footwear	19

Table 3.8: Summary Statistics of Emission Intensities

	Obs.	Mean	S.D.	Min	Max
CO2	14.00	503.68	634.58	78.38	2,012.69
CH4	14.00	1.05	2.55	0.03	9.70
N2O	14.00	0.06	0.19	0.00	0.71
NOX	14.00	1.25	1.28	0.32	5.20
SOX	14.00	1.91	1.92	0.28	7.32
CO	14.00	7.25	14.90	0.98	56.35
NMVOC	14.00	2.08	3.00	0.39	11.97
NH3	14.00	0.04	0.10	0.00	0.40

The table displays summary statistics for emission intensities of various pollutants across the 14 sectors considered. Note that these intensities do not display any time variation. These represent 1995-2009 sectoral averages across a total of 40 countries. All intensities are measured in kg/USD1000; 1995=100 at real LCU/USD

Table 3.9: Correlation of Emission Intensities

	CO2	CH4	N2O	NOX	SOX	CO	NMVOC	NH3
CO2	1.00	0.63	0.10	0.88	0.80	0.70	0.71	0.12
CH4	0.63	1.00	0.13	0.24	0.85	0.96	0.97	0.10
N2O	0.10	0.13	1.00	0.20	0.06	-0.05	0.16	1.00
NOX	0.88	0.24	0.20	1.00	0.58	0.30	0.39	0.24
SOX	0.80	0.85	0.06	0.58	1.00	0.88	0.90	0.05
CO	0.70	0.96	-0.05	0.30	0.88	1.00	0.93	-0.07
NMVOC	0.71	0.97	0.16	0.39	0.90	0.93	1.00	0.14
NH3	0.12	0.10	1.00	0.24	0.05	-0.07	0.14	1.00

The table displays the correlations among emission intensities for various pollutants across the 14 sectors considered. Note that these intensities do not display any time variation. These represent 1995-2009 sectoral averages across a total of 40 countries. All intensities are measured in kg/USD1000; 1995=100 at real LCU/USD

Table 3.10: Averages of Average Sectoral Emission Intensity, 1995-2009

Industry	Code	CO2
Other Non-Metallic Mineral	26	1862.989
Coke, Refined Petroleum and Nuclear Fuel	23	956.9238
Basic Metals and Fabricated Metal	27t28	675.3937
Chemicals and Chemical Products	24	641.975
Transport Equipment	34t35	231.6829
Pulp, Paper, Printing and Publishing	21t22	212.922
Electrical and Optical Equipment	30t33	165.4621
Manufacturing, Nec; Recycling	36t37	160.4766
Machinery, Nec	29	155.1142
Wood and Products of Wood and Cork	20	146.7433
Rubber and Plastics	25	129.7071
Food, Beverages and Tobacco	15t16	126.9798
Textiles and Textile Products	17t18	112.6842
Leather, Leather and Footwear	19	80.88471

Industry	Code	CH4
Coke, Refined Petroleum and Nuclear Fuel	23	6.937139
Chemicals and Chemical Products	24	2.032567
Basic Metals and Fabricated Metal	27t28	1.04851
Other Non-Metallic Mineral	26	0.287095
Rubber and Plastics	25	0.259174
Wood and Products of Wood and Cork	20	0.224497
Pulp, Paper, Printing and Publishing	21t22	0.200001
Food, Beverages and Tobacco	15t16	0.171497
Transport Equipment	34t35	0.074484
Machinery, Nec	29	0.063461
Manufacturing, Nec; Recycling	36t37	0.062605
Electrical and Optical Equipment	30t33	0.055674
Leather, Leather and Footwear	19	0.029444
Textiles and Textile Products	17t18	0.029016

Industry	Code	CO
Coke, Refined Petroleum and Nuclear Fuel	23	28.10301
Basic Metals and Fabricated Metal	27t28	13.71119
Other Non-Metallic Mineral	26	6.714299
Wood and Products of Wood and Cork	20	3.33507
Chemicals and Chemical Products	24	3.0766
Electrical and Optical Equipment	30t33	1.821617
Pulp, Paper, Printing and Publishing	21t22	1.684806
Textiles and Textile Products	17t18	1.560314
Machinery, Nec	29	1.170698
Manufacturing, Nec; Recycling	36t37	1.117451
Rubber and Plastics	25	1.09954
Transport Equipment	34t35	1.03152
Leather, Leather and Footwear	19	0.988043
Food, Beverages and Tobacco	15t16	0.952425

Industry	Code	SOX
Coke, Refined Petroleum and Nuclear Fuel	23	3.781532
Other Non-Metallic Mineral	26	3.373948
Basic Metals and Fabricated Metal	27t28	2.140508
Chemicals and Chemical Products	24	1.987198
Pulp, Paper, Printing and Publishing	21t22	1.66861
Electrical and Optical Equipment	30t33	1.348554
Wood and Products of Wood and Cork	20	1.287153
Transport Equipment	34t35	1.14708
Rubber and Plastics	25	0.727831
Machinery, Nec	29	0.599853
Food, Beverages and Tobacco	15t16	0.538747
Textiles and Textile Products	17t18	0.468463
Manufacturing, Nec; Recycling	36t37	0.313231
Leather, Leather and Footwear	19	0.257367

Industry	Code	N2O
Chemicals and Chemical Products	24	0.703064
Other Non-Metallic Mineral	26	0.020928
Coke, Refined Petroleum and Nuclear Fuel	23	0.011024
Wood and Products of Wood and Cork	20	0.01019
Pulp, Paper, Printing and Publishing	21t22	0.009011
Transport Equipment	34t35	0.008386
Manufacturing, Nec; Recycling	36t37	0.00801
Basic Metals and Fabricated Metal	27t28	0.007387
Rubber and Plastics	25	0.005918
Food, Beverages and Tobacco	15t16	0.004902
Machinery, Nec	29	0.003818
Electrical and Optical Equipment	30t33	0.003159
Textiles and Textile Products	17t18	0.002745
Leather, Leather and Footwear	19	0.002663

Industry	Code	NOX
Other Non-Metallic Mineral	26	4.843615
Chemicals and Chemical Products	24	1.970532
Basic Metals and Fabricated Metal	27t28	1.207739
Coke, Refined Petroleum and Nuclear Fuel	23	1.031063
Wood and Products of Wood and Cork	20	1.018366
Pulp, Paper, Printing and Publishing	21t22	0.944367
Transport Equipment	34t35	0.892484
Electrical and Optical Equipment	30t33	0.687034
Food, Beverages and Tobacco	15t16	0.537801
Machinery, Nec	29	0.501572
Textiles and Textile Products	17t18	0.475943
Manufacturing, Nec; Recycling	36t37	0.415188
Rubber and Plastics	25	0.4015
Leather, Leather and Footwear	19	0.321317

Industry	Code	NMVOC
Coke, Refined Petroleum and Nuclear Fuel	23	5.641593
Chemicals and Chemical Products	24	3.061148
Other Non-Metallic Mineral	26	2.589367
Wood and Products of Wood and Cork	20	1.653843
Food, Beverages and Tobacco	15t16	1.331466
Rubber and Plastics	25	1.070523
Basic Metals and Fabricated Metal	27t28	1.022056
Pulp, Paper, Printing and Publishing	21t22	0.879475
Transport Equipment	34t35	0.846256
Manufacturing, Nec; Recycling	36t37	0.715842
Textiles and Textile Products	17t18	0.529734
Leather, Leather and Footwear	19	0.525155
Electrical and Optical Equipment	30t33	0.501122
Machinery, Nec	29	0.375537

Industry	Code	NH3
Chemicals and Chemical Products	24	0.400923
Other Non-Metallic Mineral	26	0.032313
Basic Metals and Fabricated Metal	27t28	0.011643
Food, Beverages and Tobacco	15t16	0.011362
Transport Equipment	34t35	0.008966
Pulp, Paper, Printing and Publishing	21t22	0.00878
Manufacturing, Nec; Recycling	36t37	0.00655
Machinery, Nec	29	0.006077
Electrical and Optical Equipment	30t33	0.005984
Rubber and Plastics	25	0.005323
Wood and Products of Wood and Cork	20	0.004674
Coke, Refined Petroleum and Nuclear Fuel	23	0.003907
Leather, Leather and Footwear	19	0.002348
Textiles and Textile Products	17t18	0.001927

Note: Emission intensities are expressed in kg/USD1,000 of output at 2005 prices. CO2, CH4, and N2O pollutants are targeted by the Kyoto (1997) protocol of the UN Framework Convention on Climate Change. SOX, NOX, NMVOC, and NH3 pollutants are targeted by the Convention on Long Range Transboundary Air pollution (LRTAP) and its protocols (Helsinki (1985) on SOX, Sofia (1998) on NOX, Geneva (1991) on NMVOC, Oslo (1994) on SOX, and Gothenburg (1999) on SOX, NOX, NMVOC, and NH3).

Table 3.11: Benchmark Results: Non-Linear Relative Environmental Stringency Measure and Dirty Exports

Pollutant:	DIRTY	PC1	CO2	CH4	N2O	NOX	SOX	CO	NMVOC	NH3
Econ. Integration	0.146***	0.146***	0.146***	0.146***	0.146***	0.146***	0.146***	0.146***	0.146***	0.146***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$d(IEAs)^2$	-0.004	-0.024***	0.141***	-0.038***	-0.074***	-0.025***	-0.015**	-0.003	-0.016**	-0.070***
	(0.007)	(0.007)	(0.040)	(0.010)	(0.019)	(0.007)	(0.006)	(0.008)	(0.006)	(0.021)
$d(IEAs)^2 \times$Pollutant	-0.056***	-0.016***	-0.029***	-0.012***	-0.012***	-0.040***	-0.028***	-0.018***	-0.021***	-0.012***
	(0.014)	(0.005)	(0.007)	(0.004)	(0.004)	(0.009)	(0.007)	(0.007)	(0.008)	(0.005)
Obs.	3,040,064	3,040,064	3,040,064	3,040,064	3,040,064	3,040,064	3,040,064	3,040,064	3,040,064	3,040,064
Adj. R-Squared	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765	0.765
Country Pair Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exp.×Ind.×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Imp.×Ind.×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Emission intensities are measured in kilograms per USD 1000 of output at real exchange rates in 1995 prices. When the dirtiness indicator is binary, the industry is considered dirty if the CO2 emission intensity is above the 75th percentile of the associated emission intensity distribution. Sectoral dirtiness measure is also given by the first principal component, PC1. This principal component loads on CO2, CH4, SOX, CO, NMVOC and accounts for 58% of emission intensity of all 8 pollutants considered (i.e., CO2, CH4, N2O, NOX, SOX, CO, NMVOC, and NH3). The variable of interest $d(IEAs)^2$ is constructed as [(exporter number of IEAs)^2 - (importer number of IEAs)^2]/[(exporter number of IEAs + 1)*(importer number of IEAs + 1)].

Table 3.12: Results: Linear Relative Environmental Stringency Measure and Dirty Exports

Specification:	DIRTY	PC1	CO2	CH4	N2O	NOX	SOX	CO	NMVOC	NH3
Econ. Integration	0.143***	0.144***	0.143***	0.144***	0.144***	0.143***	0.144***	0.144***	0.144***	0.144***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
d(IEAs)	-0.012***	-0.018***	0.039***	-0.023***	-0.026***	-0.019***	-0.016***	-0.014***	-0.017***	-0.033***
	(0.002)	(0.002)	(0.007)	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
d(IEAs)×Pollutant	-0.019***	-0.002***	-0.010***	-0.004***	-0.002***	-0.011***	-0.007***	-0.004***	0.001	-0.004***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557
Adj. R-Squared	0.832	0.832	0.832	0.832	0.832	0.832	0.832	0.832	0.832	0.832
Country Pair×Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Industry dirtiness indicator is the emission intensity per USD 1000 of output at real exchange rates in 1995 prices. When the dirtiness indicator is binary, the industry is considered dirty if the CO2 emission intensity is above the 75th percentile of the associated emission intensity distribution. Sectoral dirtiness measure is also given by the first principal component, PC1. This principal component loads on CO2, CH4, SOX, CO, NMVOC and accounts for 58% of emission intensity of all 8 pollutants considered (i.e., CO2, CH4, N2O, NOX, SOX, CO, NMVOC, and NH3). The variable of interest is the environmental stringency measure, d(IEAs). This is constructed as the difference between the exporter's and importer's number of IEAs ratified.

Table 3.13: Results: Relative IEAs and Dirty Exports: Sector-by-Sector Estimates: Panel A

Sector:	*Basic Metals and Fabricated Metal*	*Chemicals and Chemical Products*	*Coke, Refined Petroleum and Nuclear Fuel*	*Electrical and Optical Equipment*	*Food, Beverages and Tobacco*	*Leather, Leather and Footwear*	*Machinery, Nec.*
Econ. Integration	0.214***	0.174***	-0.001	0.142***	0.099***	0.114***	0.070***
	(0.029)	(0.024)	(0.095)	(0.028)	(0.026)	(0.037)	(0.026)
d(IEAs)	-0.046***	-0.033***	-0.034*	-0.021***	-0.006	0.017**	-0.049***
	(0.007)	(0.006)	(0.018)	(0.005)	(0.006)	(0.007)	(0.006)
Obs.	97,006	98,414	16,776	107,502	106,444	66,270	91,170
Adj. R-Squared	0.811	0.843	0.642	0.869	0.800	0.816	0.850
Country Pair Effects							
Country Pair×Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the environmental stringency measure, d(IEAs). This is constructed as the difference between the exporter's and importer's number of IEAs ratified.

Table 3.14: Results: Relative IEAs and Dirty Exports: Sector-by-Sector Estimates: Panel B

Sector:	*Manufacturing, Nec.; Recycling*	*Other Non-Metallic Minerals*	*Pulp, Paper, Printing and Publishing*	*Rubber and Plastics*	*Textiles and Textile Products*	*Transport Equipment*	*Wood and Products of Wood and Cork*
Econ. Integration	0.180***	0.124***	0.105***	0.154***	0.128***	0.158***	0.160***
	(0.029)	(0.033)	(0.028)	(0.030)	(0.030)	(0.033)	(0.035)
d(IEAs)	0.028***	-0.066***	-0.031***	-0.048***	-0.008	-0.044***	0.033***
	(0.006)	(0.008)	(0.006)	(0.007)	(0.007)	(0.008)	(0.007)
Obs.	107,436	61,672	99,320	84,620	92,032	73,042	57,832
Adj. R-Squared	0.829	0.818	0.841	0.838	0.829	0.787	0.791
Country Pair Effects							
Country Pair×Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the environmental stringency measure, d(IEAs). This is constructed as the difference between the exporter's and importer's number of IEAs ratified.

Table 3.15: Results: Linear Relative Environmental Stringency and Dirty Exports, by IEA and Pollutant Type

Pollutant:	DIRTY	PC1	CO2	CH4	N2O	NOX	SOX	CO	NMVOC	NH3
Econ. Integration	0.143***	0.144***	0.143***	0.143***	0.144***	0.143***	0.144***	0.144***	0.144***	0.144***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
d(CC IEAs)	0.029***	0.014*	0.165***	0.008	-0.006	0.018**	0.022***	0.037***	0.022***	0.007
	(0.008)	(0.008)	(0.032)	(0.010)	(0.016)	(0.008)	(0.008)	(0.009)	(0.008)	(0.017)
d(CC IEAs)×Pollutant	-0.035***	-0.017***	-0.026***	-0.008**	-0.006*	-0.018***	-0.016***	-0.020***	-0.015**	-0.003
	(0.011)	(0.004)	(0.006)	(0.004)	(0.003)	(0.006)	(0.006)	(0.006)	(0.007)	(0.003)
d(AR IEAs)	-0.009***	-0.019***	0.077***	-0.032***	-0.042***	-0.020***	-0.016***	-0.011***	-0.017***	-0.056***
	(0.002)	(0.002)	(0.009)	(0.003)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)
d(AR IEAs)×Pollutant	-0.032***	-0.005***	-0.017***	-0.009***	-0.005***	-0.018***	-0.012***	-0.007***	-0.005**	-0.009***
	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
d(OD IEAs)	-0.026***	-0.019***	-0.078***	-0.007*	0.008	-0.021***	-0.023***	-0.027***	-0.024***	0.014**
	(0.003)	(0.003)	(0.011)	(0.004)	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)
d(OD IEAs)×Pollutant	0.014***	0.008***	0.010***	0.009***	0.007***	0.007***	0.005***	0.006***	0.017***	0.008***
	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Obs.	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557	2,985,557
Adj. R-Squared	0.832	0.832	0.832	0.832	0.832	0.832	0.832	0.832	0.832	0.832
Country Pair×Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Emission intensities are measured in kilograms per USD 1000 of output at real exchange rates in 1995 prices. When the dirtiness indicator is binary, the industry is considered dirty if the CO2 emission intensity is above the 75th percentile of the associated emission intensity distribution. Sectoral dirtiness measure is also given by the first principal component, PC1. This principal component loads on CO2, CH4, SOX, CO, NMVOC and accounts for 58% of emission intensity of all 8 pollutants considered (i.e., CO2, CH4, N2O, NOX, SOX, CO, NMVOC, and NH3). The variable of interest is the environmental stringency measure, d(IEAs). This is constructed as the difference between the exporter's and importer's number of IEAs ratified.

Table 3.16: Results: Linear Environmental Stringency Measure and Dirty Exports, by IEA, and IEA Specific Pollutant Type

Specification:	(1)	(2)
Econ. Integration	0.132***	0.133***
	(0.008)	(0.008)
d(CC IEAs)	0.036***	0.058***
	(0.009)	(0.010)
d(CC IEAs)×PC1 CC	-0.033***	
	(0.008)	
d(CC IEAs)×DIRTY CC		-0.066***
		(0.012)
d(AR IEAs)	-0.021***	-0.009***
	(0.002)	(0.002)
d(AR IEAs)×PC1 AR	-0.017***	
	(0.001)	
d(AR IEAs)×DIRTY AR		-0.039***
		(0.003)
d(OD IEAs)	-0.022***	-0.022***
	(0.003)	(0.003)
d(OD IEAs)×DIRTY OD	-0.059***	-0.056***
	(0.011)	(0.011)
Obs.	2,985,557	2,985,557
Adj. R-Squared	0.827	0.827
Country Pair×Industry Effects	Yes	Yes
Country×Year Effects	Yes	Yes
Industry×Year Effects	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Sectoral dirtiness measure is given by the agreement specific first principal components. Climate change specific first principal component (PC1 CC) accounts for 56% of the variance in the three pollutants targeted by the Kyoto protocol and for which data is available. Similarly, the acid rain specific first principal component (PC1 AR) accounts for 58% of the variance in emission intensities associated with those pollutants targeted by acid rain agreements. No data is available on those pollutants targeted by the ozone depletion agreements. In this case a binary indicator of sectoral dirtiness is used. A value of 1 denotes the transport equipment, electrical and optical equipment, machinery, n.e.c., textile and textile products, and leather and footwear sectors. DIRTY CC and DIRTY AR denote IEA-specific binary measures of dirtiness. These are based on 75th percentile cut-offs associated with the first principal components for climate change and acid rain pollutants, respectively.

Table 3.17: Results: Exporter and Importer Number of IEAs and Dirty Exports, by IEA Type

Pollutant:	DIRTY	PC1	CO2	CH4	N2O	NOX	SOX	CO	NMVOC	NH3
Econ. Integration	0.132***	0.132***	0.131***	0.132***	0.132***	0.132***	0.132***	0.132***	0.132***	0.132***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Exp. CC IEAs×Pollutant	-0.031*	-0.006	-0.033***	0.003	-0.005	-0.008	0.003	-0.007	0.019*	-0.006
	(0.017)	(0.006)	(0.009)	(0.006)	(0.005)	(0.010)	(0.009)	(0.009)	(0.011)	(0.005)
Imp. CC IEAs×Pollutant	0.034**	0.022***	0.017**	0.014***	0.007*	0.021**	0.024***	0.026***	0.033***	0.001
	(0.015)	(0.005)	(0.007)	(0.005)	(0.004)	(0.009)	(0.008)	(0.007)	(0.009)	(0.005)
Exp. AR IEAs×Pollutant	-0.043***	-0.009***	-0.020***	-0.016***	-0.008***	-0.021***	-0.016***	-0.010***	-0.013***	-0.011***
	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)
Imp. AR IEAs×Pollutant	0.019***	0.002	0.016***	-0.000	0.002	0.016***	0.009***	0.003	-0.006**	0.005***
	(0.005)	(0.002)	(0.002)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
Exp. OD IEAs×Pollutant	0.052***	0.019***	0.033***	0.026***	0.020***	0.033***	0.027***	0.023***	0.044***	0.024***
	(0.006)	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)	(0.004)	(0.002)
Imp. OD IEAs×Pollutant	0.005	-0.001	0.004*	0.001	0.002	0.009***	0.007***	0.002	-0.000	0.002
	(0.005)	(0.002)	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
Obs.	3,014,623	3,014,623	3,014,623	3,014,623	3,014,623	3,014,623	3,014,623	3,014,623	3,014,623	3,014,623
Adj. R-Squared	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
Exp.×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Imp.×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Industry dirtiness indicator is the emission intensity per USD 1000 of output at real exchange rates in 1995 prices. When the dirtiness indicator is binary, the industry is considered dirty if the CO2 emission intensity is above the 75th percentile of the associated emission intensity distribution. Sectoral dirtiness measure is also given by the first principal component, PC1. This principal component loads on CO2, CH4, SOX, CO, NMVOC and accounts for 58% of emission intensity of all 8 pollutants considered (i.e., CO2, CH4, N2O, NOX, SOX, CO, NMVOC, and NH3). The variable of interest is the environmental stringency measure, d(IEAs). This is constructed as the difference between the exporter's and importer's number of IEAs ratified.

Table 3.18: Results: Exporter and Importer Number of IEAs and Dirty Exports, by IEA, and IEA Specific Pollutant Type

Specification:	(1)	(2)
Econ. Integration	0.132***	0.132***
	(0.004)	(0.004)
Exp. CC IEAs×PC1 CC	-0.013	
	(0.009)	
Imp. CC IEAs×PC1 CC	0.029***	
	(0.008)	
Exp. CC IEAs×DIRTY CC		-0.056***
		(0.017)
Imp. CC IEAs×DIRTY CC		0.040***
		(0.015)
Exp. AR IEAs×PC1 AR	-0.009***	
	(0.001)	
Imp. AR IEAs×PC1 AR	0.003*	
	(0.002)	
Exp. AR IEAs×DIRTY AR		0.007*
		(0.004)
Imp. AR IEAs×DIRTY AR		0.004
		(0.005)
Exp. OD IEAs×DIRTY OD	-0.076***	-0.072***
	(0.006)	(0.006)
Imp. OD IEAs×DIRTY OD	-0.007	-0.007*
	(0.004)	(0.004)
Obs.	3,014,623	3,014,623
Adj. R-Squared	0.822	0.822
Exp.×Year Effects	Yes	Yes
Imp.×Year Effects	Yes	Yes
Industry×Year Effects	Yes	Yes
Country Pair×Industry Effects	Yes	Yes

Note: Dependent variable is the natural logarithm of sectoral exports. Estimates are produced using ordinary least squares. Standard errors are shown in parentheses and clustered at the exporter-importer-industry level. *** p<0.01, ** p<0.05, * p<0.1. Sectoral dirtiness measure is given by the agreement specific first principal components. Climate change specific first principal component (PC1 CC) accounts for 56% of the variance in the three pollutants targeted by the Kyoto protocol and for which data is available. Acid rain specific first principal component (PC1 AR) accounts for 58% of the variance in emission intensities associated with those pollutants targeted by acid rain agreements. No data is available on those pollutants targeted by the ozone depletion agreements. In this case a binary indicator of sectoral dirtiness is used. A value of 1 denotes the transport equipment, electrical and optical equipment, machinery, n.e.c., textiles and textile products, and leather and footwear sectors. DIRTY CC and DIRTY AR denote IEA-specific binary measures of dirtiness. These are based on the 75th percentile cut-offs associated with the first principal components for climate change and acid rain pollutants, respectively.

Chapter 4 The Kyoto Protocol and the Carbon Content of Trade: Evidence from the EORA Dataset

4.1 Introduction

The Kyoto protocol is aimed at tackling carbon dioxide (CO_2) emissions and curb the effects of climate change[1]. It involves a total of 192 parties but, among these, only about one in five is legally bound to quantitative emission reduction or limitation commitments (QERLCs). In other words, committed parties pledged to reduce, keep unchanged, or increase by a limited amount their CO_2 discharges through the 2008-2012 period[2]. On a different note, however, the emission content of international trade is found to be rather large and to increase rapidly (Hertwich and Peters, 2008a; Peters et al., 2011; Sato, 2012). Within this context one question emerges. Does commitment to the Kyoto protocol shape trade flows and their carbon content?[3] The causal link is intuitive. On one hand, if the committed parties engage in climate change reform they are expected to export more "clean" and fewer "dirty" (i.e., CO_2-intensive) goods; a category of wares for which they lose comparative advantage. On the other hand, climate change policies are awaited to increase the price of carbon and reduce the overall CO_2 emissions per unit of output. In both scenarios, the carbon content of trade is supposed to decline.

Most of the work on carbon price adjustment and the carbon content of trade is conducted using computable general equilibrium techniques. The produced estimates are found to vary widely in concordance with the parameter choice and the underwritten assumptions (Karp, 2011). Other studies, mainly in the environmental sciences and input-output analysis (IOA) fields, are focused on quantitative descriptions rather than causal analyses (Hertwich and Peters, 2008a; Peters et al., 2011; Boitier, 2012). Econometric evidence that links the Kyoto protocol and the CO_2 content of bilateral trade is rather limited. So far, the sole empirical exercise carried out in this vein is Aichele and Felbermayr (2015). However, the composition and time horizon of their sample masks important post-ratification adjustments. This work seeks to answer the above question, and to extend the literature notch on the Kyoto protocol and the carbon content of trade, in several ways. First, it extends the scope of the above mentioned study by taking advantage of the relatively new EORA26 dataset. This way, the effect of Kyoto ratification[4] on the carbon content of exports is estimated in a sample comprising 149 nations, observed between 1995 and 2012.

[1] In addition to carbon dioxide, the Kyoto protocol targets methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. Due to limited data availability, only carbon dioxide emissions are considered here.

[2] Refer to table 4.2 for details.

[3] The CO_2 content of trade is defined as $CCT = \eta T$, where η is a measure of emissions per USD of output and T denotes exports or imports in monetary terms. This is discussed further in section 4.3.1.

[4] Unless otherwise specified, Kyoto ratification and Kyoto commitment stand for ratification of

The addition of the 2008-2012 period is of paramount importance as the QERLCs adopted under the protocol only become binding during this particular time frame. Second, it employs a year-by-year analysis to scrutinize the degree of adjustments that may prevail in the wake of ratification. Third, it investigates whether the outcomes of interest (i.e., exports (X), the CO_2 intensity of exports (η), and the carbon content of exports (CCX)) are shaped by the type of QERLC adopted or by whether a party transitions towards a market economy[5]. On a secondary note, this work also adds to the burgeoning literature on IEAs and their competitiveness and the pollution haven effects.

The above approaches lead to a series of novel and important results. First, by taking into account the 2008-2012 period I find that exports of Kyoto committed parties increase significantly, by about 6%. The effects recovered by leaving out this time frame situate at about 0.5%. Furthermore, the CO_2 intensity of exports declines by about 18.5% whereas the carbon content of exports decreases by 14%. In contrast, the estimates of Aichele and Felbermayr (2015) point to much lower and, in the case of exports, opposite, effects. More specifically, their results imply that the Kyoto commitment decreases exports by 5%, their CO_2 intensity by 3%, and the carbon content of exports by 8%. Second, the year-by-year analysis emphasizes an export adjustment process that prevails during the post-ratification period. This way, exports are found to decline between 2001 and 2003, only to rebound thereafter. Zooming in, exports are also found to recover in as little as three years for less CO_2-intensive sectors (e.g., agriculture and fishing). For the more CO_2-intensive sectors (e.g., petroleum, chemicals, and non-metallic mineral products) exports resume growth five years after ratification. It is important to note that the export recovery does not come into view if the 2008-2012 time frame is disregarded. The CO_2 intensity of exports, on the other hand, is found to decrease permanently after ratification, thus signaling a potential compositional shift in the exporting basket (i.e., towards a less CO_2-intensive production mix). The effect on the carbon content of exports is similar to that on carbon intensities. Third, by looking at the type of QERLCs (decrease, keep unchanged, or increase GHG emissions by a controlled amount) I find that the ratification effects are relatively strong for parties which pledged to reduce emissions. For this group, the ratification effect on the carbon content of exports was estimated at about -20%. For countries which pledged to limited increases or no emission changes the effect situates at circa -2%. Contrary to prior beliefs, I find that the EITs significantly reduced both the CO_2 intensity and the carbon content of their exports. The analysis of QERLCs' heterogeneous nature gains in importance if viewed through the lenses of the Doha amendment to the Kyoto protocol. As part of this accord roughly one fifth of Kyoto ratifiers took on new QERLCs for the 2013-2020 period. The evidence presented here might be of interest to policy makers as well. Committed parties not only see their CO_2 intensity of exports declining significantly after ratification but exports appear to have rebounded in the latter part of the 2000s. Simply put, exports become less

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the protocol while opting for a legally binding QERLCs.

[5]Parties to the Kyoto protocol which are transitioning to a market economy are further referred

CO_2-intensive and increase as a result of Kyoto commitment. Contrary to previous beliefs, this evidence suggests that the engagement in climate change reform might not be as detrimental to a nation's competitiveness position.[6]

The remainder of the essay proceeds as follows. In section 4.2, some of the key features of the Kyoto protocol are discussed. The baseline empirical strategy and the benchmark results are discussed within section 4.3. Section 4.4 presents the time series estimation approach and the results. The heterogeneous nature of the QERLCs is scrutinized within section 4.5. Section 4.6 focuses on the economies in transition (EITs). Finally, section 4.7 concludes.

4.2 The Kyoto Protocol

This section describes the Kyoto protocol by drawing on the relevant materials provided as part of the International Environmental Agreements Database Project (Mitchell (2016)) and the European Commission. These include and are limited to information on the protocol itself, its 2012 Doha amendment, and the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto protocol is the outcome of the 1992 UNFCCC and comprises a total of 192 parties (191 sovereign states and the European Union as a regional economic integration organization). It is aimed at curbing anthropogenic emissions of greenhouse gases (GHGs) by complementing the 1987 Montreal protocol to the Vienna Convention for the Protection of the Ozone Layer, and its subsequent amendments. While the Montreal protocol is aimed at containing discharges of chlorofluorocarbons, bromofluorocarbons, and hydrochlorfluorocarbons, the Kyoto protocol is designed to target emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. However, unlike the Montreal agreement, the Kyoto protocol focuses on aggregate rather than individual emissions.

Subject to much controversy, a key feature of the Kyoto protocol is the "common but differentiated" responsibilities designated among parties. Some of these duties consist in legally binding quantitative emission limitations or reductions commitments (QERLCs). For example, some ratifiers such as Switzerland and Japan assured to reduce their aggregate GHG emissions by 8% and 6%, respectively. Other parties, such as Australia and Norway, promised to increase their GHG emissions by no more than 8% and 1%. In contrast, some parties (e.g., New Zealand) pledged to keep their emissions unchanged. Adopters of the Kyoto protocol were also presented with the option of committing to QERLCs as a group. This is the case of the pre-2004 European Union members (EU15) which jointly adopted an emission cutback of 8%. As per the European Commission's guidelines, parties become responsible for individual targets if the joint fulfillment target is not met. In this regard, EU15 members,

to as Eastern European transitioning economies or simply as economies in transition (EITs).

[6] The United States did not ratify the Kyoto protocol due to competitiveness concerns (Grubb, 2003). Also invoking competitiveness concerns, Canada did not take on QERLCs for the 2013-2020 commitment period.

and those that joined the EU starting 2004, also took on individual QERLCs[7]. For example, both Denmark and Germany committed to a 21% reduction commitment while Greece and Portugal promised to increase their GHG emissions by no more than 25% and 27%, respectively. The individual commitments took on by the EU15 nations amount to an average emission decrease of 5.2%. The reduction targets refer to the 2008-2012 period relative to 1990 levels[8]. This five year span is also referred to as the first commitment period of the protocol. By the end of this window, parties which adopted QERLCs must have met their targets or otherwise face international sanctions. The enforcement of QERLCs is discussed shortly. The nations which have committed themselves to QERLCs under the Kyoto protocol are listed within Annex I of the Framework Convention and are often referred to as Annex I parties[9,10]. Further targets, for the 2013-2020 period, were added as part of the Doha (2012) amendment to the protocol. The QERLCs are listed within the sixth column of table 4.2. Under the addendum, the EU members plus Iceland opted for a joint QERLC of -20%. In the case in which this target is not met, the EU members are responsible for carrying out the individual marks listed in the last column of table 4.2. Under the Doha amendment, some parties also pledged to non-binding QERLCs that range between -5% for Australia and -40% for Norway[11]. Canada withdrew from the protocol in 2012 while Japan and Russia declined to take on QERLCs for the second commitment period (i.e., 2013-2020). In addition to adopting QERLCs, developed parties (also referred to as Annex II countries) were prompted to initiate efforts of achieving important reductions of GHG emissions by 2005. Annex II countries were also designated to take part in the flexibility mechanisms developed under the protocol. These instruments are designed to complement domestic climate change policies. First, emissions trading (ET) under the Kyoto protocol is similar to a domestic cap-and-trade system. Under this system, committed parties with emission headroom can

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[7]These are Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. Among those only Cyprus and Malta did not commit themselves to binding emission caps. Bulgaria and Romania joined in 2007. For completion purposes, Croatia joined in 2013. Refer to table 4.2 for details

[8]For most parties the reduction targets refer to 1990 emission levels. However, Bulgaria, Hungary, Poland, Romania, and Slovenia picked different base years in accordance with the provisions stipulated within the 1^{st} Conference of the Parties. In the order specified above, the base years are 1988, 1985-1987 average, 1988, 1989, and 1986.

[9]Technically, QERLCs were assigned for Annex I countries listed in Annex B to the Kyoto protocol. A presentation of the emission reduction/cap targets accepted by ratifying parties is provided in table 4.2.

[10]It is worth pointing out that not all Annex I countries (i.e., Cyprus, Malta, and Turkey) took on binding emission caps for the 2008-2012 period. Cyprus became an Annex I member only in 2013. Malta was added to Annex I in 2009 and therefore did not commit to any reductions for the above mentioned period. According to the 2001 Marrakesh Conference of Parties, Turkey is recognized *"in a situation different from that of other Parties included in Annex I to the Convention"*. Turkey did not take on any binding QERLCs. Also, the United States signed the protocol in 1998 and opted for an emission reduction of 7%. However the Kyoto protocol was never ratified by the U.S. Administrations that followed since.

[11]These voluntary commitments are to be pursued only if other parties would subject themselves

trade their remaining allowances to parties that are in the position of not meeting their QERLC. The Clean Development Mechanism (CDM) and Joint Implementation (JI) mechanisms are built around international investment incentives. As part of the CDM, parties that adopted QERLCs can accrue certified emission reductions (CERs) by pursuing projects aimed at reducing GHG emissions in non-Annex I parties. Similarly, under JI emission reduction units (ERUs) may be earned for similar projects conducted between parties with QERLCs. Both CERs and ERUs can be used for meeting the legally binding QERLCs. The end purpose of the flexibility mechanisms is to facilitate sustainable growth in developing parties and to aid Annex I parties in meeting their emission commitments.

Some of the early concerns regarding the protocol were focused on the extent to which penalties for non-compliance can be enforced. As noted in Grubb (2003), the repercussions are mild in comparison to domestic legislation. For example, a party that does not meet the legally binding QERLCs by the end of the first commitment period is barred from taking part in the flexibility mechanisms. Furthermore, for the second commitment period the offending party's emission allowance is cut by 30%. Nevertheless, parties which committed to QERLCs under the protocol seem to have taken their duties seriously. Figure 4.4, borrowed from Aichele and Felbermayr (2015), shows that committed participants' stock of climate change policies (e.g., on energy efficiency standards, afforestation, or facilitation of research and development) rose faster than that of their non-committed peers, and by 2011 they had enforced roughly twice as many policies. Another piece of evidence regarding the efforts of committed parties is presented in figure 4.8. From here, one can observe that the total CO_2 emissions embodied in exports increased much faster for non-committed Kyoto parties. Moreover, the series appear to diverge starting 2009. At this point in time, the CO_2 content of outflows from non-committed nations starts to increase sharply. One of the first econometric analyses linking QERLCs with reduced CO_2 emissions is Aichele and Felbermayr (2013). Their study emphasizes that parties which ratified the protocol by taking on a binding emission cap saw their domestic CO_2 emissions reduced by approximately 7%. However, this cutback was offset by increases in imported emissions, particularly from non-committed nations. In the same vein, Grunewald and Martínez-Zarzoso (2011) conclude that, for committed parties, the ratification of Kyoto protocol entails a 24.5% decline in the CO_2 emission levels.

Another concern involves the QERLCs took on by the Eastern European transitioning countries. According to Grubb (2003) and Victor (2004), these targets are believed to be rather lenient. Given the disintegration of their industrial clusters, and the implied decline in CO_2 emitting capacity, some questioned whether the adopted QERLCs will prompt the EITs to engage in climate change reform. Nevertheless, in the context of the European Union (EU) Eastern Enlargement, the enforcement of a tougher environmental stance may have been used as a signaling instrument by some EITs. Once in, these nations were motivated to comply with the EU's environ-

to similar standards.

mental guidelines by otherwise hefty fines (Jug and Mirza, 2005). Further, transition economies are found to rank relatively high in terms of environmental performance according to Emerson et al. (2012)[12].

As per the above, a detailed look into the exporting behavior of Annex I and EIT parties, all of which ratified the protocol with a binding QERLC, is therefore in line. Also, it is important to dissect the time dimension, since each post-ratification year may entail an idiosyncratic Kyoto commitment effect. For instance, most parties ratified the protocol between 2001-2003 and the protocol entered into force in 2005. Further, the commitment of parties which took on QERLCs is evaluated at the end 2012. In addition, firms and industries are expected to gradually adapt to the above time-line and to the environmental policies enacted post-ratification.

4.3 Empirics: Kyoto Ratification

4.3.1 Baseline Empirical Specification and Discussion

A notable amount of empirical research focused on the link between environmental policy and exports[13]. However, the strand of literature analyzing the link between environmental policy, pollution intensities, and the pollution content of bilateral trade is not as vast. Nevertheless, it is expanding fast given the recent accumulation of data on industry-level emissions and the increased availability of detailed multi-region input output tables. One recent study in this vein and on which the present analysis builds is Aichele and Felbermayr (2015).

The effect of ratifying the Kyoto protocol on the carbon content of exports is analyzed using the gravity framework proposed by Aichele and Felbermayr (2015). However, while their study focuses on imports, the current work analyzes exports and their carbon content by using a much larger dataset (i.e., 149 countries and 18 years). The carbon content of exports from exporter x, in industry s, to importer m at time t, $CCX_{x,m,s,t}$ is depicted in (4.1). Here, $\eta_{x,s,t}$ stands for sectoral emissions per unit of output (or emission intensity) in the exporting country while $X_{x,m,s,t}$ denotes exports in monetary terms. As in the above mentioned study, the effect of environmental policy on sectoral carbon content of exports can be decomposed in two sub-effects. First, the *technique effect* is outlined by changes in sectoral emission intensities ($\eta_{x,s,t}$). Second, the *scale effect* underlines changes in the carbon content of exports which are

[12]In terms of their environmental performance index, eight out of the thirteen EITs rank ahead of the United States. According to the same report, all EITs rank ahead of the United States in their potential of reaching four climate change-specific objectives. These include emissions of GHG per capita, per unit of GDP, and per kilowatt-hour in addition to the share of energy produced using renewable sources.

[13]Kalt (1985); Robison (1988); Tobey (1990); Grossman and Krueger (1991) are some of the early analyses. De Santis (2012); Grether and De Melo (2003); Grether et al. (2012); Jug and Mirza (2005); van Beers and van den Bergh (1997); Aichele and Felbermayr (2013); van Beers and van den Bergh (2000); Ederington and Minier (2003); Ederington et al. (2005); Levinson and Taylor (2008); Kellenberg (2009); Broner et al. (2012) are among the more recent studies. Refer to section 3.2 of the previous chapter for a detailed review of this literature notch.

attributable to changes in sectoral export flows ($X_{x,m,s,t}$).[14]

$$CCX_{x,m,s,t} = \eta_{x,s,t} X_{x,m,s,t} \tag{4.1}$$

With the above in mind, I now turn to discuss the empirical specification. This is depicted in (4.2) where the variable of interest is the differential Kyoto commitment, $dKyoto_{x,m,t}$. This is constructed as the simple difference between the exporter and importer-specific Kyoto ratification status. Specifically, this differential takes a value of 1 (and -1) if the exporter (importer), but not the importer (exporter), ratified the Kyoto protocol by taking on legally binding QERLCs. In case in which both (or none of) the exporter and importer committed to the protocol, the differential is null. $TA_{x,m,t}$ denotes the degree of economic integration characterizing an exporter-importer pair. This is expected to affect the carbon content of exports through the scale effect; as a more integrated dyad is more likely to exchange a larger volume of goods. Finally, the error term $\mu_{x,m,s,t}$ is modeled as in (4.3). The reasoning behind this particular error term structure is discussed within the previous chapter[15]. Briefly, this particular design is aimed at capturing exporter and importer, time-invariant and time-variant, determinants of export flows (e.g. border tax adjustments[16]) and sectoral pollution intensities. Furthermore, the inclusion of exporter×year and importer×year effects, both nested in $\nu_{x,m,t}$, circumvents the problem of self-selection into the Kyoto protocol, the QERLC choice, or the participation in protocol's flexibility mechanisms[17]. A sector-specific time trend is also included to account for any idiosyncratic shocks that an industry may display. Furthermore, pair-sector-specific fixed effects are included to account for any time-invariant factors that may influence sectoral exports (e.g., distance, common border, common language, etc.). The inclusion of the high-dimensional effects outlined above is computationally feasible by virtue of the new *regdfe* STATA routine (Correia, 2015). All estimates are produced using ordinary least squares.

$$lnCCX_{x,m,s,t} = \beta dKyoto_{x,m,t} + \delta TA_{x,m,t} + \mu_{x,m,s,t} \tag{4.2}$$

$$\begin{aligned} \mu_{x,m,s,t} &= \nu_{x,m,t} + \nu_{x,m,s} + \nu_{s,t} \\ \nu_{x,m,t} &= \nu_{m,x,t} \end{aligned} \tag{4.3}$$

[14]
$$\frac{\partial CCX}{\partial \eta} > 0 \quad \text{and} \quad \frac{\partial CCX}{\partial X} > 0;$$

For an extended initial discussions on these two sub-effects refer to Antweiler et al. (2001); Grossman and Krueger (1991).

[15]Refer to sections 3.5.1 and 3.5.2 for details

[16]In a sense, border tax adjustments can be regarded as import duties aimed at mitigating adverse competitiveness effects and reduce carbon leakage.

[17]Aichele and Felbermayr (2015) utilize a similar approach in the context of Kyoto adoption while

As noted earlier, the ratification of the Kyoto protocol transforms the sectoral carbon content of exports through changes in the CO_2 emission intensity of exports (i.e., the technique effect) and exports (i.e., the scale effect). First, the technique effect should be negative since commitment under the protocol appears to entail a more demanding climate change reform[18]. In turn, this is expected to engender declines in the CO_2 intensity of exports; perhaps due to more efficient production processes or fuel standards, for example. To a large extent, this outcome is also supported by the findings of Aichele and Felbermayr (2015). Their findings imply that exports of Kyoto committed parties, towards their non-committed peers, are characterized by lower CO_2 intensities. In addition, Aichele and Felbermayr (2012) find that parties with QERLCs under the protocol reduced their domestic emissions by approximately 7%. Second, the scale effect is ambiguous. From a general equilibrium perspective it could be positive if the growth of "clean" exports more than offsets the decline in "dirty" outflows. This dynamic gives itself to a possible compositional shift towards less CO_2-intensive production; as climate change reform may necessitate a reallocation of resources from "dirty" sectors towards their "clean" counterparts.[19]. On the other one hand the scale effect can be negative if post-Kyoto climate change policies entail reductions in exports from both "dirty" (i.e., CO_2-intensive) and "clean" (i.e., less CO_2-intensive) sectors. In the light of the above, and should the technique effect dominate the scale effect, β is expected to be negative.

4.3.2 Data

The sample under analysis comprises 149 countries observed between 1995 and 2012 as both exporters and importers. These are listed in table 4.1. With the exception of Hong Kong, Macau, Taiwan, and the United States of America, all countries in the sample have ratified the Kyoto protocol by 2012. A total of 37 parties adopted the protocol by taking on QERLCs for the first commitment period (i.e., 2008-2012) but only 35 remain after the data assembly process is finished[20]. These are shown in table 4.2. A dataset on industry-level, bilateral exports is initially constructed using the harmonized EORA26 world input-output table[21]. This is compiled as part of the EORA World MRIO project (Lenzen et al., 2012, 2013). The export figures refer to both intermediate inputs (i.e., shipped to foreign firms) and final goods (i.e., shipped to foreign final consumers). In total, information on 14 service, 10 manufacturing, and

Head and Mayer (2013); Baier and Bergstrand (2007); Baier et al. (2014); Baldwin and Taglioni (2006); Regolo (2013); Soete and Van Hove (2015) discuss it with regards to the ratification of economic integration agreements (EIAs).

[18]Refer to figure 4.4 for details.

[19]In the previous chapter I document that the Kyoto protocol is a source of comparative disadvantage for pollution-intensive industries and a source of comparative advantage for their less pollution-intensive peers. That is, the ratification of Kyoto protocol by the exporter is equivalent to a 0.8% decline in exports of "dirty" sectors. At the same time, outflows from "clean" sectors are estimated to increase by 5.8%.

[20]Liechtenstein and Monaco are not in the sample.

[21]A toy depiction of such table is shown in figures A.1 and A.2 of the appendix.

2 primary sectors is provided. However, only the latter two categories are analyzed. In addition and for comparability purposes, outflows are further aggregated such that the industrial classification matches that of Aichele and Felbermayr (2015)[22]. This way, 1 primary and 8 manufacturing sectors are retained.[23] In turn, the typical observation denotes an exporter-importer-industry pair at a given point in time. Another advantage of using the EORA26 database is outlined by the availability of sectoral carbon dioxide (CO_2) emissions[24]. This information can be further used to construct industry-specific CO_2 intensities[25] and the CO_2 content of exports as shown in (4.1). Sector specific summary statistics on exports, the CO_2 intensity of exports, and the carbon content of exports are showcased in table 4.5. Data on the Kyoto participation is obtained from the International Environmental Agreements Database Project (Mitchell (2016)). QERLCs data for the EU15 countries is retrieved from the European Commission. For reasons already discussed in the previous chapter, the ratification as opposed to signature or entry into force is regarded as the treatment date. Economic integration is measured on a zero to six scale, with zero denoting no integration between the exporter and importer at a given point in time[26]. The overall summary statistics are presented in table 4.4.

4.3.3 Results

Before presenting the estimates obtained using the full dataset, I discuss the results recovered using a sub-sample which replicates that of Aichele and Felbermayr (2015)[27]. The results are presented in table 4.6. Column (1) reports the results obtained by estimating equation (4.2) while using exports ($X_{x,m,s,t}$) as the dependent variable. Column (2) presents the results for the sectoral pollution intensity of exports ($\eta_{x,s,t}$). Column (3) addresses the carbon terms of trade ($CTT_{x,m,s,t}$)[28]. From

[22] Mining and quarrying, and electricity, gas and water supply sector is not included due to the very high emissions per unit of output displayed. Its exclusion does not impact the results quantitatively or qualitatively. Services sectors are also left out.

[23] Refer to table 4.3 for the list of sectors.

[24] The main sources of carbon dioxide (CO_2) emissions are represented by energy production. Other sources include the production of cement and extraction of minerals, and agricultural burning.

[25] For each sector, emission intensities are constructed as a ratio of yearly CO_2 emissions to yearly output. In absence of sectoral price indexes, sectoral output is converted in 2005 prices using the GDP price indexes provided in the Penn World Tables 8.1.

[26] This measure is obtained from the NSF - Kellogg Institute Data Base on Economic Integration Agreements Project. The first level is indicative of a non-reciprocal preferential trade agreement. Similarly, levels two and three denote joint attendance within a preferential trade arrangement and a free trade agreement, respectively. Level four signals that the exporter and importer are concomitantly part of a customs union. Level five underlines the joint membership within a common market (i.e., the European Union). Finally the last stage expresses dual participation in an economic union (i.e., the Eurozone).

[27] The authors construct a bilateral dataset comprising of 40 exporters and importers between 1995 and 2007. The countries in their sample are marked with an asterisk in table 4.1.

[28] $CTT_{x,m,s,t}$ is defined as the ratio of carbon content of exports to that of imports and it is

panel A one can note that exports decline by about 2%[29] if the exporter ratified the Kyoto protocol with a binding emission cap but the importer has not. Similarly, the carbon dioxide (CO_2) intensity of exports decreases by approximately 9%. Together, these negative scale and technique effects bring about a decline in the CO_2 content of exports of 11%. In comparison, the findings of Aichele and Felbermayr (2015) are underlining a differential commitment effect of -5% on imports, -3% on the CO_2 intensity of exports, and -8% on the CO_2 content of exports.[30] In sum, parties which took on legally binding emission caps as part of the Kyoto protocol are characterized by a lower volume of outflows and a less CO_2-intensive export basket. This result is also supported by the estimates in column (3) which denote a negative differential effect on the carbon terms of trade. In turn, this finding suggests that, relative to imports, the exports of committed parties become cleaner (i.e., less CO_2-intensive). This post-Kyoto pattern may give itself to potential Heckscher-Ohlin general equilibrium effects. According to this hypothesis, less CO_2-intensive sectors expand at the expense of their more polluting counterparts. I now turn to panel B where the sub-sample mimicking that of Aichele and Felbermayr (2015) is extended to include the 2008-2012 time frame. This addition brings the differential commitment effect on exports from a statistically significant -2% to an insignificant -0.5%. The impacts on the CO_2 intensity of exports (i.e., -9%) and the CO_2 content of exports (i.e., -9.5%) are not altered significantly. In sum, for the extended sample, the exports of committed parties, although cleaner, seem unaffected by the adoption of Kyoto QERLCs. Collectively, the estimates in panels A and B suggest existence of an adjustment period. Specifically, exports decline in the wake of ratification, only to rebound post-2008. These findings represent the catalyst for the year-by-year analysis conducted in section 4.4.

The remainder of this section focuses on the benchmark estimates. These are produced using the full set of countries and displayed in table 4.7. Panel A contains the results obtained using the 1995-2007 period. From here, the differential commitment effect on exports and the CO_2 intensity of exports is 0.6% and -18% respectively. Together these scale and technique effects imply a decline in the carbon content of exports of about 17.4%. Panel B presents the estimates produced by taking into account the protocol's first commitment period (i.e., 2008-2012). The coefficients listed here underline a differential QERLC effect of approximately 6% on exports and -18.5% on the CO_2 intensity of outflows. In turn, the carbon content of exports declines by about 14%. As with the sub-sample replicating that of Aichele and Felbermayr (2015), the addition of the 2008-2012 period does not alter

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depicted below.

$$CTT_{x,m,s,t} = \frac{CCX_{x,m,s,t}}{CCX_{m,x,s,t}}$$

A similar measure is discussed in Aichele and Felbermayr (2015) and Antweiler (1996).

[29]Effects are computed based on the following formula: $(e^{\beta} - 1) * 100$.

[30]Aichele and Felbermayr (2015) analyze imports, the CO_2 intensity of imports, and the carbon content of imports. However, due to the symmetric nature of the commitment differential, their findings may be extended to exports as well.

the effects on the CO_2 intensity of exports or the carbon terms of trade, which are shown in columns (2) and (3). A similar argument could be made with regards to the CO_2 content of exports. However, the differential effect declines slightly upon expanding the time horizon (i.e., moving from panel A to panel B in column (4)). This shift is attributable in its entirely to the export recovery that seems to occur post-2008. The export adjustment argument is supported once more by the estimates in column (1). Note that by including the 2008-2012 period, the Kyoto commitment effect on exports changes significantly, from a meager 0.6% to a much larger 6%. The positive scale effect follows to some extent the logic of Rose and Spiegel (2010). In their study, membership within international environmental agreements (IEAs) is regarded as a signaling mechanism for international cooperation. Specifically, joint adoption of IEAs was found to facilitate cross-border asset exchange. Further, foreign direct investment, a type of asset exchange, was shown to complement international trade activities (Helpman, 1984; Head and Ries, 2004). On a similar note, Kee et al. (2010) link increases in carbon taxes with higher exports for OECD countries. Their argument revolves around the idea of tax-recycling and over-compensation of CO_2-intensive industries.

To summarize, ratifying the Kyoto protocol by adopting QERLCs entails a positive scale effect (i.e., the change in the volume of exports) of approximately 6%. The technique effect (i.e., the change in the CO_2 intensity of exports) is negative and much larger, thus situating at about -18.5%. Together, the scale and technique effects imply a decline in the CO_2 content of exports of roughly 14%. In addition, the results presented here are also indicative of a supply side "leakage". That is, the carbon content of outflows from parties with no QERLCs under the Kyoto protocol is increasing due to ratification.

4.3.4 Robustness Checks

In the spirit of Aichele and Felbermayr (2015), a battery of robustness checks is presented within table A.1 of the appendix. In order to produce these results I employ the specification described in (4.2). As noted before, exports are used as the dependent variable in column (1). Column (2) refers to the CO_2 intensity of exports whereas column (3) shifts the focus onto the carbon terms of trade. In column (4) the differential commitment effect on the CO_2 content of exports is presented. Panel A shows the results obtained by excluding China from the sample. Panel B excludes countries which, in 2014, found themselves among the twenty five leading oil producers[31]. The results exhibited within panels A and B are minimally altered when compared to the benchmark estimates.

One may rightfully argue that the differential Kyoto commitment may be biased as it may be correlated with latent differences between developed (i.e., parties with

[31] According to the U.S. Energy Information Administration (EIA) International Energy Statistics these are (first to last) the United States, Saudi Arabia, Russia, China, Canada, the United Arab Emirates, Iran, Iraq, Brazil, Mexico, Kuwait, Venezuela, Nigeria, Qatar, Norway, Angola, Algeria, Kazakhstan, Colombia, India, Oman, Indonesia, the United Kingdom, Azerbaijan, and Ar-

QERLCs) and developing countries (i.e., parties without QERLCs) which may also influence the scale and technique effects. Differences in preferences and the fact that countries with higher per capita income trade more with one another (Markusen, 2013; Martínez-Zarzoso and Vollmer, 2010) may reshape the scale effect. Concerning the technique effect, Hertwich and Peters (2008a); Peters et al. (2011); Boitier (2012) emphasize that CO_2 emissions embodied in exports flowing from developing towards developed nations have increased sharply since the 1990s. I address this potential issue by including a GDP per capita differential within specification (4.2). The estimates obtained this way are shown in panel C. The results hardly change vis-a-vis their benchmark figures; a signal that the symmetric and time-varying country pair effects are performing well in accounting for this particular type of omitted variable bias.

Factor endowment differences are important for two reasons. First, the classical theory of trade holds that trade patterns are shaped by differences in factor endowments. By omitting these factors, one opens the door towards a potentially biased scale effect. Second, "dirty" industries (i.e., CO_2-intensive) are characterized by relatively high capital-to-labor ratios[32]. Moreover, parties which ratified the protocol by taking on QERLCs are capital-abundant while those opting out of QELRCs are labor-abundant[33]. Thus, capital-abundant, and Kyoto committed, parties are likely to host CO_2-intensive sectors. The opposite holds true for labor-abundant, but not committed parties. I address this potential issue by including exporter-importer differences in the capital-to-labor ratios and years of schooling in equation (4.2). The results obtained are presented in panel D and, although lower, they line up rather well with their benchmarks.

A series of counterfactual tests are also conducted by closely following Aichele and Felbermayr (2013). These are presented in table A.2 of the appendix. The estimates are once again recovered by the employment of specification (4.2). Panels A, B, and C present the results for exports, the CO_2 intensity of exports, and the carbon content of exports, respectively. In the first two columns 1997 and 1998 are used as hypothetical ratification years[34]. Note the absence of any association between the estimates presented here and the benchmarks. The counterfactual differential commitment effect on exports is double than that recovered using the correct treatment date while the effect on CO_2 intensities is virtually null. Together these imply a positive effect

gentina. Among these only Canada, Russia, Norway, and the United Kingdom ratified the protocol by adopting QERLCs.

[32]Using industry-level data from the World Input Output Tables (WIOT) (Timmer et al., 2012; Dietzenbacher et al., 2013; Timmer et al., 2015), small but positive correlations are found between sectoral CO_2 intensities and capital/labor ratios. The WIOT data is available for 40 nations (all 27 European Union members (in 2011) plus 13 other nations: Australia, Brazil, Canada, China, India, Indonesia, Japan, South Korea, Mexico, Russia, Turkey, Taiwan, and the United States) from 1995 to 2009. Similar correlations but regarding nitrous oxides, sulphur dioxide, and carbon monoxide intensities are shown in Broner et al. (2012). Antweiler et al. (1998) link capital intensity with higher pollution abatement costs. Grether and De Melo (2003) and Mani and Wheeler (1998) also find that pollution intensive sectors are more capital-intensive.

[33]This very aspect is shown in figure 4.5.

[34]The first Kyoto ratification under a QERLCs regime occurred in 2001.

of hypothetical ratification on the carbon content of exports. These counterfactual tests rule out the presence of pre-ratification trends that might be captured by the true commitment differential.

As noted earlier, developed parties are more likely to have taken QERLCs under the protocol. With the exception of EITs, the opposite is true for developing countries. The estimates presented in columns (3) - (5) are aimed to tackle, from a different angle, the potential issues that may arise due to this feature. In column (3), exports and imports of Kyoto committed parties to and from their non-committed partners are stacked against the United States' exports and imports to and from non-committed nations. Column (4) is similar but a group of developed countries is used instead of only the United States.[35] To produce columns (3) and (4) I follow Aichele and Felbermayr (2015) and exclude pairs with null Kyoto commitment differentials (e.g. both exporter and importer having QERLCs as well as both exporter and importer not having QERLCs)[36]. Finally, in column (5) the United States is assigned to the group of QERLCs adopters with a hypothetical treatment year of 2002. In all three cases, the estimates confirm the benchmark results and cast away any concerns related with QERLCs being adopted overwhelmingly by developed rather than developing parties.

4.4 Empirics: Timing Effects

4.4.1 Empirical Specification and Discussion

The estimates shown in column (1) of tables 4.6 and 4.7 imply that exports of Kyoto committed parties may have increased post-2008. In order to assess the yearly effects of the differential Kyoto commitment from their sample averages the empirical specification in (4.4) is employed. Here, $dKyoto_{x,m,t+k}$ denotes the interaction terms between the Kyoto commitment differential and the binary indicators for each of the eleven post-ratification years. Thus, β_{t+k} denotes the additional differential commitment effect which prevails k years after ratification. With the exception of the summation term all else is similar to (4.2). The ratification of Kyoto protocol, by parties which adopted QERLCs, was started in 2001 by Romania and Czech Republic[37]. Given the time span of the dataset, the post-ratification period comprises eleven years. The error term is similar to the one depicted in (4.3), and is shown in

[35] These are Argentina, Bahrain, Chile, Cyprus, Hong Kong, Israel, South Korea, Kuwait, Macau, Malaysia, Oman, Qatar, Saudi Arabia, Singapore, Taiwan.

[36] This way I only observe the committed parties trading with all other nations in the sample except with other committed parties; and the United States (or the group of developed countries) trading with all other nations included. This exercise does not restrict the sample to include only committed parties and the United States (or the group of developed countries).

[37] Refer to table 4.2 for details.

(4.5).

$$lnCCX_{x,m,s,t} = \sum_{k=0}^{11} \beta_{t+k} dKyoto_{x,m,t+k} + \delta' TA_{x,m,t} + \mu'_{x,m,s,t} \tag{4.4}$$

$$\begin{aligned} \mu'_{x,m,s,t} &= \nu'_{x,m,t} + \nu'_{x,m,s} + \nu'_{s,t} \\ \nu'_{x,m,t} &= \nu'_{m,x,t} \end{aligned} \tag{4.5}$$

4.4.2 Results

The results obtained by estimating (4.4) are shown in table 4.8. As noted before, column (1) displays the results recovered with export flows as the dependent variable. In column (2), the CO_2 intensity of exports is used. Estimates in column (3) refer to the carbon terms of trade while those in column (4) pertain the carbon content of exports. I start by addressing the estimates in the first column. The marginal effects implied are plotted in figure 4.6. From here, one can notice that outflows of Kyoto committed exporters decline in the first three years after ratification by 2.7%, 4.1%, and 1.2%, respectively. Starting in 2004, the exports of committed parties increase at an average of 5.4% per year. The gains are more pronounced towards the end of the first commitment period. This result may give itself to an adjustment process which is experienced initially by both "clean" and "dirty" industries. Recall, that parties which took on QERLCs under the Kyoto protocol enacted relatively more climate change policies. In turn, these policies may have impacted production regardless of its CO_2 intensity. A short-run[38] decline in exports is, nevertheless, expected as industrial branches are interconnected through upstream and downstream linkages[39]. For instance, climate change policies are likely to increase energy prices. Energy production is notoriously CO_2-intensive as it relies heavily on the burning of fossil fuels. Additionally, climate change policies are also bound to alter the shipment of intermediate inputs due to higher fuel prices brought about by, for example, more stringent fuel or emissions standards. The inelastic nature of energy demand may also exacerbate the short-run decline. In the long run, however, exports are expected to recover once the adjustment to the post-Kyoto environmental regime is completed. For committed Kyoto parties, the adjustment to the new environmental regime may also entail a shift towards a less CO_2-intensive export bundle as "clean" sectors gain at the expense of their "dirty" peers; which are impacted relatively more by environmental policies enacted after ratification. Thus, the post-Kyoto export expansion path is expected to be driven by two types of dynamics. First, the CO_2-intensive industries adjust gradually to a new equilibrium characterized by relatively low production and exports. Second, less CO_2-intensive production and exports expand as more factors, previously tied to "dirty" industries, are being employed within these sectors.

[38] Unless otherwise notified, the term short run denotes the five year post-ratification period.

[39] Refer to footnote 17 for a supplementary argument in this regard.

The results recovered by estimating (4.4) while using the CO_2 intensity of exports as the dependent variable are presented in column (2). The marginal effects obtained using these results are plotted in figure 4.7. As expected, the CO_2 intensity of exports that originate within committed jurisdictions declines. This finding is in line with Aichele and Felbermayr (2012, 2015); Grunewald and Martínez-Zarzoso (2011). Even more, the CO_2 intensity of exports diminishes persistently throughout the entire post-ratification period. This way, eleven years after the protocol was first ratified the effect on CO_2 intensity of exports is roughly -18%. This finding is supported by the estimates presented in column (3). Here, the dependent variable is the carbon terms of trade. Negative coefficients are indicative of a decline in the export to import carbon content ratio. In other words, relative to imports, the exports of parties which adopted QERLCs under the protocol become "cleaner". This set of results line up once more with the three studies mentioned earlier. In addition, the estimates displayed in column (3) are also consistent with Hertwich and Peters (2008b) and Nakano et al. (2009) who find that parties which adopted QERLCs display a carbon trade deficit around the early 2000s; when most committed countries ratified the agreement.

The results in column (4) refer to the carbon content of exports. To aid the discussion, the yearly effects of Kyoto commitment differential are plotted in figure 4.8. From here, two aspects become apparent. First, the CO_2 content of exports declines sharply immediately after ratification due to the sizable and negative technique effect. Second, this dynamic persists until 2006 after which the differential commitment effect diminishes in magnitude. To a large extent, this lower effect is induced by the positive scale effect (i.e., an improvement in exports). Note that the technique effect is relatively stable post-2006. Despite the latter decline, the differential commitment effect on the CO_2 content of exports for 2012 stands at a significant -8.3%. These two developments can be observed in figure 4.9 which showcases the scale and technique effects of ratification together with the differential Kyoto commitment impact on the carbon content of exports.

The deleterious effect of QERLC adoption on the CO_2 intensity of exports is intuitive. This may be driven, for example, by more efficient production processes or efficiency standards for fuels and industrial equipment that were introduced as part of the climate reform enacted after ratification. However, the post-Kyoto export adjustment may not be as customary. The first paragraph notes that the scale effect may be driven by two types of developments. On one hand, for CO_2-intensive sectors, the post-ratification period is characterized by relatively low exports. On the other hand, for the less CO_2-intensive industries exports decline in the short run but expand relatively more in the long run; as more factors, previously tied to "dirty" industries, are being employed within these sectors. The estimates presented in table 4.9 underline exactly this type of adjustment[40]. Column (1) presents the differential commitment effect by taking into account the sector-specific CO_2 intensity. According to the estimates, the Kyoto ratification effect on sectoral exports is a function on their respective CO_2 intensity. For example, exports of petroleum, chemicals, and

[40]Estimations in column (1) are carried out using an empirical specification similar to (4.2). In

non-metallic mineral products, the most CO_2-intensive industry in the sample, decrease on average by 2.6% due to the adoption of QERLCs. At the other end of the spectrum, outflows from the agricultural and fishing sector increase by about 8%. Column (2) presents the associated year-by-year analysis. The timing effects of the differential commitment are plotted in figure 4.10[41] and stress a recovery of exports for parties which adopted QERLCs under the Kyoto protocol. In addition, exports from less CO_2-intensive sectors (e.g., agriculture and fishing) seem to start increasing in the third post-ratification year. Outflows from more CO_2-intensive industries (e.g., petroleum, chemicals, and non-metallic minerals) resume growth six years after ratification. On this subject, the 2008-2012 upturn in exports seems to be driven by an expansion of exports from "clean" and "dirty" industries alike. However, the export growth is larger for the former category.

To summarize, due to ratification, Kyoto committed parties are experiencing an initial decrease in exports. But, exports seem to recover in as little as three years after ratification. On a different note, the CO_2 intensity of exports declines immediately after ratification. This dynamic persists throughout the post-ratification period. Due to QERLCs adoption, the CO_2 content of exports declines, up until 2006. This is mainly due to a large and negative technique effect. After 2006, however, the Kyoto ratification implies an increase in the carbon content of exports. This hike seems to be driven by a recovery of exports. The last set of findings caters directly towards the discussion surrounding international environmental agreements (IEAs) and their detrimental effects on export competitiveness. Explicitly, outflows from less CO_2-intensive sectors are found to recover faster (i.e., 3 years) in comparison to their more polluting peers (i.e., 5 years). These results suggest that the adverse effects on export competitiveness induced by the Kyoto protocol are rather short lived. Overall, the ratification of an IEA such as the Kyoto protocol leads to lower CO_2 emission intensity of exports, lower carbon content of exports, but higher exports.

4.5 Empirics: Kyoto Ratification and Heterogeneous QERLCs

4.5.1 Empirical Specification and Discussion

The results presented in sections 4.3.3 and 4.4.2 emphasize the importance of taking on QERLCs under the Kyoto protocol. In sum, adopting such commitments appears to have increased exports and lowered the CO_2 intensity of exports. The combined result of these two dynamics is the reduction in the carbon content of sectoral exports. Further, the adoption of QERLCs also seems to entail a compositional shift towards cleaner exports. However, the type of QERLCs selected as part of the protocol are heterogeneous. For example, Germany agreed to an individual commit-

addition it includes exporter's sectoral CO_2 intensity and its interaction with the Kyoto commitment differential. The estimates in column (2) are produced using a specification similar to (4.4). In addition, this specification includes exporter's sectoral CO_2 intensity and its interaction with the Kyoto commitment differential and year-specific binary indicators.

[41]The effects are calculated using year, sector, and differential commitment-specific average CO_2

ment of -21% while France and Portugal opted for 0% and +27%, respectively[42]. This particular feature begs the question of whether the degree of adjustment to the post-Kyoto environmental regime depends on the QERLC type adopted. Specifically, are exports, the CO_2 intensity of exports, and the carbon content of exports impacted differently for parties which pledged to emission cutbacks as opposed to their less committed peers (i.e., which opted for controlled increases, or no changes at all)? The analysis of heterogeneous QERLCs gains in importance as the Doha amendment is expected to enter into force in the near future.[43] Once in force, new QERLCs will become legally binding for the 2013-2020 period.[44]

The empirical specification used to estimate the heterogeneous QERLC effect is shown in (4.6). The structure of the error term is outlined in (4.7). With the exception of the covariates of interest, the econometric details discussed within section 4.3.1 apply here as well. The focus is placed on $rdKyoto_{x,m,t}$ and $adKyoto_{x,m,t}$. First, $rdKyoto_{x,m,t}$ takes a value of 1 (and -1) if the exporter (importer), but not the importer (exporter), ratified the Kyoto protocol. If none or both countries ratified, the differential is null. Hence, $rdKyoto_{x,m,t} \in \{1, 0, -1\}$. This is further referred to as the ratification differential. Second, $adKyoto_{x,m,t}$ is constructed as the difference between the exporter's and importer's degrees of commitment to the Kyoto protocol (i.e., ζ_x and ζ_m). For the exporter ζ_x is defined as in (4.8). According to columns (1) and (2) of table 4.2, Germany represents the type of exporter for which ζ_x=2. Portugal or New Zealand represent exporters for which ζ_x=1. For non-listed exporters ζ_x=0. The same logic is applied for the importer and its degree of commitment, ζ_m. Hence, $adKyoto_{x,m,t} \in \{2, 1, 0, -1, -2\}$.

$$lnCCX_{x,m,s,t} = \alpha'' rdKyoto_{x,m,t} + \beta'' adKyoto_{x,m,t} + \delta'' TA_{x,m,t} + \mu''_{x,m,s,t} \tag{4.6}$$

$$\begin{aligned} \mu''_{x,m,s,t} &= \nu''_{x,m,t} + \nu''_{x,m,s} + \nu''_{s,t} \\ \nu''_{x,m,t} &= \nu''_{m,x,t} \end{aligned} \tag{4.7}$$

$$\zeta_x = \begin{cases} 0, & \text{if no QERLC by the exporter} \\ 1, & \text{if QERLC}_x \geq 0\% \\ 2, & \text{if QERLC}_x < 0\% \end{cases} \tag{4.8}$$

This discrete methodology of capturing the heterogeneous effects on QERLCs may have its drawbacks. For example, it implies that the effect of Kyoto ratification on an

intensities.

[42]Refer to table 4.2 for a list of party-by-party commitments.

[43]According to the amendment text, entry into force is governed by articles 20 and 21 of the Kyoto protocol. In sum, the Doha addendum enters into force on the ninetieth day after the receipt of instruments of acceptance by at least 75% (144) of the parties to the Kyoto protocol. According to UNFCCC, as of June 2016 65 parties have deposited their instrument of acceptance.

[44]The QERLCs assigned as part of the Doha amendment range from -20% for Denmark to +20%

exporter-importer pair with $\zeta_x = 2$ and $\zeta_m = 0$ doubles that for a pair characterized by $\zeta_x = 2$ and $\zeta_m = 1$. Nevertheless, this differential approach of analyzing the Kyoto ratification makes possible the inclusion of symmetric time-varying pair effects. In turn, this strategy addresses three important issues: *(i)* the non-random selection into the Kyoto protocol, *(ii)* the non-random selection of QERLCs, and *(iii)* other unobserved factors that might influence the outcomes of interest. Based on the premise that exporters which ratified the protocol by taking on negative QERLCs (i.e., ζ_x=2) are likely to enact more and stricter climate change policies, β'' is expected to be negative. Further, the sign attached to α'' is ambiguous. This is because less committed parties are equally likely to reach lower or higher levels of CO_2 emissions embodied in exports in comparison to parties which opted for non-negative QERLCs.

4.5.2 Results

The results obtained by estimating (4.6) are shown in table 4.10. As customary, column (1) displays the results obtained by treating export flows as the dependent variable. In column (2), the CO_2 intensity of exports is used as the outcome of interest. Estimates in column (3) pertain to the carbon terms of trade. Finally, the figures in column (4) apply to the carbon content of exports. Based on the commitment differentials' values, five relevant outcomes are emerging.[45] The first three involve the exporter as a Kyoto ratifier and the importer as a non-ratifier (i.e., $rdKyoto = 1$ and $adKyoto \in \{2, 1, 0\}$). The last two are given by both the exporter and the importer as Kyoto ratifiers (i.e., $rdKyoto = 0$ and $adKyoto \in \{2, 1\}$). For the sake of brevity, I discuss only the first three.

Rather than presenting each column in part, I proceed by discussing each of the three outcomes outlined earlier using the figures in panel A. First, if the exporter ratifies the protocol without taking on any commitments its exports towards non-ratifiers decline by 5%. Meanwhile, the carbon intensity and, implicitly, the carbon content of exports increase by 21.3% and 16%, respectively. It is worth pointing out that towards the end of the sample period (i.e., 2009-2012) the only non-ratifiers observed are Hong Kong, Macau, Taiwan, and the United States of America. Second, the adoption of a non-negative QERLC by exporter entails a -0.8% decline in export flows, -1.6% decline in the CO_2 intensity of exports, and a combined 2% decline in the carbon content of exports. Third, the adoption of a negative QERLC by the origin country implies a 3.5% increase in exports, 20% decline in the carbon intensity of exports, and 17.4% drop in the carbon content of exports. One may reasonably argue that the results in panel A are driven by the EITs which, with the exception of Russia and Ukraine, are also part of the group of parties which opted for emission reductions as part of the protocol. The estimates in panel B are aimed exactly at this issue. Although lower, the results further bolster the hypothesis according to which

for Bulgaria.

[45]Technically there are fifteen possible outcomes but there is little value in analyzing all of them. Among the remaining ten, six are mutually exclusive and one denotes the case in which both differentials are null. The remaining combinations are mirroring three of the five relevant outcomes.

emission reduction commitments entail larger declines in the CO_2 intensity of exports and their carbon content.

Despite the multitude of possible outcomes one aspect is clear. That is, the type of QERLC adopted as part of the Kyoto protocol matters. Specifically, taking on negative QERLCs (i.e., aim to reduce emissions) as opposed to non-negative ones or no QERLC at all involves higher exports, a lower CO_2 intensity of exports, and a lower carbon content of exports. The potential factors influencing the scale and technique effects, and therefore the carbon content of exports, were addressed within the previous two sections.

4.6 Empirics: Transition Countries

4.6.1 Empirical Specification and Discussion

Parties with QERLCs under the Kyoto protocol do not differ only in their commitment type but also in their CO_2 emissions growth prospects. Specifically, the economies in transition (EITs)[46] experienced an unraveling of their industrial assemblage which significantly curbed their CO_2 emitting capacity after 1990. Within this context, the QERLCs adopted by the EITs are believed to be rather loose (Grubb, 2003). In turn, this feature spawned early concerns surrounding the EITs's incentives of engaging in climate change reform. This next section is aimed at better understanding the extent to which the Kyoto EITs altered the carbon content of their exports as a result of Kyoto adoption.

The differential commitment effect on the carbon content of outflows for EITs estimated by employing specification (4.9). For reasons already addressed in earlier sections, the error term is modeled as in (4.10). With the exception of including the interaction term, $dKyoto_{x,m,t} \times \tau_x$, the discussion in section 4.3.1 applies here as well. τ_x represents a binary indicator of whether the exporter is part of the EITs group. Since $dKyoto_{x,m,t}$ is defined as in 4.3.1[47], β''' is expected to be negative and of comparable magnitude with the benchmark estimates presented in table 4.7. If the post-1990 industrial restructuring within the EITs entailed a less CO_2-intensive production network, or if the EITs' climate change policies were more successful at lowering the CO_2 intensity of exports, γ''' is expected to carry a negative sign. Only if the EITs failed to engage in post-Kyoto environmental reform or if the proposed policies were lenient and/or not properly enforced, γ''' should be positive and larger in absolute value when compared to β'''.

$$lnCCX_{x,m,s,t} = \beta''' dKyoto_{x,m,t} + \gamma''' dKyoto_{x,m,t} \times \tau_x + \delta''' TA_{x,m,t} + \mu'''_{x,m,s,t} \quad (4.9)$$

[46]Refer to table 4.2 for details.

[47]This is given by the difference between the exporter and importer-specific Kyoto QERLC status. $dKyoto_{x,m,t} \in \{1, 0, -1\}$.

$$\begin{aligned}\mu'''_{x,m,s,t} &= \nu'''_{x,m,t} + \nu'''_{x,m,s} + \nu'''_{s,t} \\ \nu'''_{x,m,t} &= \nu'''_{m,x,t}\end{aligned} \tag{4.10}$$

4.6.2 Results

The results obtained by estimating (4.9) are shown in table 4.11. Column (1) presents the differential Kyoto commitment effect on exports by Annex II and EIT membership status[48]. The estimates in column (2) pertain the CO_2 intensity of exports, column (3) refers to the carbon terms of trade, and the figures in column (4) are for the carbon content of exports. The results concerning Annex II countries, are in line with expectations and not much different than the benchmark results presented in Panel B of table 4.7. Specifically, exports of Annex II parties are increasing by about 6.5% while the CO_2 emission intensity of their exports decline by approximately 15.5%. Regarding the CO_2 content of exports, the negative and relatively large technique effect implies a differential commitment effect of approximately -8.5%.

In terms of sign, the results regarding the differential commitment effect for the EITs line up with prior prospects. Magnitude-wise, however, they are considerably larger. Due to ratification, EITs' exports increase by 3.5% while the CO_2 intensity of their exports is found to decrease by approximately 37%. Together these scale and technique effects imply a reduction in the EITs' carbon content of exports that situates at about 35%. These results too, suggest a move towards less CO_2-intensive exports and are once again supported by the estimates shown in column (3). However, while bearing the expected signs the technique effect and therefore the impact on the carbon content of exports seem large. It is difficult to provide a comprehensive explanation for why such a substantial effect prevails. Nevertheless, an attempt is made in what follows.

Besides their CO_2 emissions growth prospects, Annex II parties and the EITs also differ in their factor endowments. Support for this claim may be found in figure 4.5. This depicts the EITs as being capital scarce but labor abundant in comparison to their Annex II peers. These differences may be important since CO_2-intensive industries tend to be capital intensive (e.g., basic metals, petroleum, chemical, and non-metallic mineral products) (Broner et al., 2012; Antweiler et al., 1998; Mani and Wheeler, 1998; Grether and De Melo, 2003; Karp, 2011). It is therefore possible that the wedge between the Annex II parties and the EITs (involving the effect of Kyoto ratification on the CO_2 intensity of exports and the carbon content of exports) is driven by a two-pronged compositional effect. First, less CO_2-intensive industries gain at the expense of their more polluting counterparts as a result of climate change policies enacted post-Kyoto. Second, most CO_2-intensive sectors within the EITs may shrink even further due to competitive pressures set in motion by the trade liberaliza-

[48] Recall that Annex I includes of Annex II and EIT parties. Both of these groups adopted QERLCs as part of the Kyoto protocol.

tion process pre-dating the 2004 and 2007 European Union Eastern Enlargements[49]. CO_2-intensive sectors may also contract due to a relocation of these capital-intensive industries within relatively capital-abundant jurisdictions. These sector-level, Melitz and Krugman-type of adjustments may complement post-Kyoto climate change policies underwritten by the EITs in further expanding the share of less CO_2-intensive sectors in total exports[50]. In turn, these dynamics would entail a lower CO_2 intensity and carbon content of export flows. The relatively large effects characterizing the EITs also find empirical support in table 4.12. From here one can observe that the differential ratification effect on the CO_2 intensity of exports and the carbon content of exports tends to be larger for exporters with lower capital to labor ratios (e.g., the EITs). Note that the introduction of the capital-to-labor interaction term entails a decline in the effect that is initially attributed to being part of the EIT group. Evaluated at the mean, the wedges between the differential commitment effects on the CO_2 intensity and the carbon content of exports are of approximately 5 percentage points in each case. These disparities are obtained by comparing the EITs' differential commitment effects depicted within tables 4.11 and 4.12. This last set of findings suggests that factor endowments may play an important role in how sectors adjust to more stringent climate change reform.

4.7 Conclusions

An important number of studies have pointed at the growing emissions embodied in international trade flows. By taking into account the increased availability of input-output data, and in particular the relatively new EORA26 dataset, the current study adds to the literature strand concerning the Kyoto protocol and the carbon content of bilateral trade in three major ways. First, this paper broadens the reach of Aichele and Felbermayr (2015) by making use of a novel dataset which encompasses 149 nations, observed between 1995 and 2012. The 2008-2012 period is important in its own right since sector-level exports seem to decline shortly after ratification but recover in the long run. Leaving out this time frame may lead to erroneous conclusions about the competitiveness effects engendered by the adoption of Kyoto protocol. In doing so, I find that exports of Kyoto committed parties increase by about 6%. The estimates recovered by leaving out the above time window situate at about 0.5%. Furthermore, the CO_2 intensity of exports declines by approximately 18.5% whereas the carbon content of exports decreases by 14%. This last set of results confirms to some extent the findings of Aichele and Felbermayr (2015). However, the differential Kyoto commitment effect on the CO_2 intensity of exports and the carbon content of exports are found to be significantly larger. Additionally, in contrast to their study

[49] With the exception of Croatia, Russia, and Ukraine, all EITs joined the EU in 2004 and 2007. Croatia joined the EU in 2013.

[50] Melitz (2003) advances the idea that only the most productive firms export. Meanwhile the least productive firms are pushed out of the market. Here, this idea is envisioned at the industry-level. Hence only the most productive sectors survive once trade barriers are lowered. This is because capital-intensive industries are expected to be more productive within relatively capital abundant

the current analysis brings forward a positive ratification effect on exports.

Second, this essay deploys a year-by-year analysis to scrutinize any short-run and long-run adjustments that occur post-ratification. While exports are estimated to decline during the 2001-2003 period, they are also found to rebound thereafter. Along this margin, the loss of competitiveness attributable to the Kyoto protocol is rather short-lived. Exports seem to recover in as little as three years for less CO_2-intensive sectors (e.g., agriculture and fishing) and as much as six for the most CO_2-intensive (e.g., petroleum, chemicals, and non-metallic minerals). In this regard, the current essay adds to the burgeoning literature on international environmental agreements (IEAs) and their competitiveness effects. Furthermore, the CO_2 intensity of exports is found to decrease in every year after Kyoto ratification. The effect on the carbon content of exports follows a similar dynamic path. For the eleventh post-ratification year (i.e., the last year in the sample) the Kyoto ratification effect on these two outcomes is estimated at -18% and -8.4%, respectively. This development underlines a compositional shift in exports or an export "clean-up" effect that is brought about by taking on quantitative emission reduction or limitation commitments (QERLCs) under the Kyoto protocol.

Third, this essay also evaluates the heterogeneous nature of the QERLCs adopted under the protocol; and if the parties which are transitioning towards a market economy are impacted differently. By analyzing at the type of QERLCs I find that the ratification effects are stronger for parties which pledged to reduce emissions. For this particular group, the ratification effect on the carbon content of exports is estimated at about -17.4%. Meanwhile, exporters which pledged to limited increases or no emission changes see their carbon content of outflows reduced by about 2% due to ratification. In line with the previous set of results, I also find that the Eastern European transition economies (EITs) reduced both the CO_2 intensity and the carbon content of their exports by 37% and 35%, respectively.

In summary, due to the Kyoto ratification, parties with QERLCs are characterized by lower emissions embodied in exports. In addition, these effects are found to be stronger for parties that opted for reduction commitments. Unfortunately, these results also imply that the average party, with no commitments under the protocol, is characterized by increases in its carbon content of exports. In addition, the results are consistent with an increase in the carbon content of imports for committed parties. The large carbon "leakage" effects implied by adopting Kyoto QELRCs should be worrisome as climate change efforts seem to be undermined by international trade. Any reduction in CO_2 emissions achieved within the developed world (i.e., jurisdictions with QERLCs under Kyoto protocol) is bound to be offset by an increase in emissions within the developing nations (i.e., jurisdictions with no commitments under Kyoto protocol). Answers on how to address "leakage" effects should be perhaps sought within the Montreal protocol to the Vienna Convention for the Protection of the Ozone Layer (and its subsequent amendments). These IEAs include special provisions regarding international trade that, so far, seem to have been successful at

jurisdictions. Krugman (1993); Krugman and Venables (1996) discuss sectoral agglomeration and preventing "leakage". The results brought forward by the current essay further gain in their importance as new QERLCs will become binding for the 2013-2020 period, as part of Doha amendment to the Kyoto protocol.

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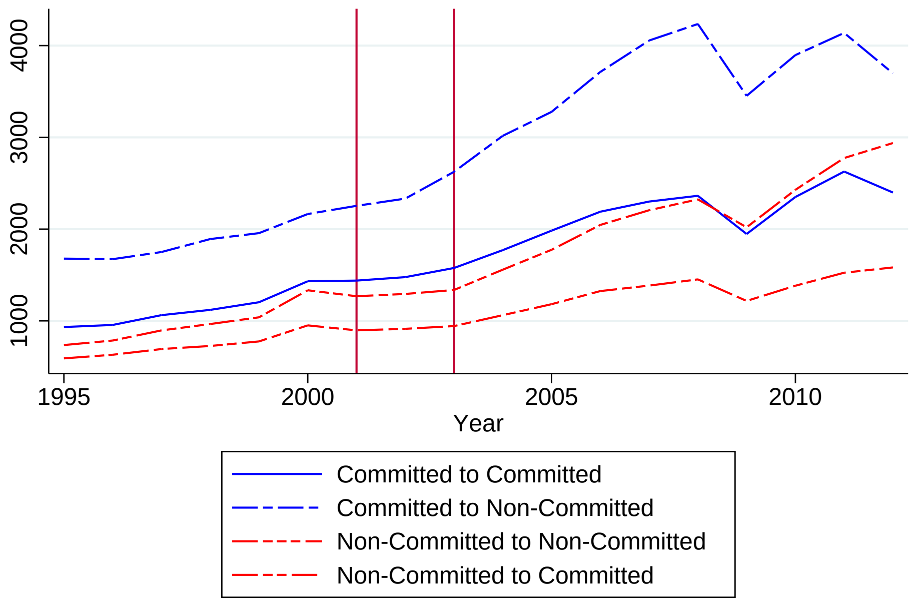
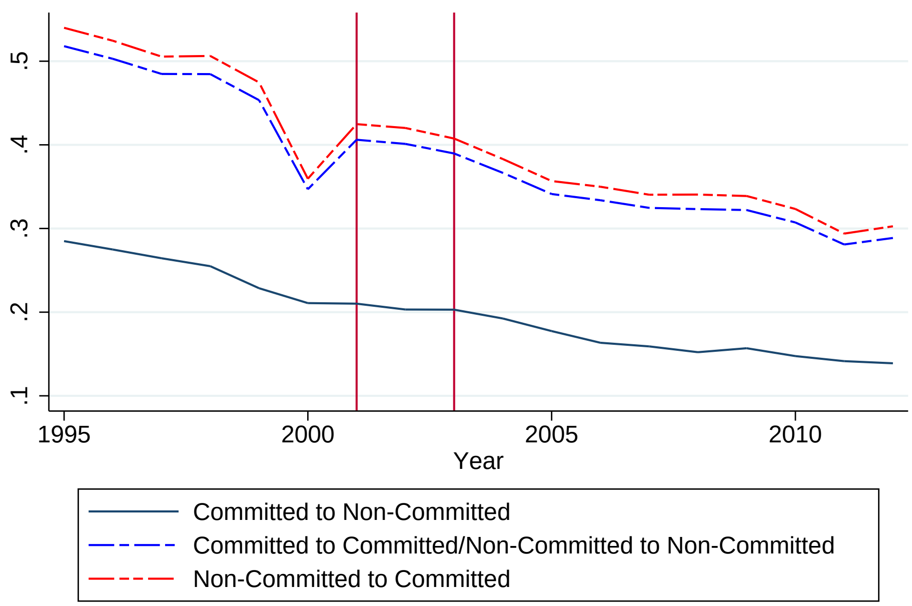
the relocation of industries in the presence of increased trade integration.

Figure 4.1: Exports by Differential Kyoto Commitment



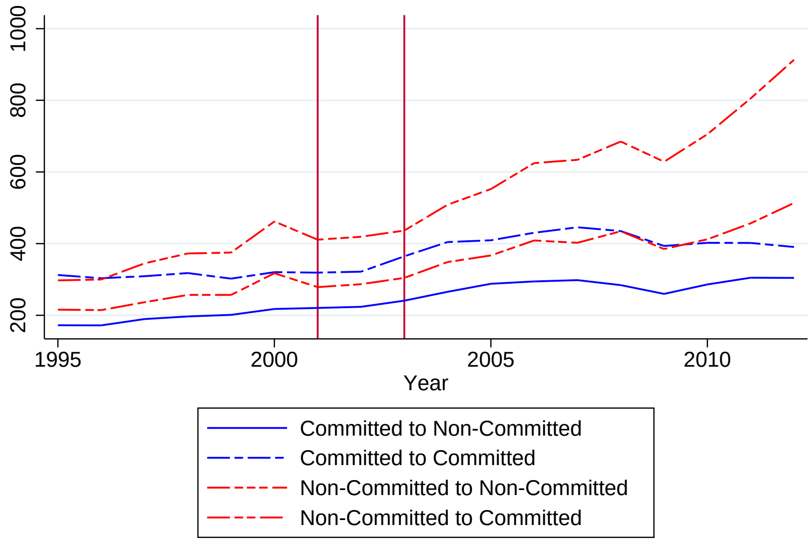
Total exports in billions of USD at 2005 prices. The vertical lines indicate the time period in which most countries have ratified the protocol with a binding emission cap.

Figure 4.2: CO2 Intensity of Exports by Differential Kyoto Commitment



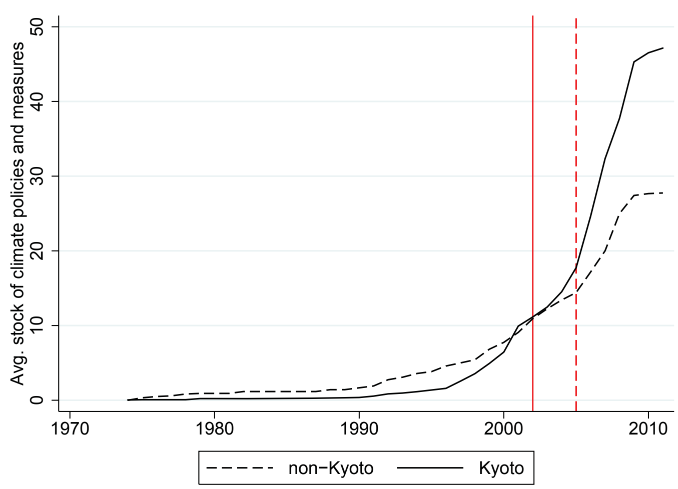
CO2 emission intensity of exports in kilograms per dollar of output at 2005 prices. The vertical lines indicate the time period in which most countries have ratified the protocol with a binding emission cap.

Figure 4.3: CO2 Content of Exports by Differential Kyoto Commitment



CO2 content of exports in 1000s of gigagrams (kilotonnes). The vertical lines indicate the time period in which most countries have ratified the protocol with a binding emission cap.

Figure 4.4: Stock of Climate Change Policies by Kyoto Commitment; Source: Aichele and Felbermayr (2015)



Note: The graph shows the average stock of climate policies and measures for Kyoto (solid line) and non-Kyoto (dashed line) countries from 1974-2011. Data is obtained from the IEA Policies and Measures: Addressing Climate Change database. The red solid line signifies the date of Kyoto ratification for most Kyoto countries. The red dashed line marks the entry into force of the Kyoto Protocol.

Figure 4.5: Average Capital to Labor Ratios by EIT/Annex I Status

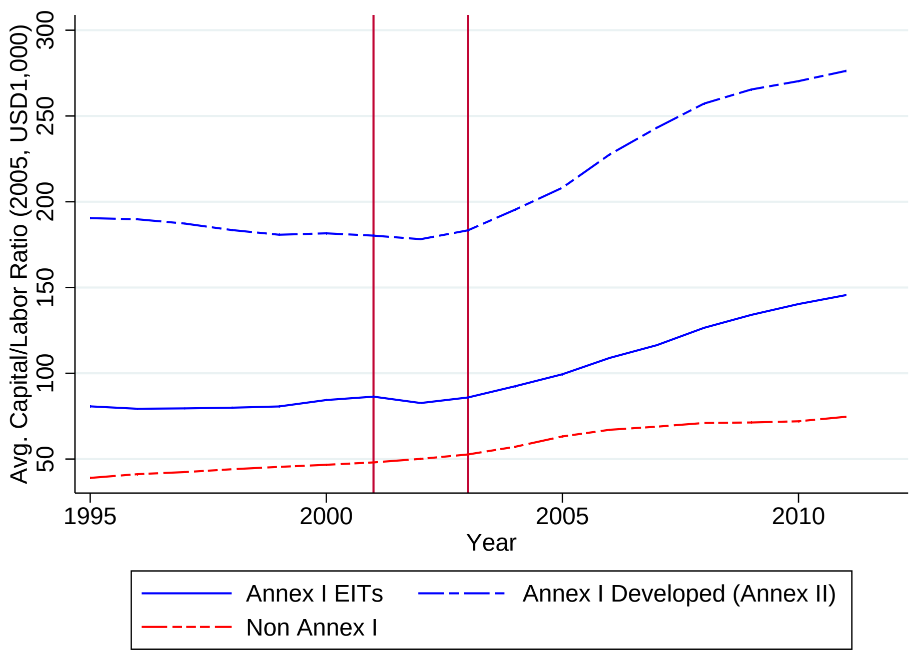


Table 4.1: Exporters and Importers

Country		
Albania	Gabon	Niger
Angola	Gambia	Nigeria
Antigua and Barbuda	Georgia	Norway*
Argentina*	Germany*	Oman
Armenia	Ghana	Pakistan
Australia*	Greece*	Panama
Austria*	Guatemala	Paraguay
Azerbaijan	Guinea	Peru
Bahamas	Honduras	Philippines
Bahrain	Hong Kong	Poland*
Bangladesh	Hungary*	Portugal*
Barbados	Iceland	Qatar
Belgium*	India*	Romania*
Belize	Indonesia*	Russian Federation*
Benin	Iran	Rwanda
Bermuda	Ireland*	Sao Tome and Principe
Bhutan	Israel*	Saudi Arabia
Bolivia	Italy*	Senegal
Bosnia and Herzegovina	Jamaica	Sierra Leone
Botswana	Japan*	Singapore
Brazil*	Jordan	Slovakia*
Brunei Darussalam	Kazakhstan	Slovenia*
Bulgaria	Kenya	South Africa*
Burkina Faso	Korea*	Spain*
Burundi	Kuwait	Sri Lanka
Cambodia	Lao People's Democratic Republic	Sudan
Cameroon	Latvia	Suriname
Canada*	Lebanon	Swaziland
Cape Verde	Lesotho	Sweden*
Central African Republic	Liberia	Switzerland*
Chad	Lithuania	Syrian Arab Republic
Chile*	Luxembourg	Taiwan
China*	Macau	Tajikistan
Colombia	Macedonia (the former Yugoslav Rep. of)	Tanzania, United Rep. of
Congo	Madagascar	Thailand
Costa Rica	Malawi	Togo
Croatia	Malaysia	Tunisia
Cyprus	Maldives	Turkey*
Czech Republic*	Mali	Turkmenistan
Cote d'Ivoire	Malta	Uganda
Denmark*	Mauritania	Ukraine
Djibouti	Mauritius	United Kingdom*
Dominican Republic	Mexico*	United States of America*
Ecuador	Mongolia	Uruguay
Egypt	Morocco	Uzbekistan
El Salvador	Mozambique	Venezuela
Estonia*	Namibia	Viet Nam
Fiji	Nepal	Yemen
Finland*	Netherlands*	Zambia
France*	New Zealand*	

All countries appear as both exporters and importers. Starred nations are included in in Aichele and Felbermayr (2015).

Table 4.2: UN Framework Convention on Climate Change: Status of Parties

Country Code	*Country Name*	*QELRC (%) Kyoto*	*QELRC (%) Kyoto EU*[c]	*Kyoto Ratif. Year*	*QELRC (%) Doha*	*QELRC (%) Doha EU*[e]
AUS	Australia[a]	8		2007	-0.5	
AUT	Austria[a]	-8	-13	2002	-20[d]	-16
BEL	Belgium[a]	-8	-7.5	2002	-20[d]	-15
BGR	Bulgaria[b]	-8		2002	-20[d]	20
CAN	Canada[a]	-6		2002		
HRV	Croatia[b]	-5		2007	-20[d]	
CYP	Cyprus				-20[d]	-5
CZE	Czech Republic[b]	-8		2001	-20[d]	9
DNK	Denmark[a]	-8	-21	2002	-20[d]	-20
EST	Estonia[b]	-8		2002	-20[d]	11
FIN	Finland[a]	-8	0	2002	-20[d]	-16
FRA	France[a]	-8	0	2002	-20[d]	-14
DEU	Germany[a]	-8	-21	2002	-20[d]	-14
GRC	Greece[a]	-8	25	2002	-20[d]	-4
HUN	Hungary[b]	-6		2002	-20[d]	10
ISL	Iceland[a]	10		2002	-20[d]	
IRL	Ireland[a]	-8	13	2002	-20[d]	-20
ITA	Italy[a]	-8	-6.5	2002	-20[d]	-13
JPN	Japan[a]	-6		2002		
LVA	Latvia[b]	-8		2002	-20[d]	17
LTU	Lithuania[b]	-8		2003	-20[d]	15
LUX	Luxembourg[a]	-8	-28	2002	-20[d]	-20
MLT	Malta				-20[d]	5
NLD	Netherlands[a]	-8	-6	2002	-20[d]	-16
NZL	New Zealand[a]	0		2002	0	
NOR	Norway[a]	1		2002	-16	
POL	Poland[b]	-6		2002	-20[d]	14
PRT	Portugal[a]	-8	27	2002	-20[d]	1
ROU	Romania[b]	-8		2001	-20[d]	19
RUS	Russia[b]	0		2004		
SVK	Slovakia[b]	-8		2002	-20[d]	13
SVN	Slovenia[b]	-8		2002	-20[d]	4
ESP	Spain[a]	-8	15	2002	-20[d]	-10
SWE	Sweden[a]	-8	4	2002	-20[d]	-17
CHE	Switzerland[a]	-8		2003	-15.8	
TUR	Turkey					
UKR	Ukraine[b]	0		2004	-24	
GBR	United Kingdom[a]	-8	-12.5	2002	-20[d]	-16
USA	United States[a]	-7				

All parties are in Annex I. This also includes the European Union (EU). Slovakia and Slovenia were added in 1998. Malta and Cyprus were added in 2009 and 2013. Liechtenstein and Monaco took QELRCs for 2008-2012 but are not in the sample. [a]Annex II members. [b]Parties transitioning to a market economy in 1992 (EITs). [c]Individual targets of EU15 members; EU15 agreed to an 8% overall reduction. In most cases 2008-2012 targets are relative to 1990 levels. [d]To be fulfilled as part of (or jointly with) the EU. [e]Individual targets for EU27 members relative to 2005; EU27 agreed to a 20% overall reduction relative to 1990. Under the Doha amendment, Belarus and Kazakhstan adopted a -5% and -12% QELRC, respectively.

Table 4.3: Industry Classification

Industry Code	*Industry Description*
1	Agriculture and Fishing
3	Basic Metals
6	Transport Equipment
7	Electrical and Machinery
8	Food and Beverages
11	Textiles and Wearing Apparel
12	Other Manufacturing
45	Petroleum, Chemical and Non-Metallic Mineral Products
910	Wood and Paper

The table displays an industry's code and its description. The Electricity, Gas, Water Supply, Mining and Quarrying industry along with the non-traded sectors Construction (13), Transport (14), and Other Services (15) are not included in the analysis and therefore not shown in the table.

Table 4.4: Summary Statistics

	Obs.	Mean	S.D.	Min	Max
Econ. Integration	3,572,424.00	0.52	1.15	0.00	6.00
Exp. in Transition	3,572,424.00	0.09	0.28	0.00	1.00
Exp. Kyoto w/ Cap	3,572,424.00	0.14	0.35	0.00	1.00
Exp. Kyoto w/ Cap (+,/,-)	3,572,424.00	0.78	0.90	0.00	3.00
Exports (USD mil.)	3,572,424.00	40.30	678.89	0.00	163,093.05
CO2 in Exports (kg./USD)	3,480,368.00	0.34	0.63	0.00	14.44
CO2 Exports (kt.)	3,437,802.00	7.79	165.82	0.00	44,435.11
Exp. K/L (1,000USD/Worker)	3,360,636.00	83.08	86.20	1.39	439.44
Exp. Years of Schooling	2,875,788.00	7.73	2.74	0.92	13.09
Exp. Pers. Engaged (mil.)	3,360,636.00	17.58	70.85	0.03	784.43

Table 4.5: Summary Statistics by Kyoto Commitment Differential

	Differential Kyoto Commitment (Kyoto Exp.-Kyoto Imp.)					
	1: Only Exporter		0: None		-1: Only Importer	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.
Agriculture and Fishing						
Exports	12.93	244.63	11.03	125.77	19.96	172.05
CO2 Intensity	0.06	0.06	0.21	0.28	0.17	0.19
CO2 Exports	1.03	26.64	1.00	11.79	2.01	13.73
Basic Metals						
Exports	61.97	650.02	31.33	413.16	31.09	330.88
CO2 Intensity	0.21	0.37	0.40	0.66	0.32	0.53
CO2 Exports	7.22	84.64	5.76	71.06	8.77	88.12
Electrical and Machinery						
Exports	228.00	2,416.77	101.57	1,279.72	125.26	1,378.86
CO2 Intensity	0.09	0.11	0.22	0.32	0.17	0.23
CO2 Exports	11.40	145.19	11.00	219.51	18.01	205.21
Food and Beverages						
Exports	30.92	378.77	23.07	252.80	28.40	289.15
CO2 Intensity	0.10	0.13	0.24	0.34	0.18	0.23
CO2 Exports	2.34	44.10	2.70	31.33	5.10	54.99
Other Manufacturing						
Exports	16.14	261.57	9.43	215.79	16.11	179.24
CO2 Intensity	0.10	0.11	0.34	0.45	0.28	0.33
CO2 Exports	0.94	17.25	1.73	63.49	3.62	41.83
Petroleum, Chemical and Non-Metallic Mineral Products						
Exports	125.11	1,244.65	65.50	684.75	67.32	711.09
CO2 Intensity	0.50	0.51	1.03	1.40	0.85	1.15
CO2 Exports	39.49	688.80	32.36	350.80	43.48	378.01
Textiles and Wearing Apparel						
Exports	25.05	317.32	26.07	459.51	43.54	579.73
CO2 Intensity	0.10	0.12	0.33	0.45	0.27	0.32
CO2 Exports	1.34	16.20	4.77	127.89	11.09	159.46
Transport Equipment						
Exports	87.95	1,852.30	41.73	696.37	33.31	787.86
CO2 Intensity	0.10	0.12	0.27	0.50	0.22	0.39
CO2 Exports	5.77	141.40	3.98	71.72	3.70	61.41
Wood and Paper						
Exports	25.81	532.56	16.21	189.49	13.45	142.12
CO2 Intensity	0.09	0.11	0.26	0.40	0.21	0.31
CO2 Exports	1.43	33.72	1.57	21.04	1.98	18.48
Total						
Exports	68.21	1,151.78	36.22	590.93	42.05	636.71
CO2 Intensity	0.15	0.27	0.37	0.67	0.30	0.54
CO2 Exports	7.88	242.29	7.33	152.33	11.05	161.44

The table displays summary statistics of dependent variables sector-by-sector. Exports are in millions of USD, CO2 intensity in kilogram per USD, and CO2 content of exports in Gg (kt) of CO2.

Table 4.6: Results: Replication of Aichele and Felbermayr (2015); w/ Exports and EORA Data

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
Panel A: 1995-2007				
dKyoto	-0.020***	-0.098***	-0.228***	-0.118***
	(0.003)	(0.003)	(0.008)	(0.004)
Obs.	182,520	182,520	182,520	182,520
Panel B: 1995-2012				
dKyoto	-0.005	-0.096***	-0.188***	-0.101***
	(0.004)	(0.003)	(0.008)	(0.005)
Obs.	252,720	252,720	252,720	252,720
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the differential Kyoto commitment, dKyoto. A joint economic integration measure is included in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports. Panel A replicates Aichele and Felbermayr (2015) w/ export rather than import flows. Panel B extends the time horizon.

Table 4.7: Benchmark Results

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
Panel A: 1995-2007				
dKyoto	0.006***	-0.196***	-0.413***	-0.191***
	(0.001)	(0.001)	(0.002)	(0.002)
Obs.	2,535,163	2,529,616	2,480,106	2,488,123
Panel B: 1995-2012				
dKyoto	0.057***	-0.204***	-0.421***	-0.150***
	(0.001)	(0.001)	(0.003)	(0.002)
Obs.	3,525,925	3,480,368	3,392,244	3,437,802
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the differential Kyoto commitment, dKyoto. A joint economic integration measure is included in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports. Panels A, and B extend Aichele and Felbermayr (2015)'s 40 country sample to include 149 nations. Panel B extends the time horizon.

Table 4.8: Results: Timing Effects

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
dKyoto×2001	-0.027***	-0.000	0.008	-0.026***
	(0.003)	(0.003)	(0.006)	(0.004)
dKyoto×2002	-0.042***	-0.127***	-0.257***	-0.168***
	(0.001)	(0.002)	(0.003)	(0.002)
dKyoto×2003	-0.012***	-0.147***	-0.302***	-0.159***
	(0.001)	(0.002)	(0.003)	(0.002)
dKyoto×2004	0.008***	-0.191***	-0.403***	-0.183***
	(0.001)	(0.001)	(0.003)	(0.002)
dKyoto×2005	0.012***	-0.207***	-0.430***	-0.195***
	(0.001)	(0.002)	(0.003)	(0.002)
dKyoto×2006	0.025***	-0.246***	-0.507***	-0.221***
	(0.001)	(0.002)	(0.003)	(0.002)
dKyoto×2007	0.055***	-0.247***	-0.511***	-0.194***
	(0.001)	(0.002)	(0.003)	(0.002)
dKyoto×2008	0.082***	-0.249***	-0.528***	-0.174***
	(0.002)	(0.002)	(0.004)	(0.003)
dKyoto×2009	0.119***	-0.237***	-0.493***	-0.127***
	(0.002)	(0.002)	(0.004)	(0.003)
dKyoto×2010	0.110***	-0.218***	-0.447***	-0.114***
	(0.002)	(0.002)	(0.004)	(0.003)
dKyoto×2011	0.135***	-0.190***	-0.377***	-0.056***
	(0.002)	(0.002)	(0.004)	(0.003)
dKyoto×2012	0.112***	-0.198***	-0.394***	-0.087***
	(0.002)	(0.002)	(0.004)	(0.003)
Obs.	3,525,925	3,480,368	3,392,244	3,437,802
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the differential Kyoto commitment, dKyoto. A joint economic integration measure is included in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports.

Figure 4.6: Timing Effects: Exports

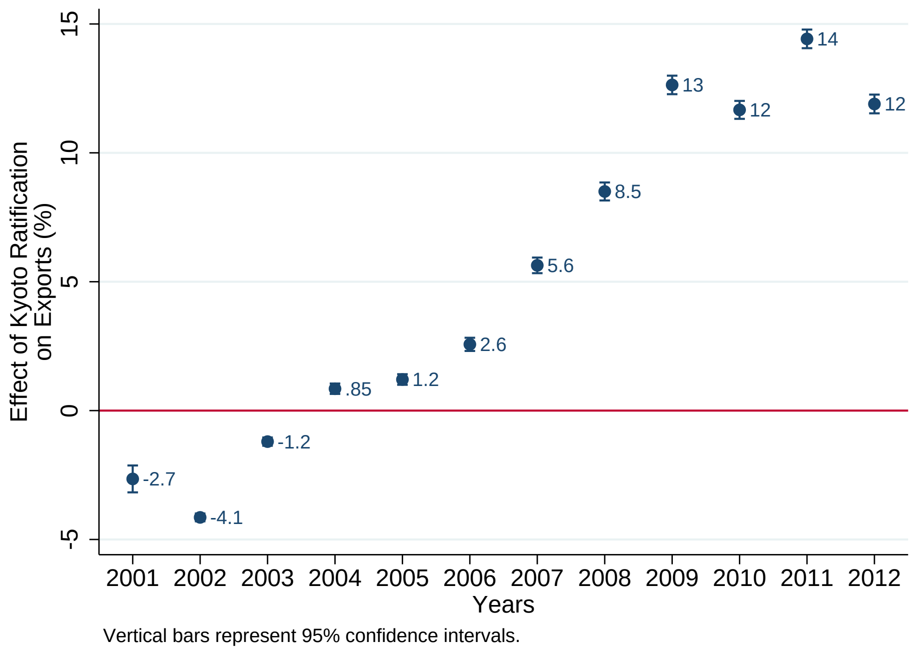


Figure 4.7: Timing Effects: CO2 Intensity

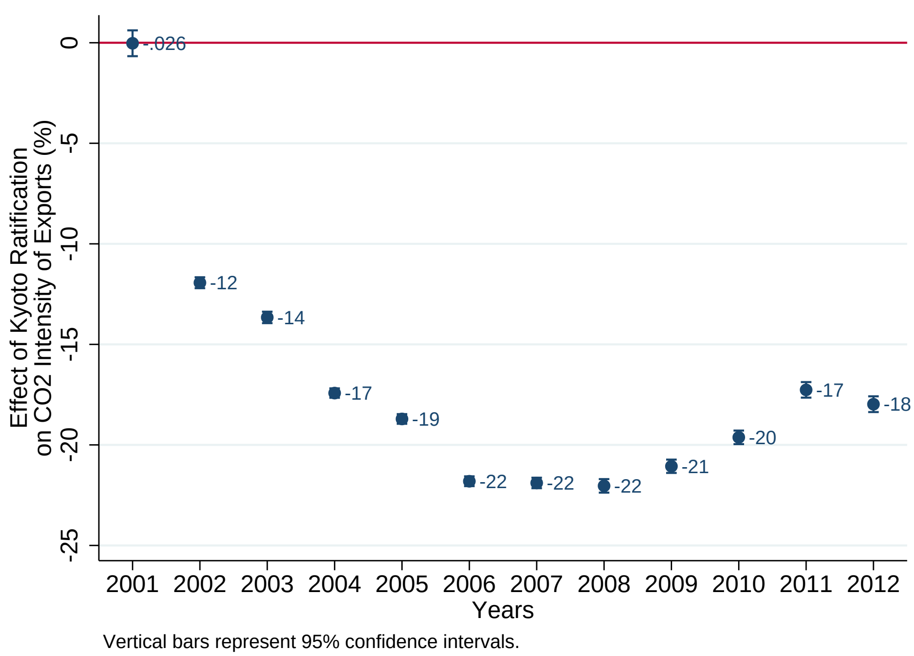


Figure 4.8: Timing Effects: CO2 Exports

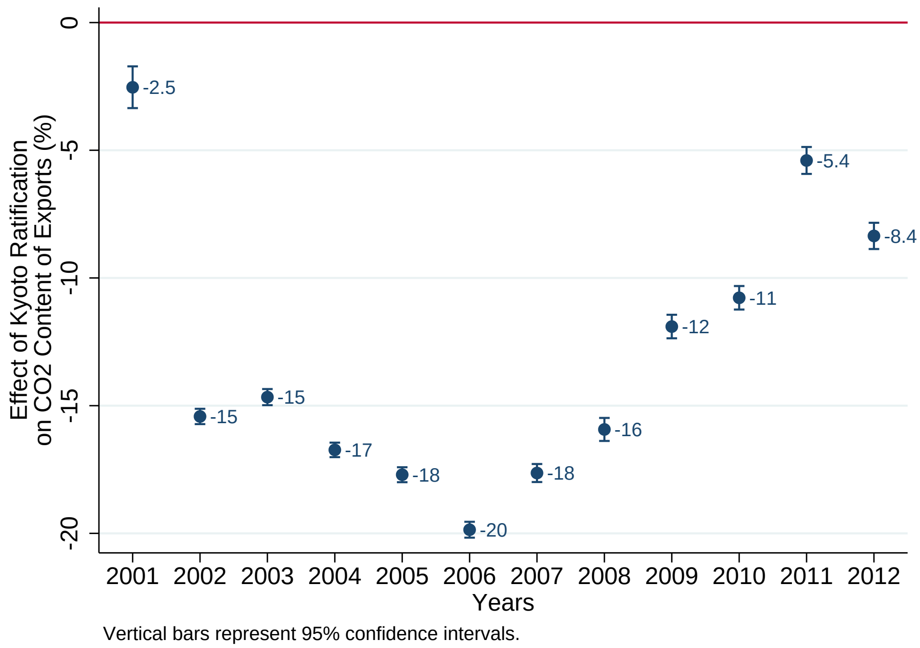


Figure 4.9: Timing Effects: Exports, CO2 Intensity, and CO2 Exports

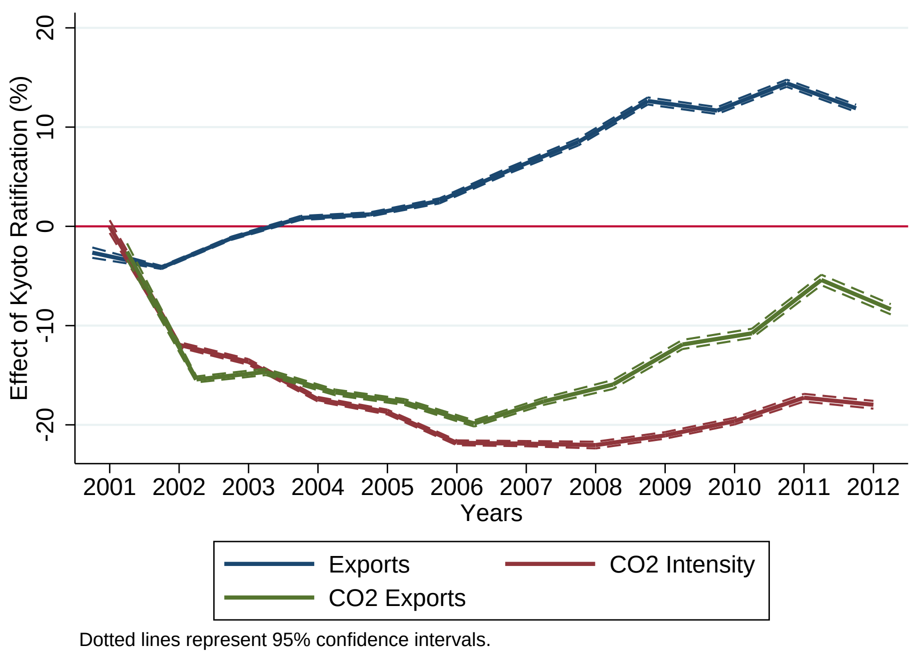


Table 4.9: Results: Timing Effects on Exports by Sectoral Emission Intensity

Dependent Variable: *ln Exports*	(1)	(2) dKyoto	(2) cont. dKyoto $\times \ln CO_2$ Int.
dKyoto	-0.061***		
	(0.002)		
ln Rep. CO2 intensity	-0.023***	-0.019***	
	(0.001)	(0.001)	
dKyoto$\times \ln CO_2$ Int.	-0.050***		
	(0.001)		
2001		-0.052***	-0.021***
		(0.005)	(0.003)
2002		-0.050***	-0.005***
		(0.002)	(0.001)
2003		-0.038***	-0.014***
		(0.002)	(0.001)
2004		-0.020***	-0.013***
		(0.002)	(0.001)
2005		-0.015***	-0.012***
		(0.002)	(0.001)
2006		-0.017***	-0.018***
		(0.003)	(0.001)
2007		-0.000	-0.021***
		(0.004)	(0.002)
2008		0.008*	-0.025***
		(0.004)	(0.002)
2009		0.060***	-0.019***
		(0.004)	(0.002)
2010		0.044***	-0.023***
		(0.004)	(0.002)
2011		0.048***	-0.032***
		(0.004)	(0.002)
2012		0.043***	-0.024***
		(0.005)	(0.002)
Obs.	3,437,802		3,437,802
Country Pair×Year Effects	Yes		Yes
Country Pair×Industry Effects	Yes		Yes
Industry×Year Effects	Yes		Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** p<0.01, ** p<0.05, * p<0.1. The variable of interest is the differential Kyoto commitment, dKyoto and the associated interactions. A joint economic integration measure is included in all specifications.

Figure 4.10: Timing Effects: Exports by Sectoral Emission Intensity

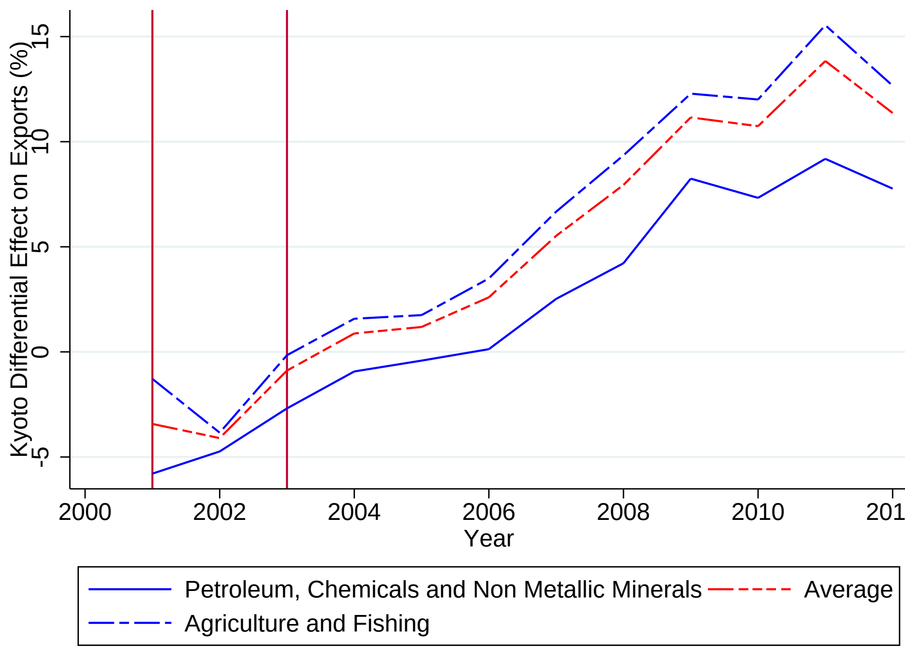


Table 4.10: Results: Kyoto and Heterogeneous QERLCs

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
Panel A: All Annex I				
rdKyoto	-0.051***	0.202***	0.409***	0.149***
	(0.002)	(0.002)	(0.004)	(0.003)
adKyoto	0.043***	-0.217***	-0.438***	-0.170***
	(0.001)	(0.002)	(0.003)	(0.002)
Obs.	3,525,925	3,480,368	3,392,244	3,437,802
Panel B: w/o EITs				
rdKyoto	-0.039***	0.095***	0.197***	0.064***
	(0.002)	(0.003)	(0.005)	(0.004)
adKyoto	0.033***	-0.119***	-0.242***	-0.090***
	(0.002)	(0.002)	(0.004)	(0.003)
Obs.	2,928,889	2,890,350	2,810,312	2,848,771
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variables of interest are the alternative Kyoto commitment differential, adKyoto, and the simple ratification differential, rdKyoto. A joint economic integration measure is included in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports. In Panel B, EITs are removed from the sample.

Table 4.11: Results: Transition Countries

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
dKyoto	0.063***	-0.143***	-0.281***	-0.083***
	(0.002)	(0.002)	(0.003)	(0.002)
dKyoto×Exp. Transition	-0.029***	-0.323***	-0.717***	-0.351***
	(0.005)	(0.006)	(0.011)	(0.007)
Obs.	3,525,925	3,480,368	3,392,244	3,437,802
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the alternative Kyoto commitment differential, adKyoto. A joint economic integration measure is included in in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports.

Table 4.12: Results: The Role of Factor Endowments

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
dKyoto	0.072***	-0.456***	-0.932***	-0.382***
	(0.007)	(0.009)	(0.017)	(0.012)
dKyoto×Exp. Transition	-0.032***	-0.269***	-0.605***	-0.299***
	(0.005)	(0.006)	(0.010)	(0.007)
dKyoto×lnK/L	-0.004**	0.069***	0.144***	0.065***
	(0.002)	(0.002)	(0.004)	(0.003)
Obs.	3,314,630	3,269,904	3,183,399	3,227,634
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** p<0.01, ** p<0.05, * p<0.1. The variable of interest is the differential Kyoto commitment, dKyoto. A joint economic integration measure is included in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports.

Chapter 5 Conclusion

This dissertation targets two major ramifications of the ongoing international trade research. The first essay adds to the literature strand on economic integration agreements (EIAs) and their effects on the diversity of international trade flows. Contrary to what most studies find, this essay shows that export diversification depends not only on trade costs but on horizontal foreign direct investment (FDI) costs as well. Since EIAs exhibit asymmetric effects on trade and horizontal FDI costs, their impact on trade diversity depends on each accord in part. The second and third essays add to the empirical research on the competitiveness effects of international environmental agreements (IEAs) and environmental regulation in general. The second essay underlines that, in general, IEAs are detrimental to exports. The effects are found to be relatively large for pollution-intensive sectors. However, a more disaggregated analysis points to a heterogeneous effect of IEAs on exports. For example, the Kyoto protocol is found to be a minor source of comparative disadvantage for pollution-intensive sectors. For the least pollution-intensive sectors, however, the Kyoto protocol emerges as a source of comparative advantage. This finding is further bolstered by the results brought forward within the third essay. Conversely, ozone depletion IEAs are found to generate declines in exports, regardless of the origin industry. The third essay focuses on the Kyoto protocol and evaluates its effects on the carbon content of exports from several perspectives.

The purpose of the first essay is to gain insight into the mechanisms through which economic integration shapes the diversity of exports. The overwhelming majority of studies on the subject hold economic integration as a catalyst to export diversity. This conclusion rests on the logic that economic integration lowers trade costs which, in turn, facilitates exports and export diversification. The first essay challenges this conclusion by showing, theoretically and empirically, that the above reasoning may not always hold. I start by developing a theoretical model which postulates that export diversity depends not only on trade costs but on horizontal foreign direct investment (FDI) costs as well. The logic behind this key theoretical insight rests on the substitutability between exporting and horizontal investment, as means of serving foreign markets. The model yields two testable predictions. First, a relative decline in trade costs generates bilateral export diversification, just as emphasized throughout the literature. Second, a relative drop in horizontal FDI costs results in less diverse exports. These predictions underline important implications that concern export diversity and economic integration agreements (EIAs); as these accords may display an asymmetric effect on horizontal FDI and trade costs. For example, shallow integration agreements (e.g., free trade agreements) entail large declines in trade costs with little or no changes in costs of cross border investment, and are expected to generate export diversity. Conversely, deeper integration agreements (e.g., economic and monetary unions) are associated with notable reductions in investment costs but little change in trade costs, and are predicted to engender less diverse outflows. In the second half of the essay I take the theoretical model to the data. The results showed that joint ratification of trade agreements in general leads to a more diverse export basket. However, joint membership within the European economic and monetary union (e.g., the Eurozone) is found to accomplish the exact opposite.

The second essay reevaluates the competitiveness effect of environmental regulation on international trade. In doing so, the study contributes to the existing literature along three important margins. First, while most studies have focused on environmental regulation or pollution abatement costs, I use the stock of ratified air pollution international environmental agreements (IEAs) as a measure of sovereign commitment to environmental reform. Second, by doing so I am able to analyze a substantially larger number of countries across a much broader time horizon. Third, by being able to observe a country as an exporter and importer over a generous period of time, I am able to account, relatively easy, for the endogenous selection into IEAs. Three sets of results are uncovered by the second essay. First, the adoption of IEAs is found to act as a source of comparative disadvantage especially for pollution-intensive sectors. Second, different categories of IEAs display idiosyncratic composition and scale effects. Climate change IEAs (i.e., the Kyoto protocol) are found to be a modest source of comparative disadvantage for pollution-intensive industries. However, for the least polluting industries, these accords represent a source of comparative advantage. Hence, the ratification of climate change IEAs suggests a compositional shift towards a "cleaner" (less pollution-intensive) export bundle. A similar piece of evidence emerges from the third essay. Conclusive evidence on acid rain IEAs as sources of comparative disadvantage is found only for pollution-intensive industries. At the other end of the spectrum, ozone depletion IEAs induce negative effects on exports regardless of whether a sector is more or less pollution-intensive. Hence, acid rain and ozone depletion IEAs bring about negative scale effects. Third, climate change and acid rain IEAs involve "leakage" effects which appear to be stronger for the first category of accords. In line with their international trade provisions, ozone depletion IEAs do not generate "leakage" effects. This result is nevertheless expected, and in line with the "leakage"-reduction provisions often included within this type of IEAs. Aside from its economic implications this result is may be of added importance with regards to the design of future IEAs.

By making use of a novel dataset, the third essay zooms in on the Kyoto protocol and its effect on the carbon content of exports, the CO_2 intensity of exports, and exports in general. The contributions made to the existing literature can be summarized as follows. First, I expand the reach of Aichele and Felbermayr (2015) by assessing a total of 149 nations observed between 1995 and 2012. Second, I employ a year-by-year analysis in order to shed light on the post-ratification short-run and long-run adjustments. Third, I evaluate whether the type of quantitative emission reduction or limitation commitment (QERLC) had any role in shaping the three outcomes of interest. A similar analysis is conducted for the Eastern European transitioning economies. The results are summarized below. First, the inclusion of the 2008-2012 period points to a significant and positive effect of Kyoto ratification on exports. Additionally, the CO_2 intensity of exports and the carbon content of exports are found to exhibit much larger declines in comparison to those brought forward by previous studies. The year-by-year analysis underscores an export decline which occurs immediately after ratification (i.e., during 2001-2003). However, exports are estimated to rebound thereafter. Exports from less CO_2-intensive sectors seem to recover in as little as 3 years. In contrast, outflows from CO_2-intensive industries appear to rebound after about 6 years. These results also contribute to the literature on the IEAs and their competitiveness effects by suggesting that the Kyoto protocol's adverse effects on exports are rather short lived. The CO_2 intensity of exports is found to decline continuously after the protocol's ratification. The effect on the carbon content of exports follows a similar dynamic path. In line with the findings of the second essay, these results also underline a compositional or a "clean-up" effect on exports. Third, the type of QERLCs adopted under the protocol matter. In this regard the ratification effect on exports, the CO_2 intensity of exports, and the carbon content of exports is stronger for parties which pledged to reduce emissions. Contrary to ante-ratification beliefs, Eastern European transition economies significantly reduced the CO_2 intensity and the carbon content of their exports.

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Appendix A

A.1 Chapter 2 Appendix

A.1.1 Proofs

First Proposition

Step 1. Given (2.2) and (2.6), export flows in each of the two sectors, that originate in H with destination F, can be written as

$$X_s^{H,F} = \gamma_s^H n \frac{\frac{1}{2}Y^F}{P_s^{F\,1-\sigma}} \left[\frac{\sigma}{\sigma-1}\right]^{1-\sigma} w^{H\,1-\sigma} \tau_s^{H,F\,1-\sigma} \beta^{H\,1-\sigma} \tag{A.1}$$

From (A.1) it follows that $X_l^{H,F} > X_h^{H,F}$ as long as

$$\frac{1}{\gamma_h^H} > \left[\frac{P_h^F}{P_l^F}\frac{\tau_l^{H,F}}{\tau_h^{H,F}}\right]^{1-\sigma} \tag{A.2}$$

Sectoral price indexes are expressed as in (2.4) and thus (A.2) can be rewritten as (A.3), which holds with strict inequality since $1 > \gamma_h^H$, $\tau_h^{H,F} > \tau_l^{H,F}$ and $\sigma > 1$

$$\tau_h^{H,F\,\sigma-1} > \tau_l^{H,F\,\sigma-1}\gamma_h^H \tag{A.3}$$

Step 2. Given (2.4), sectoral price levels and trade costs are positively related.

$$\epsilon_{\tau_s^{H,F}}^{P_s^F} = \frac{\partial P_s^F}{\partial \tau_s^{H,F}}\frac{\tau_s^{H,F}}{P_s^F} = \frac{1}{1-\sigma}\left[1 - \frac{1}{1+\gamma_s^H \tau_s^{H,F\,1-\sigma}}\right]\left[\epsilon_{\tau_s^{H,F}}^{\gamma_s^H} + 1 - \sigma\right] > 0 \tag{A.4}$$

From (A.4) it follows that

$$\left|\frac{\partial P_h^F}{\partial \tau_h^{H,F}}\frac{\tau_h^{H,F}}{P_h^F}\right| > \left|\frac{\partial P_l^F}{\partial \tau_l^{H,F}}\frac{\tau_l^{H,F}}{P_l^F}\right| \Leftrightarrow \left|\epsilon_{\tau_h^{H,F}}^{\gamma_h^H}\right| > 0 \tag{A.5}$$

In the above, $\epsilon_{\tau_s^{H,F}}^{\gamma_s^H}$ denotes the elasticity of the fraction of exporting firms with respect to trade costs. The latter holds with strict inequality given the model assumptions. Note that, $\gamma_l^H = 1$, $\epsilon_{\tau_l^{H,F}}^{\gamma_l^H} = 0$.

Step 3. From (A.1) it can be shown that sectoral exports, $X_s^{H,F}$, and trade costs, $\tau_s^{H,F}$, are negatively related since

$$\epsilon_{\tau_s^{H,F}}^{X_s^{H,F}} = \frac{\partial X_s^{H,F}}{\partial \tau_s^{H,F}}\frac{\tau_s^{H,F}}{X_s^{H,F}} = \underbrace{\frac{\partial \gamma_s^H}{\partial \tau_s^{H,F}}\frac{\tau_s^{H,F}}{\gamma_s^H}}_{<0} + (\sigma-1)\underbrace{\left(\frac{\partial P_s^F}{\partial \tau_s^{H,F}}\frac{\tau_s^{H,F}}{P_s^F} - 1\right)}_{<0} < 0 \tag{A.6}$$

There are no reasons to believe that the elasticity of the price index with respect to transportation costs is greater than unity as this would imply a more than a 100% trade costs pass through rate.

Step 4. Exports in high-τ sector grow faster than those in the low-τ industry if and only if

$$| \epsilon^{X_h^{H,F}}_{\tau_h^{H,F}} | > | \epsilon^{X_l^{H,F}}_{\tau_l^{H,F}} | \tag{A.7}$$

By using (A.4), (A.6), and some algebraic manipulations it can be shown that the above holds with strict inequality as long as $1 > \gamma_h^H$, $\tau_h^{H,F} > \tau_l^{H,F}$ and $\left| \epsilon^{\gamma_h^H}_{\tau_h^{H,F}} \right| > 0$. These three conditions are met given the assumptions of the model.

Step 5. Since $s_h^{H,F}(X_h^{H,F}(\tau_h^{H,F}), X_l^{H,F}(\tau_l^{H,F}))$ and $s_l^{H,F}(X_h^{H,F}(\tau_h^{H,F}), X_l^{H,F}(\tau_l^{H,F}))$, by using (17) it follows that

$$\frac{\partial s_h^{H,F}}{\partial \tau^{H,F}} = \frac{\frac{\partial X_h^{H,F}}{\partial \tau_h^{H,F}} X_l^{H,F} - \frac{\partial X_l^{H,F}}{\partial \tau_l^{H,F}} X_h^{H,F}}{(X_h^{H,F} + X_l^{H,F})^2} \tag{A.8}$$

$$\frac{\partial s_l^{H,F}}{\partial \tau^{H,F}} = \frac{\frac{\partial X_l^{H,F}}{\partial \tau_l^{H,F}} X_h^{H,F} - \frac{\partial X_h^{H,F}}{\partial \tau_h^{H,F}} X_l^{H,F}}{(X_h^{H,F} + X_l^{H,F})^2} \tag{A.9}$$

Therefore,

$$\frac{\partial s_h^{H,F}}{\partial \tau^{H,F}} = -\frac{\partial s_l^{H,F}}{\partial \tau^{H,F}} \tag{A.10}$$

Recalling that $X_l^{H,F} > X_h^{H,F}$, $\frac{\partial X_h^{H,F}}{\partial \tau_h^{H,F}} < 0$ and $\frac{\partial X_l^{H,F}}{\partial \tau_l^{H,F}} < 0$ and using (A.8) along with some algebraic manipulations it can be shown that

$$\frac{\partial s_h^{H,F}}{\partial \tau^{H,F}} < 0; \quad \frac{\partial s_l^{H,F}}{\partial \tau^{H,F}} > 0 \tag{A.11}$$

Using (2.12) and (A.11), the response of bilateral concentration to change in trade costs is given below.

$$\frac{\partial HHI^{H,F}}{\partial \tau^{H,F}} = \frac{1}{1-\sqrt{\frac{1}{2}}} \left[\frac{1}{2} \left((s_h^{H,F})^2 + (s_l^{H,F})^2 \right)^{-\frac{1}{2}} \left(\underbrace{\frac{\partial s_h^{H,F}}{\partial \tau^{H,F}}}_{<0} \underbrace{(s_h^{H,F} - s_l^{H,F})}_{<0, s_h^{H,F} < s_l^{H,F}} \right) \right] > 0 \tag{A.12}$$

Second Proposition

Step 1. Recalling the price index in (2.4), that γ_h^H is a positive function of $f^{H,F}$, and allowing the number of firms in Foreign's high-τ sector to change accordingly in response to changes in $f^{H,F}$, it can be shown that

$$\epsilon_{f^{H,F}}^{P_h^F} = \frac{\partial P_h^F}{\partial f^{H,F}} \frac{f^{H,F}}{P_h^F} > 0 \tag{A.13}$$

since

$$1 > \tau_h^{H,F^{1-\sigma}}$$

Step 2. Using (A.1) and (A.13) it is straightforward to show that

$$\epsilon_{f^{H,F}}^{X_h^{H,F}} = \frac{\partial X_h^{H,F}}{\partial f^{H,F}} \frac{f^{H,F}}{X_h^{H,F}} = \frac{\partial \gamma_h^H}{\partial f^{H,F}} \frac{f^{H,F}}{\gamma_h^H} + (\sigma - 1) \frac{\partial P_h^F}{\partial f^{H,F}} \frac{f^{H,F}}{P_h^F} > 0 \tag{A.14}$$

Step 3. Noting that the firms and thus exports in the low-τ sector do not respond to changes in horizontal foreign direct investment costs, by using (2.13) it follows that

$$\frac{\partial s_h^{H,F}}{\partial f^{H,F}} = \frac{\frac{\partial X_h^{H,F}}{\partial f^{H,F}} X_l^{H,F}}{(X_h^{H,F} + X_l^{H,F})^2} \tag{A.15}$$

$$\frac{\partial s_l^{H,F}}{\partial f^{H,F}} = \frac{-\frac{\partial X_h^{H,F}}{\partial f^{H,F}} X_l^{H,F}}{(X_h^{H,F} + X_l^{H,F})^2} \tag{A.16}$$

Therefore,

$$\frac{\partial s_h^{H,F}}{\partial f^{H,F}} = -\frac{\partial s_l^{H,F}}{\partial f^{H,F}} \tag{A.17}$$

Given (A.14), (A.15), and (A.17),

$$\frac{\partial s_h^{H,F}}{\partial f^{H,F}} > 0; \quad \frac{\partial s_l^{H,F}}{\partial f^{H,F}} < 0 \tag{A.18}$$

Using (2.12) and (A.18) the response of bilateral concentration to change in trade costs is given below.

$$\frac{\partial HHI^{H,F}}{\partial f^{H,F}} = \frac{1}{1 - \sqrt{\frac{1}{2}}} \left[\frac{1}{2} \left((s_h^{H,F})^2 + (s_l^{H,F})^2 \right)^{-\frac{1}{2}} \left(\underbrace{\frac{\partial s_h^{H,F}}{\partial f^{H,F}}}_{>0} \underbrace{(s_h^{H,F} - s_l^{H,F})}_{<0, s_h^{H,F} < s_l^{H,F}} \right) \right] < 0 \tag{A.19}$$

A.1.2 Data

Concentration Indexes

All three concentration measures are the product of own calculations based on bilateral export flows at SITC 3 digit Rev. 3 aggregation level. Bilateral export data under SITC 3 Rev. 3 classification is extracted from UNCTAD. Here, exporting sectors are characterized by flows totaling $100,000 or more within a given year. For comparison purposes, I follow Regolo (2013) and assume that all 255 SITC 3 digit Rev. 3 manufacturing sectors within the dataset represent potential exporting sectors. UNCTAD reports its own set of Hirschmann-Herfindahl bilateral concentration indexes. However, this measure is calculated by using the total number of active lines for a given pair and year rather than the maximum number of sectors in the classification. Employing this measure within the estimation approach does not have a significant impact on the results. The construction of bilateral export concentration indexes is detailed below.

- The normalized Hirschmann-Herfindahl index of bilateral export concentration for pair (x, m) at time t is computed as in (A.20). The share of industry i in total exports from x to m at time t, $s^i_{x,m,t}$, is computed as shown below, where I accounts for the total number of SITC 3 Rev. 3 industrial sectors.

$$H_{x,m,t} = \frac{\sqrt{\sum_{i=1}^{I}(s^i_{x,m,t})^2} - \sqrt{\frac{1}{I}}}{1 - \sqrt{\frac{1}{I}}} \tag{A.20}$$

$$s^i_{x,m,t} = Exports^i_{x,m,t} / \sum_{i=1}^{I} Exports^i_{x,m,t} \tag{A.21}$$

- The Theil index of bilateral export concentration for pair (x, m) at time t is computed as in (A.22). As mentioned above $s^i_{x,m,t}$ accounts for the export share of industry i in total bilateral export flows from x to m at time t and is computed as in (A.21). Also, $\overline{s_{x,m,t}}$ represents the average of these shares across all industries.

$$T_{x,m,t} = \frac{1}{I}\sum_{i=1}^{I} \frac{s^i_{x,m,t}}{\overline{s_{x,m,t}}} ln \frac{s^i_{x,m,t}}{\overline{s_{x,m,t}}} \tag{A.22}$$

- The Gini index of bilateral export concentration for pair (x, m) in year t is computed as in (A.23). More specifically this index is computed as the difference between the actual distribution of industry level flows from x to m and the equal distribution of industry specific, bilateral exports across all industries. $A_{L,x,m,t}$ denotes the area under the Lorentz curve.

$$G_{x,m,t} = 1 - \frac{2A_{L,x,m,t}}{I^2} \tag{A.23}$$

Economic Integration

- The integration measure used in Regolo (2013) ($TA_{x,m,t}$) was compiled for the period 1950-2012 by Jeffrey Bergstrand as part of the NSF-Kellogg Institute

Economic Integration Agreements Database Project. It is measured on a scale from 0 to 6, with the null value indicating no integration whatsoever. As per data construction methodology provided by the author, $TA_{x,m,t} = 1$ is indicative of a non-reciprocal preferential trade agreement between x and m at time t. Similarly, $TA_{x,m,t} = 2$ denotes the existence of a preferential trade arrangement. $TA_{x,m,t} = 3$ indicates the presence of a free trade agreement. If $TA_{x,m,t} = 4$, x and m are part of a customs union at t. $TA_{x,m,t} = 5$ underlines the joint membership within a common market. Finally, $TA_{x,m,t} = 6$ points to the joint membership in an economic union; in this case the Eurozone. Pertaining to the current sample, values of 5 appear after 1993, the year in which the European Single Market was launched. Values of 6 show up after 1999 and denote country pairs which share the euro.

- The variable associated with joint Eurozone membership ($EZ_{x,m,t}$) was constructed based on information provided by the European Central Bank. This variable takes a value of 1 if both the exporter and importer are part of the Eurozone at time t and 0 otherwise. Starting in 1999, 11 European countries joined the European economic and monetary union. The initial adopters are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. This group is referred throughout as EZ11. Since then, 8 other countries have joined: Greece in 2002, Slovenia in 2007, Cyprus and Malta in 2008, Slovakia in 2009, Estonia in 2011, Latvia in 2014 and Lithuania in 2015. Given that the last available year within the dataset at hand is 2011, Estonia, Latvia and Lithuania are not regarded as part of the Eurozone.

Endowments

Following Regolo (2013), exporter-importer differences in factor endowments are constructed as shown in (A.24). Country specific physical capital stock (K) and employment (L) figures are from version 8.0 of the Penn World Tables. Information on national stock of arable land (A) is obtained from the World Development Indicators dataset published by the World Bank and complemented using the environmental accounts of the World Input Output Database. In PWT v8.0 human capital is not expressed simply as average years of schooling (H/L) but rather as an index. This is obtained by combining data on the average years of schooling with that on rates of return to education. Thus, one can use the index and back out figures on average years of schooling (H/L). Experimenting with differential variables which are built using either the index or the raw average years of schooling has no quantitative or qualitative impact on the results. All estimations are produced using the average years of schooling differential.

K/L differential for exporter (x) and importer (m) for year (t) is denoted by $d_{K/L,x,m,t}$. Here, $K/L_{k,t}$ represents the physical capital to labor ratio in country k at time t, $k = \{x, m\}$. Similarly, exporter and importer specific K/L ratios can be replaced with their counterparts, H/L and A/L, to obtain $d_{H/L,x,m,t}$ and $d_{A/L,x,m,t}$ respectively.

$$d_{K/L,x,m,t} = |ln(K/L_{x,t}) - ln(K/L_{m,t})| \tag{A.24}$$

Geographic Variables

Data regarding distance, contiguity and whether or not the exporter and the importer are sharing a common language is provided by CEPII.

Other Variables

- GDP and population figures are extracted from PWT v8.0. There are several measures of gross domestic product within this dataset. I am using the output-side real GDP measured in constant 2005 USD at current purchasing power parity (PPP). Choosing expenditure-side measures or figures adjusted for PPP has no impact on the empirical analysis. This data series is used to construct the per capita GDP variable. Information on total factor productivity figures is from PWT 8.0. The PWT dataset comprises two measures of total factor productivity. Both measures are constructed by dividing the relative output by relative input levels. The key difference is given by the term "relative". One measure involves output and stock of factors relative to the U.S. at current PPPs whereas the other refers to output and factors relative to national levels in the year 2005. The results are not quantitatively and qualitatively altered by experimenting with the two measures. All estimations are produced using the former measure.

- GDP per capita and total factor productivity variables are used to construct the analogous exporter-importer differential measures, $d_{GDPpc,x,m,t}$ and $d_{TFP,x,m,t}$, as depicted below. Here, $GDPpc_{k,t}$ and $TFP_{k,t}$ represent the real GDP per capita and total factor productivity in country k at time t, $k = \{x, m\}$.

$$d_{GDPpc,x,m,t} = |ln(GDPpc_{x,t}) - ln(GDPpc_{m,t})| \tag{A.25}$$

$$d_{TFP,x,m,t} = |ln(TFP_{x,t}) - ln(TFP_{m,t})| \tag{A.26}$$

- The country specific Hirschmann-Herfindahl index used for producing column (7) of tables 2.5 and 2.6 is from UNCTAD.

- The financial openness measure is constructed by following Bos et al. (2011). More specifically, this variable is given by the ratio of total liabilities (portfolio equity liabilities, FDI liabilities, debt liabilities and financial derivatives) to GDP. Data on portfolio equity liabilities, FDI liabilities, debt liabilities and financial derivatives are provided by Philip Lane on his website.

- A nation's trade openness is defined as the ratio of its exports and imports to its GDP. PWT v8.0 contains information on national export/GDP and import/GDP ratios and thus adding the two gives out the trade openness measure.

A.2 Chapter 4 Appendix

A.2.1 Robustness Checks

Table A.1: Robustness Checks

Dependent Variable:	(1) *ln Exports*	(2) *ln CO2 Intensity of Exports*	(3) *ln CTT*	(4) *ln CO2 Exports*
Panel A: w/o China				
dKyoto	0.057***	-0.206***	-0.425***	-0.151***
	(0.001)	(0.002)	(0.003)	(0.002)
Obs.	3,477,973	3,433,038	3,345,536	3,390,472
Panel B: w/o Top 25 Oil Producers				
dKyoto	0.064***	-0.219***	-0.449***	-0.158***
	(0.001)	(0.002)	(0.003)	(0.002)
Obs.	2,591,422	2,554,732	2,479,920	2,516,430
Panel C: Diff. lnGDPpc				
dKyoto	0.052***	-0.213***	-0.439***	-0.164***
	(0.001)	(0.001)	(0.003)	(0.002)
Obs.	3,314,575	3,270,018	3,183,328	3,227,678
Panel D: Diff. Factor Endowments				
dKyoto	0.038***	-0.179***	-0.368***	-0.143***
	(0.001)	(0.002)	(0.003)	(0.002)
Obs.	2,426,709	2,390,976	2,335,604	2,371,149
Country Pair×Year Effects	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the differential Kyoto commitment, dKyoto. A joint economic integration measure is included in specifications (1), (2) and (4). The carbon terms of trade (CTT) is measured as the ratio of carbon content or exports to that of imports. Top 25 oil producers are the United States, Saudi Arabia, Russia, China, Canada, the United Arab Emirates, Iran, Iraq, Brazil, Mexico, Kuwait, Venezuela, Nigeria, Qatar, Norway, Angola, Algeria, Kazakhstan, Colombia, India, Oman, Indonesia, the United Kingdom, Azerbaijan, and Argentina. Panel C includes differences in logarithms of GDP per capita. Panel D includes differences in logarithms of physical capital to labor ratio and years of schooling.

Table A.2: Counterfactual Analysis

Dependent Variable:	Fictitious Treatment Date		Comparison w/ High Income Non-Kyoto		
	(1) *1997*	(2) *1998*	(3) *United States only*	(4) *All Developed*	(5) *United States in Kyoto*
Panel A: ln Exports					
dKyoto	0.098***	0.096***	0.060***	0.060***	0.053***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	1,156,752	1,156,752	1,326,860	1,833,515	3,525,925
Panel B: ln CO_2 Int.					
dKyoto	-0.001	-0.007***	-0.209***	-0.209***	-0.200***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Obs.	1,171,420	1,171,420	1,306,980	1,807,659	3,480,368
Panel C: ln CO_2 Exports					
dKyoto	0.096***	0.088***	-0.152***	-0.152***	-0.150***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	1,139,055	1,139,055	1,304,647	1,801,916	3,437,802
Country Pair×Year Effects	Yes	Yes	Yes	Yes	Yes
Country Pair×Industry Effects	Yes	Yes	Yes	Yes	Yes
Industry×Year Effects	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is denoted in the first row of the table. Estimates are produced using ordinary least squares on pooled sectoral data. Standard errors are shown in parentheses and clustered at the country-pair-industry level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The variable of interest is the differential Kyoto commitment, dKyoto. A joint economic integration measure is included in specifications A, B, and C. Columns (1) and (2) limit the sample to the pre-treatment period (1995-2000) and a fictitious treatment of Kyoto ratifiers in either 1997 or 1998. Columns (3) and (4) compare committed parties with the United States, and Argentina, Bahrain, Chile, Cyprus, Hong Kong, Israel, South Korea, Kuwait, Macau, Malaysia, Oman, Qatar, Saudi Arabia, Singapore, Taiwan, and the United States respectively. In column (6) the United States is included in the treatment group with a hypothetical ratification date in 2002.

Figure A.1: Multi Region Input-Output Table: Supply-Use Table; Source: EORA26 MRIO Documentation

Year: 2000

	T (or Z)	Country 1 Sector 1	Country 1 Sector 2	Country 1 Sector 3	Country 1 Sector 4	Country 2 Sector 1	Country 2 Sector 2	Country 2 Sector 3	Country 2 Sector 4	Country 3 Sector 1	Country 3 Sector 2	Country 3 Sector 3	Country 3 Sector 4
Country 1	Sector 1	346	156	95	594	819	154	832	397	409	562	241	554
Country 1	Sector 2	354	443	7	908	42	92	561	839	470	770	83	368
Country 1	Sector 3	291	795	243	825	753	2	340	232	251	605	526	610
Country 1	Sector 4	637	259	289	813	500	716	947	645	856	221	898	41
Country 2	Sector 1	547	466	910	276	518	149	779	553	197	285	305	828
Country 2	Sector 2	752	936	822	638	611	496	98	924	608	689	872	972
Country 2	Sector 3	295	444	7	828	929	535	367	257	890	429	641	26
Country 2	Sector 4	113	518	791	459	79	748	254	218	586	673	424	157
Country 3	Sector 1	46	457	552	572	632	680	730	607	796	186	15	958
Country 3	Sector 2	962	96	544	96	675	113	711	337	787	571	241	211
Country 3	Sector 3	531	190	686	191	374	615	788	738	351	32	565	622
Country 3	Sector 4	857	776	897	18	915	482	308	458	253	145	982	270
VA (or PI, Primary Inputs) block:													
Country 1	Value Added	1,172	1,120	1,676	1,648	-	-	-	-	-	-	-	-
Country 2	Value Added	-	-	-	-	1,019	4,730	401	471	-	-	-	-
Country 3	Value Added	-	-	-	-	-	-	-	-	626	1,278	1,532	2,995
Total input		**6,901**	**6,657**	**7,518**	**7,868**	**7,864**	**9,511**	**7,117**	**6,677**	**7,082**	**6,445**	**7,326**	**8,612**
Satellite Accounts (Q):	Q												
Direct Emissions (Kt CO2)		300	320	280	400	400	320	200	150	400	230	400	500

Figure A.2: Multi Region Input-Output Table: Final Demand Table; Source: EORA26 MRIO Documentation

Year: 2000		FD (or Y) block: Country 1 Final Demand	Country 1 Final Demand	Country 2 Final Demand	Country 2 Final Demand	Country 3 Final Demand	Country 3 Final Demand	Gross output	Exports		
	T (or Z)	Households	Change in Inven	Households	Change in Inven	Households	Change in Inventory	xout	Total	to companies	to foreign final consumers
Country 1	Sector 1	394	0	902	0	446	0	**6,901**	5,316	3,968	1,348
Country 1	Sector 2	514	0	694	0	512	0	**6,657**	4,431	3,225	1,206
Country 1	Sector 3	384	0	753	0	909	0	**7,518**	4,980	3,318	1,662
Country 1	Sector 4	91	0	653	0	301	0	**7,868**	5,778	4,825	954
Country 2	Sector 1	630	0	565	0	857	0	**7,864**	5,300	3,813	1,487
Country 2	Sector 2	847	0	209	0	37	0	**9,511**	7,173	6,289	884
Country 2	Sector 3	165	0	419	0	886	0	**7,117**	4,610	3,559	1,051
Country 2	Sector 4	800	0	355	0	501	0	**6,677**	5,022	3,721	1,301
Country 3	Sector 1	338	0	320	0	194	0	**7,082**	4,934	4,276	658
Country 3	Sector 2	479	0	14	0	608	0	**6,445**	4,027	3,535	492
Country 3	Sector 3	269	0	814	0	559	0	**7,326**	5,197	4,114	1,083
Country 3	Sector 4	700	0	822	0	729	0	**8,612**	6,233	4,710	1,522
								89,578			
VA (or PI, Primary Inputs) block:											
Country 1	Value Added										
Country 2	Value Added										
Country 3	Value Added										
Total input											
Satellite Accounts (Q):	Q										
Direct Emissions (Kt CO2)		30	-	50	-	10	-				

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Vita

Mihai Paraschiv

EDUCATION

University of Kentucky, Lexington, KY
- M.Sc. Economics, December 2012

Central Michigan University, Mount Pleasant, MI
- M.A. Economics, May 2010

Bucharest University of Economics, Bucharest, Romania
- B.Sc. Statistics and Economic Forecasting, July 2008

EMPLOYMENT

University of Kentucky
Instructor of Record (2012-2016)
- ECO101 Contemporary Economics Issues (3 sections)
- ECO201 Principles of Microeconomics (4 sections)
- ECO202 Principles of Macroeconomics (3 sections, including 1 online)
- ECO370 The Global Economy (1 section)
- ECO395 Undergraduate Independent Study (1 section)
- ECO401 Intermediate Microeconomic Theory (1 section)

Teaching Assistant (2011-2016)
- ECO101 Contemporary Economics Issues
- ECO201 Principles of Microeconomics
- ECO202 Principles of Macroeconomics
- ECO391 Economics and Business Statistics
- ECO402 Intermediate Macroeconomic Theory
- ECO473 Economic Development
- ECO491 Applied Econometrics

Central Michigan University
Teaching Assistant (2009-2010)
- ECO202 Principles of Microeconomics
- BUS300 Applied Business Statistics

Central Michigan University
Research Assistant (2009-2010)

HONORS AND AWARDS

- Outstanding Teaching Assistant Award, Department of Economics, University of Kentucky (2015)
- Graduate Student Award Session, Southern Economic Association (2015)
- Luckett Fellowship, Department of Economics, University of Kentucky (2014-2015)
- Gatton Fellowship, Department of Economics, University of Kentucky (2012-2013, 2013-2014)

- Max Steckler Fellowship, University of Kentucky (2011-2012)
- National Forecasting Commission of the Romanian Government Special Prize (July, 2008)
- Romanian Government Fellowship for Undergraduate Studies, Bucharest University of Economics (2004-2008)