

POST-NAFTA U.S. IMPORTS AND CARBON CONTENT OF TRADE:
A SECTORAL ANALYSIS

A Master's Thesis

by
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Ankara
July 2017



To My Family

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A SECTORAL ANALYSIS

The Graduate School of Economics and Social Sciences
of
Bilkent University

by

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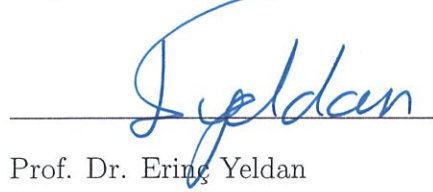
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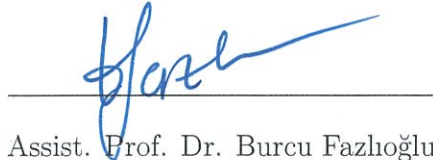
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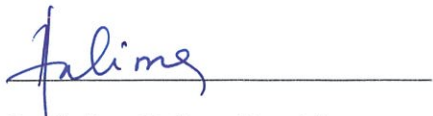
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ABSTRACT

POST-NAFTA U.S. IMPORTS AND CARBON CONTENT OF TRADE: A SECTORAL ANALYSIS

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This thesis examines the changes in the carbon dioxide content of international trade following a multilateral free trade agreement. In this study, the focus is centered on the effects of the North American Free Trade Agreement on the U.S. import flows and the carbon dioxide content of U.S. imports with its major trade partners. In the light of the recent decline in the carbon dioxide emissions generated by the U.S. manufacturing industry, we analyze the value and the carbon content of the U.S. imports from its NAFTA and non-NAFTA importing partners for the implementation period of NAFTA. Using a gravity model of international trade, U.S. imports and carbon dioxide content of U.S. imports are examined for the post-NAFTA period, i.e. 1995-2010, within a panel data framework. With the sectoral trade data and input-output analysis, the direct and indirect carbon dioxide content of trade is computed for the disaggregated imports of U.S. from its NAFTA and non-NAFTA trade partners. The carbon dioxide content of imports is calculated by using the sectoral data of direct carbon dioxide emission coefficients,

Leontief inverse matrices and real trade data at a sectoral level. The estimation results indicate that, both the value and the carbon dioxide content of the U.S. imports from NAFTA partners are significantly greater compared to the value and the carbon dioxide content of the U.S. imports from other major non-NAFTA U.S. importing partners within the period 1995-2010.

Keywords: CO_2 Embodied in International Trade, Gravity Model of International Trade, North American Free Trade Agreement (NAFTA).

ÖZET

NAFTA SONRASI DÖNEMDE A.B.D İTHALATI VE İTHALATIN KARBON DİOKSİT İÇERİĞİ: SEKTÖREL ANALİZ

Özcebe, Gülayça
Yüksek Lisans, İktisat Bölümü
Tez Danışmanı: Doç. Dr. Fatma Taşkın

Temmuz 2017

Bu yüksek lisans tezi, çok taraflı bir serbest ticaret anlaşması sonrasında uluslararası ticaretin hacmindeki ve karbon dioksit içeriğindeki değişimleri incelemektedir. Çalışmanın odak noktası Kuzey Amerika Serbest Ticaret Anlaşması (NAFTA)'nın Amerika Birleşik Devletleri'nin ithalatı üzerindeki etkisi ve A.B.D.'nin önemli ticaret ortakları ile yaptığı ithalatın karbon dioksit içeriği olarak belirlenmiştir. Amerika Birleşik Devletleri imalat sanayii bazlı karbon dioksit emisyonlarının azalışından yola çıkılarak, A.B.D.'nin iki yönlü ithalat hacmi ve ticaretin karbon dioksit içeriği NAFTA sonrası dönem için analiz edilmiştir. Bu ilişki, uluslararası ticaretin panel Çekim Modeli çerçevesinde test edilmiştir. En büyük A.B.D. ithalat ortakları NAFTA üyeliklerine göre ikiye ayrılmıştır. NAFTA sonrası dönemi, yani 1995-2010 yıllarını, kapsamakta olan bu çalışma sektörel düzeyde gerçekleştirilmiş olup, A.B.D.'nin en büyük ithalat partnerleri ile arasında gerçekleştirdiği ithalatın hacmi ve ticaretin karbon dioksit miktarı gözlemlenmiştir. Bu ampirik

analiz sonucunda NAFTA sonrası dönemde, A.B.D.'nin NAFTA ülkeleri ile ticaretinin ve ticaretin karbon dioksit içeriğinin diğer ortaklarına kıyasla daha çok olduğu sonucuna ulaşılmıştır.

Anahtar kelimeler: Kuzey Amerika Serbest Ticaret Anlaşması (NAFTA), Panel Çekim Modeli, Uluslararası Ticaretin CO_2 İçeriği.



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CHAPTER I

INTRODUCTION

The global trade has become one of the cornerstones of the modern world's economy as it has made significant contributions to nations' economic growth and development. The issue of economic gains from free trade has been longstanding in the literature ever since Adam Smith's theory of division of labor and David Ricardo's remarkable contributions of the comparative advantage analysis to the literature on the international trade. Despite a huge literature analyzing the impacts of international trade on the economic growth and development, little was known about the local and cross-border environmental consequences of the free or freer trade.

As the international trade framework evolved from multilateralism to regionalism in early 1990s, the global economy has been integrated more with increasing number of the free trade agreements. The mainspring of a free trade agreement is to liberate the international trade between two or more countries by reducing or removing tariff or non-tariff trade barriers in bilateral or multilateral trade. By this means, parties become a member of a free trade area to maintain stable trade

relations between each other and enhance higher levels of competition by opening their economies to the international marketplace. Further, reduction or elimination of trade barriers cheapen the international trade between the parties and provide an environment for new investment opportunities.

The spread of trade liberalization together with the increasing numbers of bilateral and multilateral free trade agreements lead to formation of economically integrated regions. North American Free Trade Agreement (NAFTA) has been one of the most significant multilateral free trade agreements since it has put into force in 1994. The North American free trade area, as a natural consequence of the North American Free Trade Agreement, is one of the major free trade zones integrating the economies of Canada, Mexico and the United States.

Indeed, debates on the environmental impacts of free trade attracted considerable attention as one of the controversial conflicts of globalized world as the governments of Canada, Mexico and the United States decided to enter into the North American Free Trade Agreement or NAFTA. Prior to the NAFTA, the greatest multilateral effort of international trade was the General Agreement on Tariffs and Trade (GATT) which was a side agreement of the International Trade Organization, aiming the spread of multilateral trade (Steffek and Ehling, 2008).

The scope of GATT was not enough to provide legal environmental protection and prevent the long-run environmental impacts of free trade in the pre-1990s. Furthermore, the asymmetry between the development levels of Canada, Mexico and the United States led farther criticisms and controversies and became the initial motive to the literature on the costs of the liberalization on the environment.

This thesis examines the changes in the value of the import flows and carbon dioxide content of imports following a multilateral free trade agreement. The focus

of the thesis is centered upon the North American Free Trade Agreement because of two reasons: first, due to its historic value for trade and environment literature as one of the oldest and greatest free trade and investment agreements of today's globalized world, and second, its contribution to ensure the bilateral trade liberalization between Mexico-United States and Mexico-Canada by removal of tariff barriers between three countries (Cherniwchan, 2017). Gravity model of international trade is used to follow the changes in the value of the U.S. imports and carbon dioxide embodied in the U.S. imports in the post-NAFTA era, i.e. 1995-2010. Considering the applications of input-output analysis, we calculated the total (direct and indirect) carbon dioxide emission coefficients at a sectoral level and used them to compute the carbon dioxide content of imports at a sectoral level. The thesis goes on to examine the difference between the value and the carbon dioxide content of the U.S. imports from its NAFTA and non-NAFTA importing partners throughout the period 1995-2010.

Our analysis contributes to several strands of the literature by focusing on the role played by a regional free trade agreement during its implementation period both from economic and environmental perspectives. First, we explore whether NAFTA creates a significant influence on the value of the U.S. imports from its NAFTA partners vis-à-vis non-NAFTA partners or not. From the economic point of view, we show that, the value of the U.S. imports from Canada and Mexico has been significantly greater than the other major U.S. importing partners within the period 1995-2010. Second, we address the linkage between trade and environment by computing the carbon dioxide intensity of partner countries' production, therefore the carbon dioxide intensity of the international trade, and the carbon dioxide content of bilateral trade for the case of NAFTA. Yet, such industry level studies that address with pollution content of international trade are rare in the literature on the regional free trade agreements and we make an attempt to fill this

gap by focusing on the case of NAFTA. From the environmental point of view, we show that there is a relation between trade and environment and this interaction between trade and environment. Our results indicate that, following the implementation of NAFTA in 1994, not only the value of the U.S. imports but also the carbon dioxide intensity and the carbon dioxide content of the U.S. imports from both Canada and Mexico are higher relative to the other major non-NAFTA U.S. trading partners.

This thesis is organized as follows. Chapter II provides a brief background information about the history of the North American Free Trade Agreement (NAFTA), North American Agreement on Environmental Cooperation (NAAEC) and some facts about post-NAFTA trade and carbon dioxide emission patterns. Chapter III discusses the previous works on the related literature on the association of trade liberalization, environment and NAFTA. Chapter IV presents the review on the Gravity Model of International Trade. Chapter V discusses the derivation of the carbon dioxide embodied in international trade and gives information about the relevant data and data sources. Chapter VI presents the econometric model. Chapter VII provides discussion on the empirical results. Chapter VIII discusses the robustness checks, and finally, Chapter IX concludes the thesis.

CHAPTER II

BACKGROUND INFORMATION ABOUT THE NORTH AMERICAN FREE TRADE AGREEMENT

2.1 Background Information about NAFTA

The North American Free Trade Agreement, or NAFTA, is a trilateral free trade agreement (FTA) between Canada, Mexico and the United States of America. The history of NAFTA began during the 1980s United States presidential elections, when the United States President Ronald Reagan first proposed the idea of a single market in the North America. In 1985, Canada's proposal of a free trade agreement with the United States was followed by negotiations on the Canada-United States Free Trade Agreement (CUSFTA). The CUSFTA was signed in 1988 and came into force in 1989.¹ Following the U.S. President Ronald Reagan, George H. W. Bush's administration initiated the negotiations toward a free trade agreement between Mexico and the United States in June 1990 and this led the way for negotiations of a multilateral trade agreement among the governments of Canada, Mexico and the United States (Hufbauer and Schott, 1992). Before

¹For further information, see [http : //www.naftanow.org/about/](http://www.naftanow.org/about/)

the Canadian, Mexican and American government agreed to pursue a free trade agreement, the Mexican economic trade and investment relations with Canada and the United States were proceeded with bilateral framework agreements. In 1992, NAFTA was signed by the Canadian Prime Minister Brian Mulroney, Mexican President Carlos Salinas de Gortari, U.S. President George H. W. Bush and came into force in 1994. Inclusion of Mexico to the Canada-United States free trade bloc broadened Canada-U.S. Free Trade Agreement (CUSFTA) to the North American Free Trade Agreement (NAFTA). Today, NAFTA is one of the greatest free trade agreements of today's globalized world as it establishes the second largest free trade bloc known as the North American free trade area.

The objectives of NAFTA, in general, are to strengthen the North America free trade bloc, while boosting the economic growth by eliminating the trade barriers and promoting investments across the borders of three NAFTA members. Particularly, the agreement was prepared to promote the following objectives:

1. *eliminate barriers to trade in, and facilitate the cross-border movement of, goods and services between the territories of the Parties;*
2. *promote conditions of fair competition in the free trade area;*
3. *increase substantially investment opportunities in the territories of the Parties;*
4. *provide adequate and effective protection and enforcement of intellectual property rights in each Party's territory;*
5. *create effective procedures for the implementation and application of this Agreement, for its joint administration and for the resolution of disputes;*
6. *establish a framework for further trilateral, regional and multilateral cooperation to expand and enhance the benefits of this Agreement.*

(North American Free Trade Agreement, Article 102)²

²For the full text of NAFTA, see <https://www.nafta-sec-alena.org/Home/Texts-of-the-Agreement/North-American-Free-Trade-Agreement>

As an integral part of the agreement, by accepting the rules of the NAFTA, Canada, Mexico and the United States also agreed to follow the principles of national treatment, most-favored nation treatment and transparency across governments of member states (NAFTA, Article 104). Those principles provide the equal treatment among the native population and foreigners within the NAFTA borders. Further, most-favor-nation principle prevents each NAFTA members to do better deals with countries other than NAFTA members. Although NAFTA was signed as a trilateral free trade agreement, since 1994, it serves as a framework for not only the North American free trade pack but also the North American economic cooperation.

NAFTA presents a critical position in the history of regional free trade agreements. It became the first free trade agreement that two powerful and developed economies signed a free trade agreement with a developing country (Romalis, 2007). Because of this cooperation among member states with different development levels, most of the oppositions to the NAFTA focused on the lax enforcement mechanism and the effects of liberalization on worker rights and environmental standards. This fact created fear of NAFTA's unintended results such as job losses in developed countries, especially in the United States, and job relocations to Mexico. As U.S. President candidate, Bill Clinton made on his campaign pledge and declared that he would support the agreement if it is revisited to support worker rights and environmental protection during 1992s United States presidential elections campaigns (Markell and Knox, 2003). To allay the fears of the worker rights and environmental degradation, the North American Agreement on Labor Cooperation (NAALC) and the North American Agreement on Environmental Cooperation (NAAEC) were also included to NAFTA as two side agreements and entered force in January 1, 1994 and NAFTA became the first free trade agreement (with a side agreement) for environmental appraisal (Van Roozendaal, 2009).

2.2 Background Information about NAAEC

One of the critical debates about NAFTA has been its environmental impacts. As NAFTA aimed to reduce the trade barriers and encourage investment between Canada, Mexico and the United States, from the environmental perspective, the fear of pollution haven was triggered as two developed countries reached an agreement with a developing country. It was the first time that U.S. environmentalist groups and protesters put pressure on the implementation of such comprehensive free trade agreement. Trade liberalization was expected to cause environmental degradation in Mexico and along the Mexico-United States border region, where Maquiladoras has been operating.³ Besides, the timing of NAFTA was after the establishment of the U.S. environmental regulations, i.e. National Environmental Protection, Clean Air Act and similar other legal regulation, in early 1990s (Raustila, 1995). Newly developed laws regarding the environment could be affected from the terms of the North American Free Trade Agreement. Therefore, actions taken by environmentalist groups, protesters and non-governmental organizations were not only to prevent the probable trade-related environmental damages but also to maintain the existence of established environmental regulations.

As a low income developing country, the concerns were mainly for Mexico. Trade-related increase in economic activities was expected to increase the pollution concentrations in Mexico. As a consequence of lax Mexican environmental regulations, change in production mix and amount of output could be a probable outcome of Mexico's specialization in polluting sectors. This concept is known as the *pollution haven effect* and refers to the relocation of corporations operating in pollution intensive industries from countries with stringent environmental policy and reg-

³Maquiladoras are foreign owned Mexican manufacturing facilities, which export their products to foreign countries. The idea of NAFTA as a comprehensive trade and investment agreement attracted considerable attention to the Mexican Maquiladora industry settled along the Mexico-U.S. border region.

ulations to the ones with laxer environmental rules and regulations. The fear of environmentalists of Mexico becoming the pollution haven of the North American free trade bloc placed Mexico at the forefront of the controversial debates about NAFTA and the environment.

While NAFTA was signed in 1992, actions of the protester groups did not get a favorable outcome throughout the administration of the U.S. President George H. W. Bush. Environmental laws were broadly considered in the text of the North American Free Trade Agreement but there was no special focus on the environmental provisions. Neither the implementation of NAFTA nor progression of side agreements with improved labor and environmental provisions took place during President Bush's administration period. During 1992 U.S. presidential election campaigns, Bill Clinton made his campaign pledge and declared that, he would support the North American Free Trade Agreement only if the labor rights and environmental issues are revisited. Majority of environmentalists were willing to revisit NAFTA to improve the lax Mexican enforcement mechanism with a trilateral commission and give further sanctioning powers to ensure the implication of national environmental laws and policies (Raustiala, 1995).

Within the group of Canada, Mexico and the United States, only United States was supporting the creation of a side environmental agreement. Despite the fact that Canada and Mexico were against the establishment of an environmental side agreement and a multinational commission with extensive powers on NAFTA members, the pressure of environmentalist groups were successful. A separated side accord for environmental provisions was eventually established President Clinton's administration period. North American Agreement on Environmental Cooperation (NAAEC) was completed and signed in 1993 and came into force on the same day that the North American Free Trade Agreement (NAFTA) together

with the other side accord on the labor standards, i.e. North American Agreement of Labor Cooperation (NAALC). That way, NAFTA became the first free trade agreement with side agreement on environment.

The main objective of NAAEC, in general, is to protect of Parties' environments from the adverse effects of liberalization of the international trade. As it is stated in the text of the North American Agreement of Environmental Cooperation, the agreement was prepared to promote the following objectives:

1. *foster the protection and improvement of the environment in the territories of the Parties for the well-being of present and future generations;*
2. *promote sustainable development based on cooperation and mutually supportive environmental and economic policies;*
3. *increase cooperation between the Parties to better conserve, protect, and enhance the environment, including wild flora and fauna;*
4. *support the environmental goals and objectives of the NAFTA;*
5. *avoid creating trade distortions or new trade barriers;*
6. *strengthen cooperation on the development and improvement of environmental laws, regulations, procedures, policies and practices;*
7. *enhance compliance with, and enforcement of, environmental laws and regulations;*
8. *promote transparency and public participation in the development of environmental laws, regulations and policies;*
9. *promote economically efficient and effective environmental measures; and*
10. *promote pollution prevention policies and practices.*

*(North American Agreement on Environmental Cooperation, Article 1)*⁴

⁴For the full text of NAAEC, see [http : //www.cec.org/sites/default/files/naaec.pdf](http://www.cec.org/sites/default/files/naaec.pdf)

The commission established under NAAEC was called as the North American Commission for Environmental Cooperation (CEC). The major goals of this commission were determined as promoting environmental cooperation across Canada, Mexico and the United States; enhance the national environmental laws and regulation mechanisms, and dispute resolution process in line with the North American Free Trade Agreement.

2.3 Some Facts About Post-NAFTA Trade and CO_2 Emission Patterns

The constitution of the North American cooperation generally considered as a response to the European trading bloc (Hufbauer and Schott, 1992). The decision of the European Community (EC) to form a single market in 1993 led free movement of labor, capital, goods and services across the borders of the European countries.⁵ Closer economic and institutional integration among European countries placed the European Union to an important position in the international arena. Even though NAFTA did not create a North American Union as European Union did, creation of the North American alliance made great contributions in terms of economic growth, enhanced trade and investment. Being a member of the North American trading bloc, which has almost the same economic size and population as EU did, brought NAFTA member states to a position where they became capable of competing with the single market of the European Union. Today, the size of the European market is greater than the North America's, however, the cooperation among the NAFTA constitutes the second great free trade pact on a global scale (Romalis, 2007).

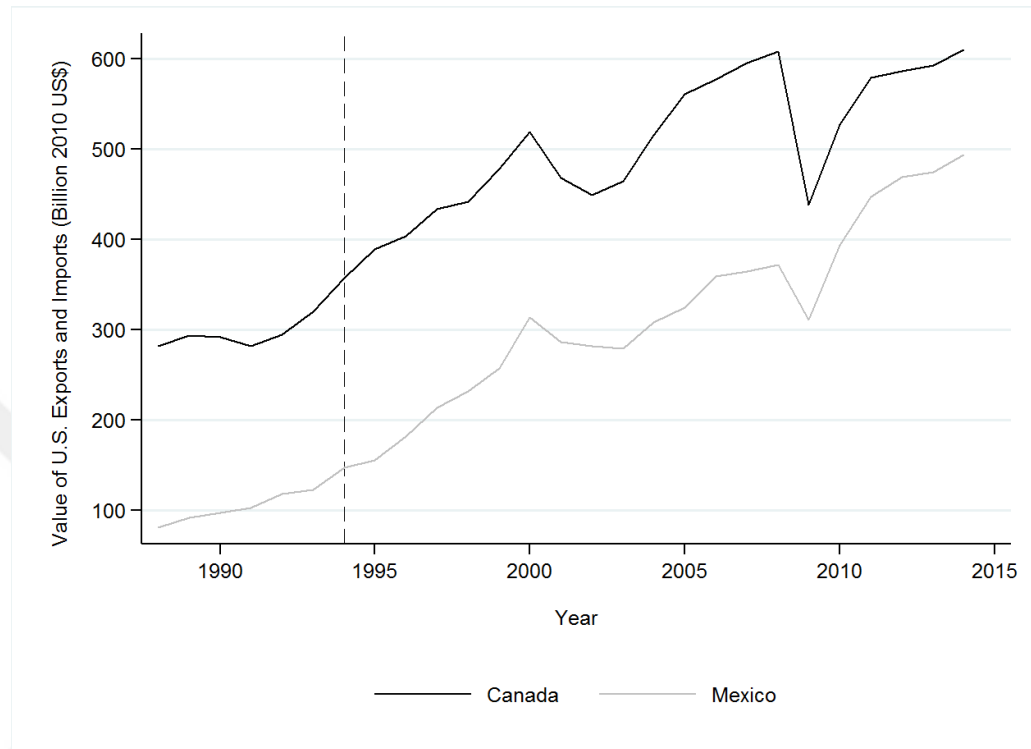
⁵For further information, see <https://europa.eu/european-union/about-eu/history>.

Same controversial discussion also exists when the significant increase in Canada-U.S. and Mexico-U.S. trade trends are evaluated. Some argue that, NAFTA made a great contribution to North American integration, concerning the boost in intra-NAFTA trade volumes and foreign direct investment. However, others believe that signature of NAFTA has a little effect on the North American cooperation. As stated by Hufbauer and Schott (2004), same trade volume boost, especially bilateral trade between Mexico-U.S. would have happen if NAFTA had not been signed in 1992.

Despite debates over the impacts of NAFTA on member nations, it should not be surprising that, a wide variety of conclusions have been obtained. A group of researches focuses on the benefits of the North American integration, while others support that NAFTA has been a costly deal for its member. Hence any change in economy is dynamic and multidimensional, it is simply too complicated to observe the impact of the implementation of such comprehensive trade and investment agreement in isolation from other macroeconomic events on the overall economy. However, following graphs help to gain insight into how U.S. trade flows figure in the pre-NAFTA (i.e. 1988-1994) and post-NAFTA (i.e. 1994-2014) era.

Figure 1 presents the value U.S. total trade on goods with Canada and Mexico. There is a remarkable increase in the value of the U.S. trade with Canada and Mexico throughout the period 1988-2014. As shown in the figure, the difference between the values of the U.S. total trade with Canada and Mexico is much smaller in 2010 compared to 1988 values. Further, the value of the U.S. total trade with both countries show similar fluctuations through time. Figure 2 provides a supportive evidence for the Figure 1, in showing the U.S. imports of goods from Canada and Mexico. Despite the fact that, the value of the U.S. imports from Canada exceeds the value of the U.S. imports from Mexico, we observe that,

Figure 1: Value of the U.S. Total Trade (Exports and Imports) of Goods with Canada and Mexico, 1988-2014



SOURCE: Author's calculation. Data of trade on goods is received from CENSUS and turned into real values with U.S. CPI data received from World Bank and reported in constant 2010 U.S. Dollars.

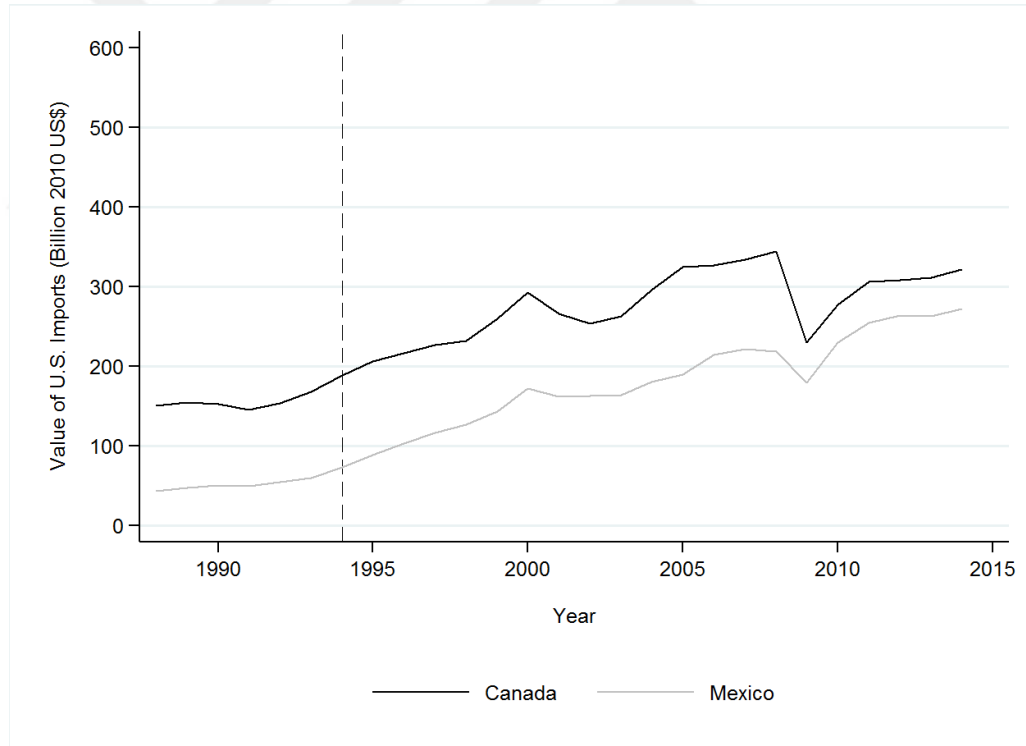
NOTE: The black dashed line represents the year 1994, when NAFTA was implemented.

the difference of the value of the U.S. imports from Canada and Mexico becomes smaller over time. At this point, there are several remarks need to be considered.

In the pre-1994 era, trade between Canada and the United States was liberalized with the Canada-U.S. Free Trade Agreement in 1989. However, NAFTA was the exact origin of the trade liberalization between Mexico and the United States. Mid-1980s were politically critical and economically turning point years for the Mexican economy because of the transition from highly protective to liberal trade policy regime. Prior to the mid-1980s, Mexico's priority was the improvement and the protection of its national industries. Performance of the Mexican economy

as one of the greatest oil producers was successful under the Import Substitution Industrialization (ISI) model. Given the external debt that Mexico had, rapid reduction in the world oil prices hit the Mexican economy in the early 1980s and caused Mexico to suspend its payments. The 1982 Latin American debt crises was one of the major factors led the Mexican administration to pursue neoliberal policy reforms and to take initiative steps for liberalized trade: first step was the General Agreements on Tariffs and Trade (GATT) in 1986, and second step was the North American Free Trade Agreements (NAFTA) in 1992.

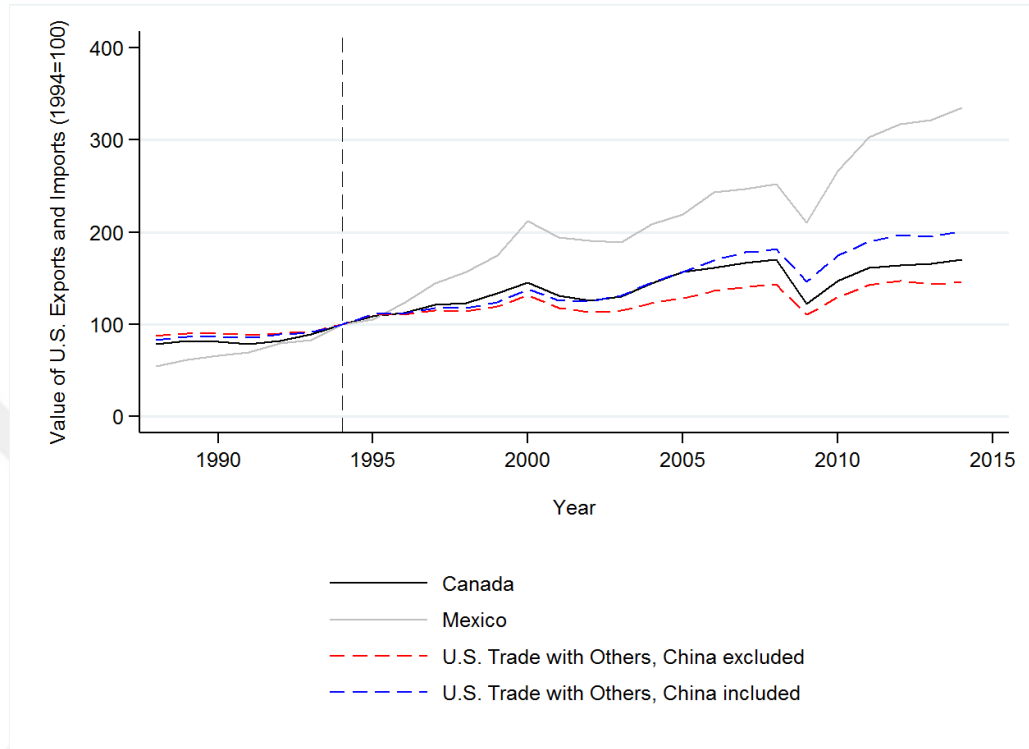
Figure 2: Value of the U.S. Imports of Goods from Canada and Mexico, 1988-2014



SOURCE: Author's calculation. Data of trade on goods is received from CENSUS and turned into real values with U.S. CPI data received from World Bank and reported in constant 2010 U.S. Dollars.

NOTE: The black dashed line represents the year 1994, when NAFTA was implemented.

Figure 3: Value of the U.S. Total Trade (Exports and Imports) of Goods, 1994=100

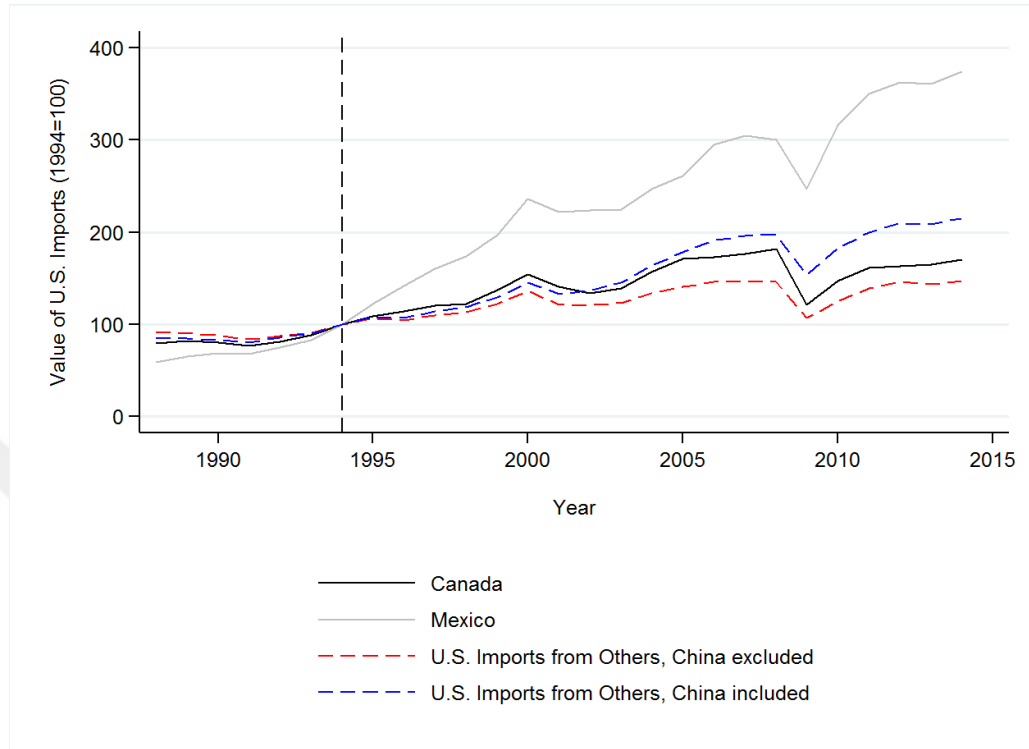


SOURCE: Author's calculation. Data of trade on goods is received from CENSUS and turned into real values with U.S. CPI data received from World Bank and reported in constant 2010 U.S. Dollars.

NOTE: The black dashed line represents the year 1994, when NAFTA was implemented.

Figure 1 and Figure 2 provides a general opinion about the actual values of the value of the U.S. trade with Canada and Mexico for the period 1988-2014, however, Figure 3 and Figure 4 are certainly more intuitive due to their demonstrative power of pre-NAFTA and post-NAFTA U.S. trade flows. Hence NAFTA came into effect in 1994, 1994 values of the U.S. trade with Canada, Mexico and other major U.S. partners (both including and excluding China) are set as 100 both in Figure 3 and Figure 4. By this means, we obtain a clear vision of pre-NAFTA and post-NAFTA changes of the U.S. trade on goods with its NAFTA and non-NAFTA importing partners. Figure 3 demonstrates the U.S. total trade with Canada, Mexico and the other major U.S. importing partners, while Figure

Figure 4: Value of the U.S. Imports of Goods, 1994=100



SOURCE: Author's calculation. Data of trade on goods is received from CENSUS and turned into real values with U.S. CPI data received from World Bank and reported in constant 2010 U.S. Dollars.

NOTE: The black dashed line represents the year 1994, when NAFTA was implemented.

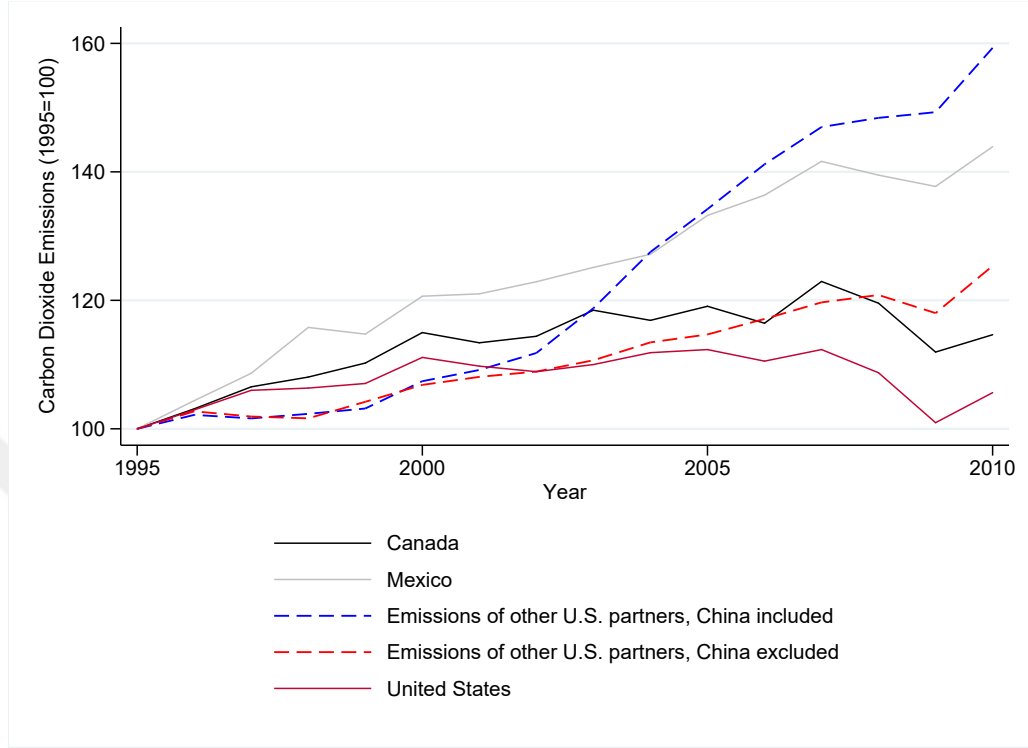
4 illustrates the U.S. imports of goods from Canada, Mexico and other major U.S. importing partner. We observe that, the increases in the U.S. total trade with Mexico and U.S. imports from Mexico are more pronounced in Figure 3 and Figure 4. As shown by the figures, following the trade liberalization between Mexico and the United States, the value of the U.S. trade with Mexico increased much more relative to the U.S. trade with Canada and the other major U.S. importing partners. As previously stated, the Canada-U.S. trade liberalization was started with the CUSFTA in 1989, prior to the NAFTA. Since CUSFTA was in force prior to the NAFTA, implementation of NAFTA starting from 1994 did not dramatically change the rules of trade for Canada. However, NAFTA was the beginning of the

liberalized trade between Mexico and the United States. From both Figure 3 and Figure 4, we observe that, the increase in the value of the U.S. trade with Canada is increasing over time, however, this increase is relatively stable throughout the period 1988-2014. We also observe the same stable pattern for the increase in the value of the U.S. trade with other major U.S. importing partners. Despite the fact that trade liberalization between Mexico and the U.S. was later than Canada, the enhanced increase in the value of the U.S. trade with Mexico started with the transitional period from protectionist to liberalized Mexican trade policy and became greater with the implementation of the NAFTA, which reduced the bilateral trade resistance between Mexico and the U.S.⁶

As we turn our focus from the post-NAFTA trade patterns to the carbon dioxide emissions of NAFTA and non-NAFTA U.S. importing partners, we again observe a remarkable increase in the volume of the carbon dioxide emitted by Mexico. Figure 5 illustrates the carbon dioxide emissions from fuel combustion, while Figure 6 demonstrates the carbon dioxide emissions to GDP ratio for Canada, Mexico, U.S. and other major U.S. import partners. Figure 5 covers the period 1995-2010 and shows the carbon dioxide emissions from fuel combustion, where the volume of the emissions are set as 100 in 1995. In this way, we obtain post-NAFTA relative carbon dioxide emission patterns. In particular, the volume of the carbon dioxide emissions generated by Mexico increased faster than the volume of carbon dioxide emitted by both Canada and the U.S. within the period of 1995-2010. Although the volume of the carbon dioxide emissions generated by Canada are greater than the emissions generated by the U.S., the trends of carbon dioxide emitted by Canada and the U.S. fluctuates similarly throughout the period

⁶It is worth noting that, NAFTA's implementation is a multiple-stage progress, implying that, NAFTA did not rapidly reduced or removed trade barriers immediately in 1994. Governments of Canada, Mexico and the United States agreed on reducing barriers within a period of time starting from 1994. For this reason, it is more rational to consider the impacts of NAFTA throughout a period rather than an event occurred at a point of time.

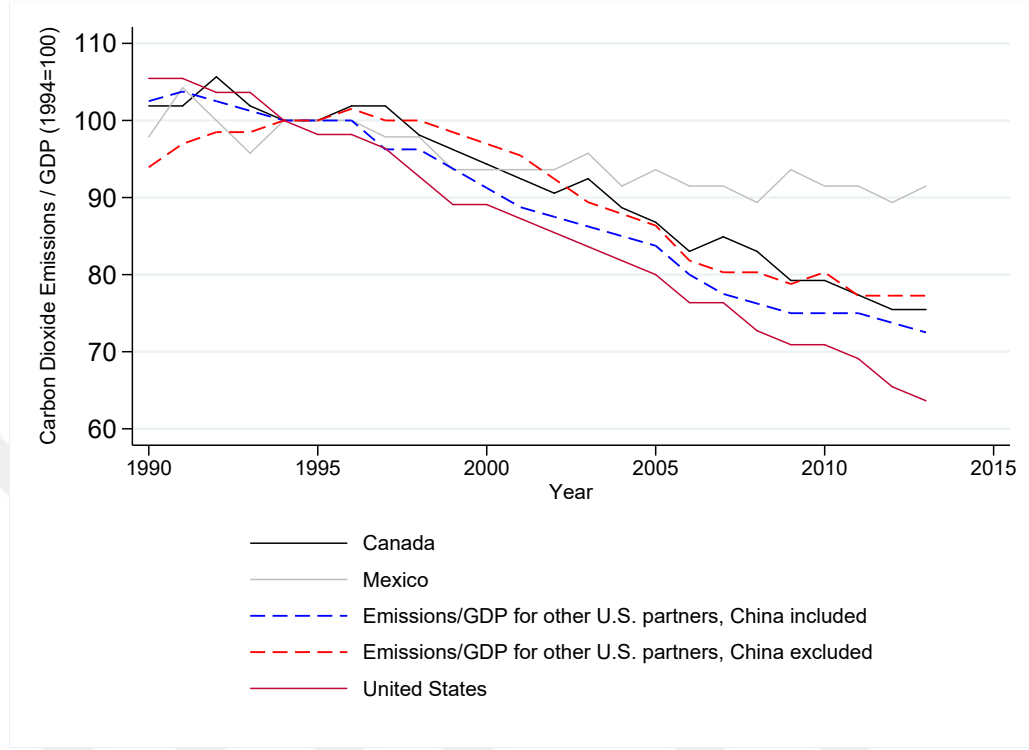
Figure 5: CO_2 Emissions from Fuel Combustion, 1995=100



SOURCE: Author's calculation. Data on CO_2 Emissions from Fuel Combustion is provided by CO_2 Emissions from Fuel Combustion (2015) documentation published by the International Energy Agency (IEA).

1995-2010. Moreover, we observe that, the increase in the Mexico's carbon dioxide emissions is highest among all U.S. importing partners except China. Figure 6, on the other hand, provides a different perspective on the emissions concept. Figure 6 covers the period 1980-2014 and presents the carbon dioxide emissions to GDP ratio, where we set the ratio as 100 in 1994. By this means, we observe the reduction in the amount of carbon dioxide emissions per dollar of output produced over time. As it is shown in both figures, the emissions to GDP ratio shows the largest decline and is the lowest among its both NAFTA and non-NAFTA import partners.

Figure 6: CO_2 Emissions to GDP Ratio, 1994=100



SOURCE: Author's calculation. Data on CO_2 Emissions to GDP ratio is provided by CO_2 Emissions from Fuel Combustion (2015) documentation published by the International Energy Agency (IEA).

To sum up, NAFTA offered a great opportunity to Mexico as it gave access to one of the largest markets of the world. Following NAFTA, Mexican trade with United States showed a rapid increase compared to the other U.S trade partners. In the light of this, given the information about the emissions generated by Mexico, we are interested in the adverse environmental impacts of NAFTA. From the environmental perspective, our focus is particularly on the carbon dioxide embodied in the U.S. imports. In order to evaluate the post-NAFTA U.S. trade and carbon content of the U.S. trade, we employ the gravity model of trade. Before addressing the previous studies on the gravity model and explaining the methodology we adopted for this thesis, we first provide a brief literature review on the association of trade liberalization, environment and NAFTA in the following chapter.

CHAPTER III

LITERATURE REVIEW

NAFTA is a comprehensive free trade and investment agreement, which enables freer trade between member countries and encourage investment across the borders of North American free trade bloc. In the literature, there are various studies analyzing NAFTA from different perspectives. In this thesis, however, our focus is on the U.S. imports; carbon dioxide intensity of the production in the U.S. partner countries and carbon dioxide content of the U.S. imports from those countries. Therefore, in this chapter, we briefly explain the literature on the impacts of NAFTA on the trade and investment patterns; on the environmental quality; rules and regulations in member countries, and finally, on the association between NAFTA and the pollution haven hypothesis.

3.1 NAFTA's Impacts on Trade and Investment

As a trade and investment agreement, NAFTA would expected to strengthen the intra-NAFTA trade and investment relations, while contributing to the economic growth and development of member countries. A number of studies support that

NAFTA made a substantial contribution to the economic growth of the parties involved to the North American Free Trade Agreement, while others consider the size of the effect on the trade related economic growth as modest.

Krueger (1999) observes the preliminary impacts of NAFTA on trade patterns. Krueger (1999) specifically focuses on the trade flows between Mexico and the United States. She states that, Mexican trade liberalization and exchange rate regime are two critical issues that also influence the Mexican trade patterns since mid-1980s. She uses a dataset covering sixty-one countries that accounts about the 80% of the world trade and analyzes the trade flows and U.S. market shares with an aggregate level data. She presents that, even prior to the NAFTA, two third of the Mexican trade was with the U.S. She also uses a commodity-level data to investigate that increasing share of U.S. imports from both NAFTA and non-NAFTA countries and clarifies that, NAFTA has a trade creating impact. Krueger (1999) claims that, Mexican trade liberalization during mid-1980s and change in exchange rate also made great contribution to expanding trade volumes in 1980s, and finally, she concludes that, NAFTA has relatively small influence on the trade patterns compared to the impacts of changing real exchange rate and liberalized trade.

Kose et al. (2004) argue that, NAFTA dramatically increased the Mexican trade and financial flow. They provide statistics to support that, there is a NAFTA-related growth in Mexico, and as a policy recommendation, authors conclude that, developing countries should increase the globalization process in the same way as Mexico did.

According to Moreno Brid et al. (2005), there are pros and cons of the implementation of the NAFTA. Authors claim that, there is a positive NAFTA effect on

the Mexico's transition from being an oil-exporting country to one of the greatest exporters of the manufacturing industry across the world. However, observed trade related Mexican economic growth is detected as slower than expected.

Montenegro and Soloaga (2006) use a gravity model framework to evaluate the difference between U.S.-Mexico and U.S.-third parties trade flows following the NAFTA. They use a worldwide international trade data consisting of 120 countries, which represent ninety percent of the world trade for the period 1988 to 2003. They set 1988 to 1991 as the pre-NAFTA period, while setting 1997 to 2000 as post-NAFTA era. Their result indicate that, there is no evidence for any change in the U.S. trade patters in a way that can create trade diversion at expense of third countries.

In his paper Romalis (2007) explore that, CUSFTA and NAFTA enhanced intra-NAFTA trade, however, had a modest impact on the welfare. He derives a difference-and-difference based model and applies to a product-level trade dataset covering of 5,000 HS-6 commodities for the period 1989-1999 to compare the Canada's and Mexico's trade with U.S. compared to the European Union's trade with the U.S. in the same product groups.

Although there are studies either support or oppose the positive impacts of NAFTA on the trade-related economic growth, the general view is that it is difficult to isolating the effect of a free trade agreement on the trade patterns within a complex and multi-dimensional structure of the overall economy. As stated by Villareal and Fergusson (2015), there have been post-implementation periods of negative and positive economic growths in Mexico. From the Canadian perspective, the effect was neither improving nor damaging.

3.2 NAFTA and the Environment: Impacts on the Environmental Quality, Rules and Regulations

In the past few recent decades, increasing importance of international trade and environment linkages have been the subject of considerable interest of the researchers and a large body of research in the literature. Especially for NAFTA, trade and environment relation has been attracting considerable attention because of the difference between the development levels of the member countries and adverse effects of such a comprehensive trade and investment agreement.

An early assessment of Grossman and Krueger (1991), which is a study done prior to the NAFTA, uses reduced-form estimation model to show that, for two of three pollutants (sulfur dioxide and smoke), an increase in per capita GDP leads to higher levels of pollution at low-national income regions. However, increase in per capita income leads to lower levels of pollution concentration at high-national income urban areas. For the Mexican case, trade liberalization is expected to trigger the economic growth in Mexico. Authors state that, an increase in Mexico's per capita income to 4,000 - 5,000 U.S. dollars in the post-liberalization era would result in a reduction in the country's pollution concentrations.⁷ Further, their results indicate that, within the NAFTA framework, trade liberalization would lead Mexico to specialize in labor-intensive and agricultural sectors. This would save Mexico from becoming a pollution haven in the post-NAFTA era.

Grossman and Krueger (1995) indicate that, economic growth does not lead to an inevitable environmental degradation. Their results are supportive of the results provided by Grossman and Krueger (1991, 1993). Grossman and Krueger

⁷In the literature, this relation is known as the *Environmental Kuznet's Curve*. According to the Environmental Kuznet's Curve, there is a threshold income level, at which the relation turns downward and result in a higher demand for environmental quality.

(1995) also indicate, an increase in gross domestic product can be considered as a reason to intensified pollution in very low-income countries. In other words, pollution concentrations are expected to increase until a threshold level of per-capita GDP is achieved. As the threshold level is achieved, at which demand for higher environmental standards start to increase, the pollution concentrations are expected to be reduced. Authors emphasize that, this linkage may present at different threshold levels across different types of pollutants and state that, those threshold levels belonging to various pollutants are generally below the 8,000 1985 U.S. dollars.

Husted and Logsdon (1997) express that, the environment of Mexico was worsening before the negotiations of a probable NAFTA in early 1990s. They evaluate Mexico's environmental policymaking and environmental quality with the four criteria of environmental performance: (i) environmental policy, (ii) environmental enforcement, (iii) business behavior, and finally, (iv) environmental quality. They use the dataset on regulatory inspections and plant closings for the period 1982-1995. Authors state, initiation of NAFTA negotiations between Salinas and Bush triggered an improvement in environmental regulations, i.e. environmental policy and enforcement, in Mexico. The data of regulatory inspections and plant closings presented by Husted and Logsdon (1997) shows that, NAFTA induces a positive increase in regulatory inspections and plant closings.

Logsdon and Husted (2000) revisit the early assessment of Mexico's environmental policymaking and environmental quality with the four criteria of environmental performance which were previously stated by Husted and Logsdon (1997). By expanding the data presented by Husted and Logsdon (1997), Logsdon and Husted (2000) state that, environmental policy maintains improvement with the supportive funding. Nevertheless, they evidence the weakening environmental enforcement

mechanism in Mexico. At the business level, environmental support increases, however, further discussion about environmental quality remains unclear due to the fluctuating nature of environmental quality.

Observing the shift in the U.S. manufacturing sector toward cleaner production, Ederington et al. (2004) use industry level data for the period 1972-1994 to see whether there is a trade-related compositional shift in the U.S. imports. They find no evidence to such compositional shift in the U.S. imports. They conclude that, independently from the tariff reductions, U.S. imports were also getting cleaner over the specified time period.

Khanna and Plassmann (2004) focus on five pollutants by looking at the environmental Kuznet's curve relation in the U.S. for the year 1990. They explored that, even the high income households in the U.S. have not reached to the threshold levels at which they demand for a better environmental quality. In other way, even in the U.S. the income-pollution has not yet turn downward in the inverted-U-shaped relation, at which demand for a better environment increases.

Gamper-Rabindran (2006) uses a dataset covering industry level SIC-4 data for the period 1989-1999 to observe the composition, location and technique effects and concludes that at industry level, the adverse environmental consequences of NAFTA, i.e. composition or location effect, in the post-implementation era did not take place in Mexican manufacturing industry. In other words, Mexico did not shift its production to the dirtier industries following the implementation of the NAFTA.

MacDermott (2006) studies the link between the trade liberalization and the pollution haven hypothesis in the NAFTA case by using a industry level data within

the gravity model framework. As a proxy of environmental policy stringency measure, he uses emissions data. He shows that, in the light of increased foreign direct investment flows, NAFTA has influenced the pollution haven effect in an encouraging way.

In his paper Levinson (2009) analyzes the source of emission reductions of four pollutants generated by U.S. manufacturing sector. He observes whether this reduction is occurred because of a technological improvement through a cleaner production or a change in the composition of domestic production and imports. His research is based on two parts. In the first part of his analysis, he decomposes the annual pollution into scale, composition and technique effects. He figures out the technological shift from conventional to cleaner production technologies play the major role in the reduction of manufacturing emissions. In the second part of his analysis, he checks whether imports of pollution intensive goods account for the clean-up of the U.S. manufacturing industry. He concludes, composition effect resulted from international trade flows plays a minor role in the reduction of relevant emissions. He also uses input-output analysis. Similar to Levinson (2009), in this thesis we use the input-output framework to compute the direct and indirect carbon dioxide content of imports to see whether the imports from NAFTA members to U.S. has a significant difference from the its non-NAFTA partners.

Jáuregui Nolen et al. (2010) use a state-level data to analyze the relation between NAFTA and the pollution originated from manufacturing production in 32 states of Mexico for the period 1993-2000. Their results provide evidence both to the positive effect of trade-liberalization on the pollution levels caused by the Mexican manufacturing industry and to support the evidence of the environmental Kuznets curve.

Lipford and Yandle (2010) illustrate from environmental Kuznets curve that, Mexico's per capita income growth has been moderate and insufficient to provide a better environmental quality in Mexico. For many pollutants, the per capita income in Mexico remains below the turning point, where demand for a better environment excels the environmental quality. This implies, even though NAFTA contributed Mexico's macroeconomic performance, it has not been sufficient to provide a better quality environment in Mexico.

In his paper, Cherniwchan (2017) explores the relationship between NAFTA's impact on level of pollution generated by U.S. manufacturing plants. Cherniwchan (2017) especially focuses on the concentrations of PM_{10} and SO_2 following the NAFTA. He uses a panel data analysis covering the period starting from 1991 to 1998. His results show that, NAFTA has a reducing effect on the PM_{10} and SO_2 emissions generated by the U.S. manufacturing industry.

In this thesis, we examine the U.S. imports and the carbon dioxide content of the U.S. imports from NAFTA partners vis-à-vis non-NAFTA U.S. importing partners throughout the period 1995-2010. This allows us to observe whether the implementation of NAFTA had a significant change in U.S. import patterns and the pollution embodied U.S. imports. As we are interested in the trade liberalization between Canada, Mexico the United States and the carbon dioxide content of the U.S. with its NAFTA member importing partners, we addressed several studies on the association of trade, environment and NAFTA. To observe the post-NAFTA U.S. import levels and carbon dioxide content of the U.S. imports, we apply the gravity model of international trade to an industry level data. The following chapter provides the literature review on the gravity model of international trade.

CHAPTER IV

THE GRAVITY MODEL OF INTERNATIONAL TRADE

In this thesis, the main focus is on the volume and the carbon dioxide content of the U.S. imports from its NAFTA, i.e. Canada and Mexico, and its non-NAFTA trading partners in the post-NAFTA era. For this purpose we use the gravity model of international trade. The application of the gravity model to examine the change in the carbon content of trade following the Kyoto Protocol is studied by Aichele and Felbermayr (2015). In this study, we adopted the same methodology of computing carbon dioxide content of imports and also applied gravity model to good and carbon dioxide amounts. Our focus is to explore whether the carbon dioxide intensity and carbon dioxide content of the U.S. imports from Canada and Mexico change with a comprehensive regional free trade and investment agreement.

The gravity model of trade has become one of the intensely used models in international trade over the past few decades. Tinbergen (1962) was one of the pioneers of the literature, who introduced the specification of the gravity model to economics. The standard equation was inspired by the Newton's Law of Universal Gravitation in physics, which states that the gravitational force between any attracting particles in the universe is directly proportional to the product

of particles' masses and inversely proportional to the square of distance between the centers of the particles (Newton et al., 1952). Tinbergen (1962) became the first to bring an economic perspective to the concept of the gravitational force and proposed that bilateral trade flows between any trading countries are directly proportional to the products of their economic sizes, generally represented by the gross domestic products of countries, and inversely proportional to the geographical distance between relevant countries.

The simple gravity equation is defined as follows:

$$X_{ij} = \beta_0 \frac{(Y_i)^{\alpha_1} \times (Y_j)^{\alpha_2}}{(D_{ij})^{\alpha_3}}$$

or in log-linear form

$$\ln X_{ij} = \alpha_0 + \alpha_1 \ln Y_i + \alpha_2 \ln Y_j + \alpha_3 \ln D_{ij}$$

$$(\alpha_1 > 0, \alpha_2 > 0 \text{ and } \alpha_3 < 0)$$

where X_{ij} stands for the value of bilateral trade flows from country i to country j ; Y_i and Y_j represents the size of the economic activities of country i and country j , respectively; and finally, D_{ij} is the geographic distance measure between the trading partners. Coefficients α_1 , α_2 and α_3 present the elasticities of economic sizes and the distance measure. Expected signs for α_1 and α_2 are positive, while negative for α_3 .

Due to its explanatory power in bilateral trade flows between trading entities, the gravity model became popular and widely used in the empirical international trade literature. Despite its common usage in the empirical research, theoretical support was developed later.

Anderson (1979) became the first, who brought a theoretical explanation to the gravity model. In his seminal paper, he derived gravity equation from a conditional general equilibrium model with constant-elasticity-of-substitution (CES)

preferences over the Armington assumption, implying each country completely specializes in the production of a good which is not produced by any other countries.⁸ He also supported with some evidence that, increases in economic activities increase, while increasing costs reduce the international trade between countries.

Bergstrand (1985) provided further micro foundations to the theoretical literature on the gravity model. Bergstrand (1985) also developed a general equilibrium model with similar assumptions as in Anderson (1979). He constructed a model with CES preferences over the Armington assumption. In addition, he included price indexes (P_i and P_j) to the standard gravity specification exogenously by assuming constant utility and production across the countries.

Foundations were followed by Bergstrand (1989) as he expanded Bergstrand (1985) by diverging from complete specialization. He developed a model of two factor, two industry, n country economy to explain the intra-industry trade. He showed that, gravity equation can be obtained by assuming monopolistic competition in differentiated goods. Helpman and Krugman (1985) and Helpman (1987) also derived theoretical gravity equation within monopolistic competition in differentiated good models.

McCallum (1995) explored the border effects on international trade within the gravity framework and showed that Canadian trade between provinces are much greater than the Canadian trade with the United States due to increasing transaction costs, such as legal differences, across borders.

Deardorff (1998) discussed the correspondence between gravity equation and the Heckscher-Ohlin model of classical trade theory. He showed that, gravity model is

⁸See Armington (1969).

also supported within Heckscher-Ohlin model under identical or CES preferences and complete specialization.

Eaton and Kortum (2002) derived a Ricardian model of trade, in which both geographic barriers and technological differences among countries are influential factors of specialization.

Anderson and Van Wincoop (2003) pointed out the importance of the multilateral resistance terms for the gravity model of trade. They included multilateral resistance terms to the model presented by McCallum (1995) and showed that, Canadian trade between provinces are not as much as than the Canada-U.S. trade as McCallum (1995) was stated.

Haveman and Hummels (2004) developed a new point of view to the Neoclassical trade models with incomplete specialization and demonstrated the similarity between the models of complete and incomplete specialization.

Silva and Tenreyro (2006) elaborated on the estimation technique of the gravity model and pointed out that, Ordinary Least Squares (OLS) is not an appropriate estimation technique for log-linearized gravity equation hence it creates heteroskedasticity problem, which leads to biased OLS estimates. They instead propose Poisson Pseudo Maximum Likelihood (PPML) estimation method. With Monte Carlo simulations, they compare the performance of two estimators, and show that PPML is more appropriate to deal with estimation problems that arise in the presence of heteroskedasticity and zeros in trade data between pairs of countries.

Chaney (2008) and Helpman et al. (2008) derives gravity models with firm heterogeneity. Model derived by Helpman et al. (2008) decomposed the effects of

trade frictions into intensive and extensive margins, respectively. As defined by Helpman et al. (2008), extensive margin stands for the number of exporters, while intensive margin refers to the volume of the trade. Likewise Silva and Tenreyro (2006), the model derived by Helpman et al. (2008) is also capable of dealing with zeros in trade data.

In conclusion, there is a large body of literature focusing on the gravity model of international trade from theoretical and empirical perspectives. In this thesis, we employ the gravity model of trade to analyze post-NAFTA U.S. bilateral import patterns and the carbon dioxide content of the U.S. imports from Canada, Mexico and other U.S. import partners. In the following chapter, we provide details of the methodology used, derivations and data sources.

CHAPTER V

DATA REQUIREMENTS

In the previous chapter, we mentioned about the theory of the gravity model of trade. We employ the *bilateral trade flows (imports) of the U.S. and its trading partners*, *carbon dioxide intensity of the production in the partner (exporter) countries*, and finally, *carbon dioxide content of the U.S. imports* for the dependent variable.⁹ The data on the bilateral trade flows are reported at industry level and they are readily available. The data for carbon dioxide intensity and carbon dioxide content of trade at industry level are, however, need to be computed. To do this, we adopted the methodology proposed by Aichele and Felbermayr (2015) and we constructed our own data of bilateral carbon dioxide emissions embodied in the U.S. imports from its major importing partners in nineteen industries for the period 1995-2010. In this chapter, the main objective is to provide explanations for a variety of data and data sources that we use directly in our empirical analysis

⁹There are datasets presenting the carbon dioxide embodied international trade, however, they don't fulfill the requirement of this thesis because of two reasons. First, these datasets are formed by using world input-output tables. As explained by Aichele and Felbermayr (2011), to observe the amount of emissions relocated from a country to another, using a single-region (national) input-output tables are preferred over multi-region (world) input-output tables. Second, these datasets do not cover some of the countries included in our analysis.

and in the required computation. A full list of relevant data and data sources is also available in Appendix A.

In this thesis, we will analyze the carbon content of trade in addition to explaining the trade amounts. The gravity model is also applied to explaining the carbon dioxide content of the intermediately traded goods across international exchange. One such study is conducted by Aichele and Felbermayr (2015). In their paper, Aichele and Felbermayr (2015) construct a gravity model for carbon dioxide content and analyze the bilateral trade flows to explore whether Kyoto Protocol caused to carbon leakage.^{10,11} To do this, they compute and compare the carbon content of Kyoto and non-Kyoto countries. As a result, they find a relevant evidence for carbon leakage under Kyoto Protocol. According to Aichele and Felbermayr (2015), the increase of the carbon imports of a Kyoto member country from a non-Kyoto country is about 8%.

The following section explains the empirical derivation of the carbon dioxide content of the international trade adopted from Aichele and Felbermayr (2015).

5.1 Derivations of CO_2 Intensity and CO_2 Content of Trade

In order to generate our dependent variables, we use the following derivation of input-output modeling. The simple idea behind the theory is that, *output of a sector can either be used as an intermediate input by another sector or become a part of the final demand*. In deriving the carbon dioxide content of trade (imports), we need the information about the inter-industrial transactions within an economy.

¹⁰For the theoretical derivation of the gravity model for carbon dioxide emissions, see Aichele and Felbermayr (2015).

¹¹Carbon leakage is a specific type of pollution haven. It refers to the relocation of the carbon intensive industries to cross border nations with lax environmental policies and regulations.

Let matrix A be the $n \times n$ square structural matrix presenting the direct input requirements coefficients.

$$A_{n \times n} = \begin{bmatrix} a_{1,1} & a_{1,2} & \dots & a_{1,n} \\ a_{2,1} & a_{2,2} & \dots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1} & a_{n,2} & \dots & a_{n,n} \end{bmatrix}$$

Elements of direct input requirements coefficients matrix, i.e. $a_{i,j}$ ($i, j = 1, \dots, n$), is referred either as input or technical coefficients and present the amount of the output of sector i that is delivered to sector j to produce a unit of its own sectoral product. As stated by Leontief (1986), the structural matrices are obtained from the input-output tables, which are prepared in terms of values. In order to obtain input coefficients, the value of sector i 's output delivered to sector j should be divided by the value of sector j 's total sectoral output.¹² Thus, input coefficients can also be interpreted as the dollar amounts of sector i 's output delivered to sector j to produce a dollar of its own sectoral output.

In this thesis, however, we need total input requirements matrix rather than direct input requirements matrix. The difference between direct and total input requirements matrices is as follows: a direct input requirements matrix presents only the amount of sector i 's output required to sector j to produce its sectoral output. This neglects the sector i 's industrial transactions with sectors other than j . Hence sector j needs also other sectors' products in order to maintain its production, using direct requirements matrix is therefore incomplete. Using total requirements matrix, on the other hand, provides the direct and indirect input coefficients.

¹²In this thesis, we use an input-output table described in terms of U.S. dollars.

Let $B = (I - A)^{-1}$ be the $n \times n$ total requirements matrix, i.e. Leontief total requirements matrix, where I is the $n \times n$ identity matrix. Each element of total requirements matrix are denoted by $b_{i,j}$ ($i, j = 1, \dots, n$).

$$B_{n \times n} = (I - A)^{-1} = \begin{bmatrix} b_{1,1} & b_{1,2} & \dots & b_{1,n} \\ b_{2,1} & b_{2,2} & \dots & b_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n,1} & b_{n,2} & \dots & b_{n,n} \end{bmatrix}$$

Each element $b_{i,j}$ stands for the dollar amount of sector i 's output that is delivered to sector j to produce a dollar of its own sectoral output, including the amount of i used in all other sectors that are also necessary for sector j to maintain its production (Levinson, 2009).

To obtain the pollution embodied in international trade (imports) we use matrix B to calculate the direct and indirect pollution coefficients. For this purpose, we first need to calculate the pollution coefficients as follows:

Let P be the $1 \times n$ vector of sectoral pollution.

$$\underbrace{P_{1 \times n}}_{\text{Sectoral Pollution Vector}} = \begin{bmatrix} P_1 & P_2 & \dots & P_n \end{bmatrix}$$

In order to obtain the sectoral pollution coefficients, we divide each element of the pollution vector with that sector's total output and obtain the $1 \times n$ sectoral pollution coefficients matrix, i.e. vector p . Each element of vector p , i.e. p_k ($k = 1, \dots, n$), presents the pollution per dollar of output.

$$\underbrace{p_{1 \times n}}_{\text{Sectoral Pollution Coefficients Vector}} = \begin{bmatrix} p_1 & p_2 & \dots & p_n \end{bmatrix}$$

Multiplying the $1 \times n$ sectoral pollution coefficients vector (p) with the $n \times n$ Leontief total (direct and indirect) requirements matrix (B) gives the $1 \times n$ vector of direct and indirect sectoral pollution coefficients (C) for each sector.

$$\underbrace{\begin{bmatrix} p_1 & p_2 & \dots & p_n \end{bmatrix}}_{p_{1 \times n}} \times \underbrace{\begin{bmatrix} b_{1,1} & b_{1,2} & \dots & b_{1,n} \\ b_{2,1} & b_{2,2} & \dots & b_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n,1} & b_{n,2} & \dots & b_{n,n} \end{bmatrix}}_{B_{n \times n}}$$

$$\underbrace{pB}_{1 \times n} = C_{1 \times n} = \begin{bmatrix} c_1 & c_2 & \dots & c_n \end{bmatrix}$$

Up to now, we obtained the direct and indirect pollution coefficients at a sector level that is necessary in computing the pollution embodied in trade (imports). To obtain the pollution content of trade (imports), we multiply the sectoral pollution coefficients vector with the trade matrix.

Let T be the $n \times n$ square matrix of international trade. The diagonal of T matrix represents the value of the trade in n sectors.

$$\underbrace{T_{n \times n}}_{\text{Trade Matrix}} = \begin{bmatrix} t_1 & 0 & \dots & 0 \\ 0 & t_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & t_n \end{bmatrix}$$

Hence our focus is on the pollution content of imports, we define the imports matrix, where diagonal elements present the value of the imports for the specified sector.

$$\underbrace{M_{n \times n}}_{\text{Imports Matrix}} = \begin{bmatrix} m_1 & 0 & \dots & 0 \\ 0 & m_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & m_n \end{bmatrix}$$

Multiplying the $1 \times n$ direct and indirect sectoral pollution coefficients vector (C) with the $n \times n$ imports matrix (M) gives the $1 \times n$ vector of total pollution embodied in imports (E) at a sector level.

$$\underbrace{\begin{bmatrix} c_1 & c_2 & \dots & c_n \end{bmatrix}}_{C_{1 \times n}} \times \underbrace{\begin{bmatrix} m_1 & 0 & \dots & 0 \\ 0 & m_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & m_n \end{bmatrix}}_{M_{n \times n}}$$

$$\underbrace{CM}_{1 \times n} = E_{1 \times n} = \begin{bmatrix} e_1 & e_2 & \dots & e_n \end{bmatrix}$$

To take this relationship to data, we first construct the data on the sectoral pollution coefficients by using data on *direct pollution* and *output* at sectoral level. Then we use the Leontief total requirements matrices and sectoral data on *pollution coefficients* to compute total (direct and indirect) pollution coefficients. At the final stage, we use the sectoral data on the international trade and total pollution coefficients to construct the data on *carbon dioxide embodied in international trade*. In this thesis, the “*pollution*” concept is narrowed down to CO_2 emissions and we specifically focus on the emissions caused by the fossil fuel combustion.¹³ In the rest of the thesis, carbon dioxide emissions will be used instead of pollution.

5.2 Data and Data Sources

5.2.1 Bilateral Trade

Bilateral trade data is required to obtain the import flows of the United States from its importing partners. The data on the bilateral trade between the United States and its importing partners are taken from the United Nations Commodity Trade Database, which is commonly known as UN COMTRADE. The imports data provided by UN COMTRADE is expressed in terms of “Cost, Insurance and Freight (C.I.F)” prices, while the exports data is denominated in “Free On Board (F.O.B)” prices. As our main objective is to analyze the carbon dioxide intensity and carbon dioxide embodied U.S. imports, we need to obtain the pure dollar value of the the U.S. imports from its importing partner. Therefore, we use the data on exports to the U.S., which is reported in F.O.B. prices, instead of the data on the U.S. imports from its importing partners reported in C.I.F. prices.

We collect the trade data at the five-digit SITC, Revision 3 level for nineteen U.S.

¹³As stated in the *CO₂ Emissions from Fuel Combustion (2015)* report published by International Energy Agency (IEA), carbon dioxide emissions generated by the energy sector cover approximately 60% of the global GHG emissions.

Table 1: List of major U.S. Import Partners

ISO-3 Code	Country Name
BRA	Brazil
CAN	Canada
CHN	People's Republic of China
DEU	Germany
FRA	France
GBR	United Kingdom
HKG	China, Hong Kong SAR
IND	India
IRL	Ireland
ITA	Italy
JPN	Japan
KOR	Republic of Korea
MEX	Mexico
MYS	Malaysia
PHL	Philippines
RUS	Russian Federation
SAU	Saudi Arabia
SGP	Singapore
THA	Thailand

This list represents the major U.S. importing partners for 1995 and afterwards. We aimed to maintain minimum of 70% of the U.S. imports representativeness for each year. While this set of countries represent different percentages of the U.S. imports annually, for the overall period (1995-2010) representativeness is in between 74% – 79%. This set is determined with respect to the volume of annual bilateral U.S. imports and data availability. Although Venezuela, Nigeria and some other Asia countries are placed in the list of major U.S. importing partners, due to missing data of input-output tables, it is not possible to do a industry level analysis with those countries. Therefore, we replaced Venezuela, Nigeria and other Asia countries with Brazil, Hong Kong, India, Philippines, Russian Federation, and Thailand. This replacement does not lead to any problem because; both excluded and included countries have the same share of U.S. imports in the overall period. Further, all countries are classified in similar levels of development. Only Hong Kong is classified as a developing country, however, its share of total U.S. imports is maintained around or below 1% for the whole period.

importing partners.^{14,15} The list of the major U.S. trading partners used in this thesis are provided in Table 1. To match the classification of the trade data with other data sources, we used a concordance table provided by the European Union's Ramon server between ISIC, Revision 3 and SITC, Revision 3.¹⁶ The collected data is then aggregated into nineteen ISIC, Revision 3 industries.¹⁷ The list of the ISIC, Revision 3 industry classifications are reported in Table 2.

As shown in the Table 2, ISIC, Revision 3 industry classifications are divided into two groups as *traded* and *non-traded* sectors. Roughly, traded sectors present commodity based industries, while non-traded industries are the service sectors. As we cover the inter-industrial interactions between sectors, both traded industries and non-traded industries have an important role in the computation of the sectoral pollution coefficients and sectoral carbon dioxide intensity of the production of the U.S. trading partners. The necessity of non-traded industries is stressed within the input-output framework under the empirical derivations section. To put it in a different way, we already mentioned the importance of the contributions made by non-traded industries to the production processes of traded industries, or vice versa. Eventually, in calculating the carbon dioxide content of U.S. imports, our focus is on traded-industries only. Therefore, the data on international trade provided by the UN COMTRADE is obtained only for the traded industries.

¹⁴SITC (Revision 3) is the abbreviation of the *Standard International Trade Classification, Revision 3*.

¹⁵ISIC (Revision 3) is the abbreviation of the *International Standard Industrial Classification of All Economic Activities, Revision 3*.

¹⁶For the ISIC (Rev. 3) - SITC (Rev. 3) Concordance Table, see <http://ec.europa.eu/eurostat/ramon/>.

¹⁷The aggregation for the traded industries is done in the following way; first, product level data is aggregated into individual industries. Then, *C01, C02 and C05 to C01T05; C10, C11, C12, C13 and C14 to C10T14; C15 and C16 to C15T16; C17, C18 and C19 to C17T19; C21 and C22 to C21T22; C30, C32 and C33 to C30T33X; C40 and C41 to C40T41*

Table 2: Industry Descriptions According to ISIC, Revision 3

Industry Number	Traded Industry Codes	Industry Description
1	C01T05	Agriculture, Hunting, Forestry and Fishing
2	C10T14	Mining and Quarrying
3	C15T16	Food Products, Beverages and Tobacco
4	C17T19	Textiles, Textile Products, Leather and Footwear
5	C20	Wood and Products of Wood and Cork
6	C21T22	Pulp, Paper, Paper Products, Printing and Publishing
7	C23	Coke, Refined Petroleum Products and Nuclear Fuel
8	C24	Chemicals and Chemical Products
9	C25	Rubber and Plastics Products
10	C26	Other Non-Metallic Mineral Products
11	C27	Basic Metals
12	C28	Fabricated Metal Products
13	C29	Machinery and Equipment, nec
14	C30T33X	Computer, Electronic and Optical Equipment
15	C31	Electrical Machinery and Apparatus, nec
16	C34	Motor Vehicles, Trailers and Semi-Trailers
17	C35	Other Transport Equipment
18	C36T37	Manufacturing nec; Recycling
19	C40T41	Electricity, Gas and Water Supply
Industry Number	Non-Traded Industry Code	Industry Description
20	C45	Construction
21	C50T52	Wholesale and Retail Trade; Repairs
22	C55	Hotels and Restaurants
23	C60T63	Transport and Storage
24	C64	Post and Telecommunications
25	C65T67	Financial Intermediation
26	C70	Real Estate Activities
27	C71	Renting of Machinery and Equipment
28	C72	Computer and Related Activities
29	C73T74	R&D and Other Business Activities
30	C75	Public Administration and Defence; Compulsory Social Security
31	C80	Education
32	C85	Health and Social Work
33	C90T93	Other Community, Social and Personal Services
34	C95	Private Households with Employed Persons

5.2.2 Direct Sectoral Pollution (Emission) Coefficients

As showed in section 5.1 that, the very first step to calculate the pollution embodied in international trade is the calculation of the *sectoral pollution coefficients*. To calculate the sectoral pollution coefficients, it is required to divide direct sectoral pollution by the sectoral output. We use the carbon dioxide emissions from fuel combustion as a proxy for pollution. Thus, for this computation (i) *sectoral carbon dioxide emissions data* and (ii) *sectoral output data* are necessary.

The data of carbon dioxide emissions generated by each industry of each country is obtained from *CO₂ Emissions from Fuel Combustion (2015)* documentation published by the International Energy Agency (IEA). IEA provides the data for 47 products and 40 flows at a country- and region-level.¹⁸ In our analysis, we use the aggregation of all products for specified 30 flows given the set of nineteen countries that are selected for this thesis. Hence the data is originally provided at the IEA-format, it is required to convert IEA-format into ISIC, Revision 3 so that this *CO₂* information match the classification in which trade, sectoral output and input-output table are reported in. This conversion between IEA-format and ISIC, Revision 3 is done using the concordance table provided by OECD. Finally, the unit of the original IEA emissions data is in *Mt of CO₂ (million tonnes of CO₂)* and converted into *Kt of CO₂ (thousand tonnes of CO₂)*.

In the previous subsection, we explained the calculation of the sectoral carbon dioxide emission coefficients. Hence we want to calculate the sectoral carbon dioxide emission coefficients, we need the data on sectoral output. The full set of the sectoral output data is obtained from the harmonised national input-output tables provided by the OECD.

¹⁸The list of flows with their long and short names are provided in Appendix A.

5.2.3 Total (Direct and Indirect) Sectoral Emission Coefficients: CO_2 Intensity of Production

The major aim of this thesis is to analyze the carbon dioxide embodied in international trade. As stated previously, the data for carbon dioxide embodied international trade is not readily available and requires further calculations. In the previous section, we mentioned about the data requirements of sectoral carbon dioxide emission coefficients. To clarify, the data requirement mentioned in the previous subsection is for the computation of *direct* emission coefficients and does not count the indirect emissions of any of the given sectors to the global emissions. In other words, direct emission coefficients present the direct emissions per dollar production for each sector and does not compute the emissions generated by intermediate inputs used in the production of the final good. In simple terms, to calculate carbon dioxide embodied international trade, we need the data of total emission coefficients. The total carbon dioxide emission coefficients cover both direct and indirect emissions. This implies, total emission coefficients includes the carbon dioxide content of the intermediate inputs used in the production of the final output.

To compute the total emission coefficients, we need the data of direct emission coefficients and the Leontief total requirements matrices (or the Leontief inverse matrices) for each country. Leontief inverse matrix provides the information of the total (direct and indirect) input requirements of a sector from all sectors to fulfill the final demand. By this means, as we recall the empirical derivation section, the multiplication of direct emission coefficients with the Leontief total requirements matrix gives us the total emission coefficients for each sector of each country. The OECD provides the national Leontief inverse matrices that presents the inter-industrial transactions of the domestic production for each year in the period 1995-

2010.¹⁹ They are obtained from the harmonised national input-output tables that we previously used for sectoral output data with a commonly used methodology known as Leontief inversion approach.²⁰

5.2.4 Other Variables

The data on the sectoral output, as previously reported, comes from harmonised national input-output tables provided by the OECD and converted into constant 2010 U.S. dollars by using the U.S. consumer price index provided by the World Bank. The data of the real effective exchange rate (REER), which takes the 2010 as the base period, is taken from Bank for International Settlements (BIS). The data on the gravity variables, which includes the bilateral distance, land area of the partner (exporter) country, common official language, come from CEPII Geography database, which is constructed by Head et al. (2010); Mayer and Zignago (2011), and finally, Melitz and Toubal (2014). Finally, for the variables reported in nominal values, conversion to real term is required. This conversion is done by using the annual U.S. Consumer Price Index (CPI) data provided by the World Bank. The CPI data is reported annually and the base period is specified as 2010 (2010=100).

¹⁹We use the Leontief matrices of years 1995, 2000, 2005 and 2010 for the periods 1995-1998, 1999-2002, 2003-2007, and 2008-2010, respectively.

²⁰See Leontief (1986) for further information about Leontief inversion.

CHAPTER VI

ECONOMETRIC MODEL

The general form of the gravity model we used in this thesis is specified as follows;

$$\begin{aligned} \log Y_{i,US,s,t} = & \alpha_0 + \alpha_1 \log (OUTPUT_{i,s,t}/OUTPUT_{US,s,t}) + \alpha_2 \log (REER_{i,t}/REER_{US,t}) \\ & + \alpha_3 \log (Land\ Area_i) + \alpha_4 \log (Distance_{i,US}) + \alpha_5 (Common\ Language) \\ & + \alpha_6 (MEXICO) + \alpha_7 (CANADA) \\ & + \alpha_8 (MEXICO \times Year) + \alpha_9 (CANADA \times Year) \\ & + \varepsilon_{i,US,s,t} \end{aligned}$$

where i represents the trading partner of the United States from where it purchases its imports, s presents the industry, and finally, t is the time.

$Y_{i,US,s,t}$ denotes three dependent variables we use in this thesis. They are listed as follows:

1. *Total industry import flows of the United States from its major importing partners,*²¹
2. *Carbon dioxide intensity of the domestic production of the partner country,*
3. *Carbon dioxide content of the bilateral imports of the United States from its importing partners.*

Table A.3 and Table A.4, in Appendix A, represent the descriptive statistics of our sector level panel data for all of the explained variables employed in this thesis: U.S. imports, carbon dioxide intensity of the U.S. imports, and finally, carbon dioxide content of the U.S. imports. Since Canada and Mexico are two NAFTA members with different development levels, we first provide the summary statistics for Canada and Mexico. Table A.3 provides the descriptive statistics of the value, carbon dioxide intensity and carbon dioxide content of the U.S. imports from Canada and Mexico, respectively. Following this, we repeat the same procedure by dividing countries into two groups as NAFTA member countries and non-NAFTA member countries. Table A.4 provides the descriptive statistics of the U.S. imports from NAFTA and non-NAFTA member countries, carbon dioxide intensity and the carbon dioxide content of the U.S. imports from NAFTA and non-NAFTA member countries. From both tables, we observe that, U.S. imports, carbon dioxide intensity of the U.S. imports and carbon dioxide content of the U.S. imports differ across industries and across countries or country blocs.

The right hand side of the estimation equation consists of the explanatory variables. $OUTPUT_{i,s,t}/OUTPUT_{US,s,t}$ is the ratio of the sectoral output of the partner country to the sectoral output of the United States at time t. $REER_{i,t}/REER_{US,t}$

²¹As indicated earlier, we use export flows of the U.S. importing partners to the United States.

denotes the ratio of the real effective exchange rate of the partner country to the real effective exchange rate of the of the United States at time t . *Land Area* represents the land area of the partner country. $Distance_{i,US}$ is the bilateral distance measure between the capital city of the partner country and the capital city of the United States. *Common Language* is a binary variable which takes the value of 1 whenever the partner country shares the same common official language with the United States and 0 otherwise. *MEXICO* and *CANADA* are NAFTA dummy variables and $MEXICO \times Year$ and $CANADA \times Year$ are the time interactions of the NAFTA dummy variables.

The estimation results, where the value, carbon dioxide intensity and carbon dioxide content of the U.S. imports are explained via gravity model, are presented in the following chapter.

CHAPTER VII

EMPIRICAL RESULTS

In this chapter, we present our empirical results for the impacts of NAFTA on the three dependent variables discussed in the previous chapters; U.S. imports, carbon dioxide intensity of the production of the U.S. importing partners, and finally, carbon dioxide content of the U.S. imports from its major trading partners.²² Our goal is to examine the impact of NAFTA and ask the question whether there are any changes in the value of the U.S. imports, CO_2 intensity and CO_2 content of imports of U.S. following the NAFTA. We evaluate whether Canada and Mexico differ from other major U.S. import partners in the emphasized criteria within the NAFTA implementation era or not.

Due to data availability at the sectoral level, we chose to work with post-NAFTA period and put the emphasis on the period 1995-2010. However, the impact of the global financial crisis through the economies was observed after 2008, which was quite destructive and widespread. Even though the crisis started in 2008, we observe the real impact of the financial crisis on the international trade values in

²²For simplicity, we will refer to carbon dioxide intensity of the production of the U.S. importing partners as carbon dioxide intensity throughout this chapter.

2009 with a sharp and drastic drop in worldwide trade and immediate recovery the following year. Thus, we drop 2009 from all our empirical analyses. With this change, we hope to minimize the influence of financial crisis on our dataset in explaining the U.S. imports, carbon intensity of the production in member countries and the carbon content of the U.S. imports.

We provide the results of the empirical implementation of the gravity model. As the dependent variables are considered, this study shows differences from the mainstream studies of the gravity model estimations. The mainstream studies employing gravity model use aggregate level trade data in order to analyze the bilateral trade relations between trading entities. In this study, we employ a sector level trade data to observe the NAFTA impact on the U.S. imports, carbon dioxide intensity and the carbon dioxide content of the U.S. imports. Within the gravity estimation context, the estimate of the U.S. imports are meaningful as it considers the country specific characteristics' impacts on the bilateral trade. Using carbon dioxide intensity and carbon dioxide content of bilateral trade as dependent variables are, however, uncommon in gravity models. Therefore, especially the results for carbon dioxide intensity should not to be treated as the standard results of a gravity model but should be examined as classical linear regression framework.

The importance of analyzing three of our dependent variables are essential, intuitive and are as follows. First, given the U.S. imports from both NAFTA and non-NAFTA U.S. importing partners for the specified industries, analyzing the U.S. imports verify the information whether there is a significant increase in the amount of the U.S. imports from Canada and Mexico relative to the remaining partners. Second, analyzing the carbon dioxide intensity helps us to see whether there is a significant difference in the production scheme of the NAFTA-member trading partners relative to that which are not NAFTA members. We presume two

possible cases following the implementation of the NAFTA: either there are some technological transfers between member countries that would advance the cleaner technologies in NAFTA member countries in line with improved trade and investment relations or there would be no NAFTA related influence in the production scheme. The first scenario could be interpreted as *NAFTA accelerates the clean-up progress of the member countries*. Third, analyzing the carbon dioxide content of the U.S. imports within the NAFTA implementation era helps us to consider whether U.S. imports from Canada and Mexico became more pollution intensive relative to the U.S. imports from non-NAFTA trading partners.

As explanatory variables, we choose the sectoral output ratio of trading partner to the U.S., real effective exchange rate ratio of trading partner to the U.S., gravity variables (land area of the partner country, bilateral distance measure between the capital cities of trading entities, common official language), and finally, NAFTA dummies for Canada and Mexico together with their interactions with year, i.e. *Canada x Year* and *Mexico x Year*, to see whether there is a different relation between U.S.-Canada and U.S.-Mexico compared to other non-NAFTA U.S. importing partners and whether through freer trade and increased imports there is carbon dioxide replacement from the U.S. to its NAFTA trading partners.

Here, we choose to differentiate between Canada and Mexico in the formulation of the regressions due to the fact that two countries are quite distinct in their level of economic development, culture and geographic location with respect to U.S. We expect to see different factors to be involved in the decisions pertaining to trade and environmental in these two countries.

In estimating the given gravity estimation, we use three empirical estimation techniques: (i) pooled Ordinary Least Squares (OLS), (ii) panel Fixed Effects

(FE), and finally, (iii) Poisson Pseudo Maximum Likelihood (PPML) estimation approaches.

For the model selection among the discussed models, we use model specification tests to determine which panel specification is more appropriate for our regression analysis. To specify either pooled OLS or panel Fixed Effects estimation technique is more appropriate for estimating the relationship, we use the F-test for the joint significance of fixed effect coefficients.²³ Second, to decide whether pooled OLS or panel Random Effects estimation technique should be used in estimating the relation, we use the Breusch-Pagan Lagrange Multiplier test.²⁴ Finally, to choose whether panel Fixed Effects estimation technique or panel Random Effects estimation technique should be used, we use the Hausman model specification test.²⁵ We follow the same procedure for each of our dependent variables. The results of F-, Breusch-Pagan Lagrange Multiplier and Hausman tests (for the models with no fixed effects and year fixed effects) are reported in Table 3, respectively.

For the log-linearized model, we use pooled OLS and panel Fixed Effects estimation techniques, while using the PPML estimation technique for the generalized linear model. For the pooled OLS and panel Fixed Effects estimations, we employ the logarithm of our three dependent variables (imports, carbon dioxide intensity, and the carbon dioxide content of the U.S. imports). However, for the PPML estimation technique, we use the same set of dependent variables without taking logarithms. All independent variables in the log-linear models are defined in log-

²³In the case that null hypothesis is rejected, F-test suggests that panel Fixed Effects estimation technique is more appropriate and should be used. In the opposite case, where the null hypothesis is failed to be rejected, F-test suggests pooled OLS should be preferred over the panel Fixed Effects estimation technique.

²⁴In the case that null hypothesis is rejected, Breusch-Pagan Lagrange Multiplier test suggests, panel Random Effects estimation technique should be used. In the opposite case, the model specification test suggests pooled OLS rather than the panel Random Effects estimation technique.

²⁵According to the Hausman test, rejecting the null hypothesis suggest panel Fixed Effects estimation technique is superior to the panel Random Effects estimation technique.

Table 3: Model Specification Tests for the Sector Level Data, China Included

Model and Test Specification	F-Test (F-Statistics)	Breusch-Pagan LM Test (Chibar-Squared)	Hausman Test (Chi-Squared)
	H0: Pooled OLS H1: Fixed Effects Model	H0: Pooled OLS H1: Random Effects Model	H0: Fixed Effects Model H1: Random Effects Model
Imports, No Fixed Effect	Prob > F = 0.0000	chibar2 = 25495.18 Prob > chibar2 = 0.0000	chi2 = 14.73 Prob > chi2 = 0.0006
Imports, Year Fixed Effect	Prob > F = 0.0000	chibar2 = 25664.22 Prob > chibar2 = 0.0000	chi2 = 21.43 Prob > chi2 = 0.0000
Intensity, No Fixed Effect	Prob > F = 0.0000	chibar2 = 24043.94 Prob > chibar2 = 0.0000	chi2 = 46.78 Prob > chi2 = 0.0000
Intensity, Year Fixed Effect	Prob > F = 0.0000	chibar2 = 25064.18 Prob > chibar2 = 0.0000	chi2 = 19.26 Prob > chi2 = 0.0001
Content, No Fixed Effect	Prob > F = 0.0000	chibar2 = 25466.59 Prob > chibar2 = 0.0000	chi2 = 32.70 Prob > chi2 = 0.0000
Content, Year Fixed Effect	Prob > F = 0.0000	chibar2 = 25607.01 Prob > chibar2 = 0.0000	chi2 = 31.40 Prob > chi2 = 0.0000

arithmetic forms except the binary variables. It is also worth noting that, in order to take advantage of the richness of the sectoral cross country data, panel Fixed Effects estimation method is defined with *Country*×*Sector* fixed effects. As a final remark, all reported models are estimated by using clustered robust standard errors to correct for heteroskedasticity.

Our sectoral panel data with relatively short time interval did not allow us to examine the dynamic properties of the value, carbon dioxide intensity and carbon dioxide content of trade. Hence, including lagged dependent variables to the panel models with short time dimension may lead to the biased coefficients problem, lagged dependent variable estimation approach has not been investigated in this thesis. The period determined for this thesis is 1995-2010. Since we exclude the year of global financial crisis, i.e. 2009, from our empirical analysis, we have only fifteen years to analyze. As stated by Arellano and Bond (1991) and Bond (2002), according to Monte Carlo experiments, the panel models for even fifteen years period, the created bias cannot be ignored; i.e. lagged dependent variable estimation technique cannot eliminate the biasedness problem. With a longer time series dimension, it would have been possible to include a lagged dependent variable and search for dynamic relationship and extent the estimation techniques to include Arellano and Bond (1991) and Bond (2002).²⁶

Last but not least, imports can be interpreted as the *scale effect* while carbon dioxide intensity can be considered as the *technique effect*. As we explained the derivation of the carbon dioxide content of imports in subsection 5.1, the carbon dioxide content of trade (imports) is simply the multiplication of the value of the trade (imports) and carbon dioxide intensity, i.e. direct and indirect carbon diox-

²⁶For future extension of this thesis, with samples that has a longer time dimension following Arellano and Bond (1991) and Bond (2002) we may identify the dynamic properties of trade and carbon dioxide content of trade by applying the lagged dependent variable techniques.

ide emissions, for each sector, for each country and for each year. Therefore, for log-linearized models, i.e. pooled OLS and panel estimation techniques, the coefficient of carbon dioxide content of imports is equal to the summation of coefficients of the value of trade (imports) and carbon dioxide intensity. This implies, not only scale but also technique effect is featured in the interpretation of the coefficients reported for carbon dioxide content of trade (imports).

Before discussing the empirical findings in more detail, the variables of interest should also be noted. We are specifically interested in the NAFTA dummies, which are dummy variables for Canada and Mexico. A positive and significant coefficients for the NAFTA dummies imply that, there is a significant difference in the specified dependent variable for that NAFTA country relative to other U.S. importing partners, and vice versa. In addition to the NAFTA dummies, we allow for the year interactions with the NAFTA dummies, i.e. *Canada* $\times$ *Year* and *Mexico* $\times$ *Year*. The two-way interactions are essentially included in our empirical strategy because of two major reasons: first, we want to observe the time changing effects of being a NAFTA partner on the explained variables compared to the other U.S. importing partners. Second, in accordance with the Hausman test results, which according to the test results indicate the relevance of Fixed Effects model, we use the panel Fixed Effects estimation technique. As this Fixed Effects estimator drops the variables with no within variation, it is only possible to control the time-varying explanatory variables within the Fixed Effects framework. This implies that, the impact of NAFTA dummies of Canada and Mexico, that might have occurred following NAFTA as well as the time-invariant variables such as land area, bilateral distance and common official language, cannot be controlled with the Fixed Effects estimation technique. By including interaction terms to our analysis, however, we can still estimate the region-specific differences of being either Canada and Mexico over time. A positive sign of these interaction terms

indicates, region specific effects show an increase over time, while reverse is true for the negative signs of the interactions.

7.1 Results and Discussion

The estimates obtained from all models are presented in Table 4 to Table 6. The estimates in Table 4, Table 5 and Table 6 present the results of the pooled Ordinary Least Squares, panel Fixed Effects and Poisson Pseudo Maximum Likelihood (PPML) estimation techniques for the U.S. imports, carbon dioxide intensity and carbon dioxide content of the U.S. imports from its major importing partners, respectively. For each model specification, we include fixed effects in the same way and as follows: (i) *no fixed effects*, (ii) *year fixed effects*, (iii) *country-year fixed effects*, and finally, (iv) *sector-year effects*.²⁷

The estimates of the pooled OLS with additional fixed effects are intuitive, however, suffer from the biased estimates problem. Estimating the same empirical relation with log-linearized panel estimation method and generalized linear PPML estimation corroborate the findings of the pooled OLS. Although there are some minor changes in the significance of explanatory variables, estimate signs are consistent across the models.

7.1.1 U.S. Imports

The estimates in Table 4 represents the results of the pooled OLS, panel FE and PPML estimation techniques for the U.S. imports. Columns (1)-(4) present the pooled OLS estimates, columns (5)-(8) present the FE estimates, and finally, columns (9)-(12) present the PPML estimates.

²⁷For the panel Fixed Effects estimation, these fixed effects are added in addition to the default *Country*×*Sector* fixed effects.

There is a positive and significant relation between the U.S. imports and relative sectoral output growth in almost all cases. This implies, U.S. imports have been from countries with relatively higher sectoral output growth for the period 1995-2010. The real effective exchange rate ratio is found to be statistically insignificant.

Estimates for land area, bilateral distance, common official language and NAFTA dummy variables (Canada and Mexico) are only available for pooled OLS and PPML estimation techniques. Land area of the origin country is negatively significant. Bilateral distance and common official language, however, are found to be statistically insignificant in almost all specifications. This implies, at sector level, two of three gravity variables we selected for our empirical analysis failed to explain the variations in the value of the U.S. imports.

In most of the specifications, the NAFTA dummy variables are found to be statistically significant at 1% with a positive sign except columns (3) and (11). This indicates that, in the post-NAFTA era, the value of the U.S. imports from Canada and Mexico have been significantly greater than the U.S. imports from other non-NAFTA U.S. importing partners.

The estimates of year interactions of the NAFTA dummies, however, are found to be rarely significant across different estimation techniques. *Mexico* x *Year* interaction is found to be positive and statistically significant when the relation is estimated by the panel FE and PPML with additional country-year fixed effects. *Canada* x *Year* interaction is found to be negative and statistically significant when the relation is estimated by the pooled OLS and panel FE with additional year and sector-year fixed effects. However, the same coefficient in PPML estimates are found to be statistically insignificant. In short, there is some evidence

Table 4: Regressions on Sector Level Data, U.S. Imports, China included

DEPENDENT VARIABLE	Log IMPORTS				Log IMPORTS				IMPORTS			
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE	(6) FE	(7) FE	(8) FE	(9) PPML	(10) PPML	(11) PPML	(12) PPML
<i>Log(Output_o/Output_{US})</i>	0.864*** (0.111)	0.853*** (0.113)	1.108*** (0.189)	0.775*** (0.100)	0.553*** (0.065)	0.455*** (0.053)	0.110 (0.074)	0.616*** (0.041)	0.827*** (0.115)	0.828*** (0.114)	0.889*** (0.116)	0.835*** (0.123)
<i>Log(REER_o/REER_{US})</i>	-0.136 (0.308)	0.270 (0.399)	-3.815 (34.094)	0.484 (0.388)	-0.350 (0.191)	0.058 (0.182)	-0.443 (0.230)	-0.154 (0.164)	-0.224 (0.207)	0.155 (0.287)	-1.004*** (0.294)	0.196 (0.375)
<i>LogLandarea</i>	-0.179*** (0.042)	-0.164** (0.044)	0.215 (0.364)	-0.136** (0.045)					-0.216*** (0.050)	-0.209*** (0.050)	-0.373*** (0.078)	-0.136* (0.056)
<i>LogDistcap</i>	0.163 (0.319)	0.169 (0.321)	1.521 (2.283)	0.117 (0.322)					0.621 (0.459)	0.668 (0.479)	-1.706* (0.807)	0.600 (0.391)
<i>CommonLanguage</i>	0.077 (0.215)	0.068 (0.218)	2.316 (2.484)	-0.017 (0.211)					0.264 (0.167)	0.265 (0.159)	0.199 (0.578)	0.380** (0.137)
<i>MEXICO</i>	2.629*** (0.482)	2.743*** (0.457)	8.432 (30.549)	2.618*** (0.447)					2.623*** (0.535)	2.688*** (0.497)	0.405 (0.737)	2.614*** (0.410)
<i>CANADA</i>	3.804*** (0.664)	4.016*** (0.639)	5.869 (11.929)	3.931*** (0.639)					4.001*** (1.096)	4.269*** (1.117)	-1.075 (2.129)	3.919*** (0.900)
<i>MEXICO</i> x <i>Year</i>	0.003 (0.016)	-0.016 (0.017)	-0.286 (1.784)	-0.019 (0.018)	0.019 (0.015)	-0.007 (0.016)	0.040* (0.016)	-0.005 (0.016)	0.023 (0.014)	0.017 (0.013)	0.037** (0.012)	0.009 (0.008)
<i>CANADA</i> x <i>Year</i>	-0.006 (0.011)	-0.027* (0.012)	-0.118 (1.446)	-0.032* (0.012)	0.008 (0.008)	-0.021** (0.006)	0.012 (0.010)	-0.016* (0.007)	0.006 (0.019)	-0.007 (0.019)	0.008 (0.015)	-0.010 (0.010)
CONSTANT	22.851*** (3.065)	22.348*** (3.062)	5.210 (18.186)	21.149*** (3.199)	21.640*** (0.165)	21.203*** (0.149)	20.528*** (0.195)	21.714*** (0.119)	20.168*** (4.532)	19.465*** (4.680)	43.127*** (7.611)	17.479*** (4.181)
<i>YearEffects</i>		x				x				x		
<i>CountryYearEffects</i>			x				x				x	
<i>SectorYearEffects</i>				x								x
<i>NumberofObservations</i>	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320
<i>R²</i>	0.388	0.391	0.462	0.712	0.112	0.161	0.27	0.282	0.323	0.327	0.348	0.814

^a To obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis. *, **, *** present the statistical significance at 10%, 5% and 1% levels.

that, NAFTA has an increasing impact on the value of the U.S. imports from Mexico and decreasing impact for imports from Canada over the period 1995-2010.

7.1.2 CO_2 Intensity

Table 5 reports the results of the pooled OLS, panel FE and PPML estimation techniques for the carbon dioxide intensity. Columns (1)-(4) present the OLS estimates, columns (5)-(8) present the FE estimates, and finally, columns (9)-(12) present the PPML estimates.

Relative sectoral output growth is found to be statistically insignificant in explaining the carbon dioxide intensity of the production in the partner country. Simply, there is no relation between the sectoral output ratio of the partner country to the U.S. and the carbon intensity of the partner country's production. There is a negative and significant relation between the carbon dioxide intensity and relative real effective exchange rate growth in almost all cases.

Estimates for land area, bilateral distance, common official language and NAFTA dummy variables (Canada and Mexico) are only available for pooled OLS and PPML estimation techniques. Land area of the origin country, bilateral distance and common official language are statistically significant at 1% level with a positive sign in most of the cases. As stated previously, interpreting the carbon intensity is not as intuitive as interpreting the bilateral trade variable within the gravity model framework. However, given the scope of the sector level dataset we constructed for this thesis, there is a positive relationship between the carbon intensity of the production with the given gravity variables.

Likewise the U.S. imports, in most of the models, the NAFTA dummy variables are found to be statistically significant at 1% with a positive sign except column

Table 5: Regressions on Sector Level Data, CO_2 Intensity, China included

DEPENDENT VARIABLE	Log CO ₂ INTENSITY			Log CO ₂ INTENSITY			CO ₂ INTENSITY					
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE	(6) FE	(7) FE	(8) FE	(9) PPML	(10) PPML	(11) PPML	(12) PPML
<i>Log(Output_o/Output_{US})</i>	0.033 (0.032)	0.036 (0.033)	-0.005 (0.052)	0.031 (0.017)	-0.140*** (0.032)	-0.050 (0.031)	-0.039 (0.028)	-0.063* (0.029)	-0.020 (0.066)	-0.014 (0.068)	-0.015 (0.122)	0.027*** (0.005)
<i>Log(REER_o/REER_{US})</i>	-0.803*** (0.113)	-0.631*** (0.153)	-4.940 (14.869)	-0.620*** (0.117)	-0.979*** (0.033)	-1.052*** (0.052)	-1.084*** (0.041)	-1.035*** (0.044)	-0.704*** (0.145)	-0.529** (0.185)	-1.179*** (0.083)	-0.639*** (0.020)
<i>LogLandarea</i>	0.261*** (0.013)	0.265*** (0.014)	-0.104 (0.177)	0.267*** (0.012)					0.298*** (0.025)	0.299*** (0.026)	0.319*** (0.039)	0.278*** (0.007)
<i>LogDistcap</i>	1.382*** (0.106)	1.391*** (0.107)	0.512 (0.891)	1.388*** (0.117)					1.864*** (0.059)	1.870*** (0.059)	1.450*** (0.139)	1.660*** (0.037)
<i>CommonLanguage</i>	0.616*** (0.063)	0.621*** (0.064)	-1.848 (1.172)	0.616*** (0.061)					0.649*** (0.074)	0.650*** (0.075)	1.364*** (0.081)	0.659*** (0.019)
<i>MEXICO</i>	1.589*** (0.128)	1.449*** (0.128)	1.949 (13.251)	1.442*** (0.144)					1.776*** (0.130)	1.644*** (0.113)	1.997*** (0.097)	1.458*** (0.029)
<i>CANADA</i>	2.332*** (0.298)	2.234*** (0.311)	0.603 (5.180)	2.229*** (0.333)					3.222*** (0.122)	3.134*** (0.100)	2.159*** (0.342)	2.592*** (0.061)
<i>MEXICO x Year</i>	-0.023*** (0.004)	-0.006 (0.004)	-0.075 (0.773)	-0.006 (0.004)	-0.013** (0.004)	0.004 (0.003)	-0.008* (0.004)	0.003 (0.003)	-0.021*** (0.000)	-0.005 (0.003)	-0.007 (0.004)	0.000 (0.000)
<i>CANADA x Year</i>	-0.021*** (0.005)	-0.004 (0.006)	0.186 (0.631)	-0.005 (0.006)	-0.012* (0.004)	0.006 (0.004)	-0.014** (0.004)	0.005 (0.004)	-0.028*** (0.001)	-0.012** (0.004)	-0.019*** (0.002)	-0.002* (0.001)
<i>CONSTANT</i>	-37.787*** (1.025)	-37.839*** (1.049)	-25.075** (6.398)	-37.965*** (1.100)	-22.110*** (0.078)	-21.806*** (0.085)	-21.880*** (0.067)	-21.888*** (0.074)	-43.295*** (0.618)	-43.239*** (0.620)	-40.608*** (2.144)	-41.441*** (1.100)
<i>YearEffects</i>		x				x				x		
<i>CountryYearEffects</i>			x				x				x	
<i>SectorYearEffects</i>				x				x				x
<i>NumberofObservations</i>	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320
<i>R²</i>	0.547	0.558	0.652	0.76	0.465	0.552	0.684	0.583	0.338	0.347	0.419	0.606

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T11 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis. *, **, *** present the statistical significance at 10%, 5% and 1% levels.

(3). This indicates that, there is a strong evidence for the production processes in the NAFTA member U.S. importing partner countries, i.e. Canada and Mexico, being significantly more carbon intensive than the production processes in the non-NAFTA member U.S. importing partner countries in the post-NAFTA era. We observe that, the amount of carbon dioxide emissions generated by Canadian and Mexican production have been relatively greater than the emissions generated by other major U.S. trading partners. This implicitly implies, given the industry level information, the carbon dioxide intensity of the U.S. imports from Canada and Mexico has been greater than the carbon dioxide intensity of the U.S. imports from others in the given period.

The estimates for the year interactions of NAFTA dummies are frequently significant across different estimation techniques. *Mexico* x *Year* interaction is negatively significant in columns (1), (5), (7) and (9), while *Canada* x *Year* interaction is negatively statistically significant in columns (1), (5), (7), (9), (10), (11) and (12). A negative estimate for the year interactions with NAFTA dummies can be interpreted in the following way: although the Canadian and Mexican production processes has been more carbon intensive than the ones in non-NAFTA U.S. trading partners, there is some evidence that, this carbon intensive production scheme in Canada and Mexico seems to diminish over the period 1995-2010. This may point out that technology in NAFTA partners are more polluting but there is some evidence of improvement, i.e. moving towards less carbon dioxide intensive technologies, overtime following NAFTA.

7.1.3 CO₂ Content of the U.S. Imports

Table 6 presents the results of the pooled OLS, panel FE and PPML estimation techniques for the carbon dioxide content of the U.S. imports.²⁸ Columns (1)-(4) present the OLS estimates, columns (5)-(8) present the FE estimates, and finally, columns (9)-(12) present the PPML estimates.

As the carbon dioxide content of U.S. imports is set as the dependent variable, both sectoral output ratio and real effective exchange rate ratio become statistically significant in most of the specifications. The results indicate, there is a positive relation between the carbon content of the U.S. imports and the relative sectoral output growth of the partner country compared to the U.S. Further, there is a negative relation between the carbon content of the U.S. imports and real effective exchange rate ratio in most of the specifications.²⁹

We have some evidence that, changes in the land area, bilateral distance measure and common official language have positive impacts on the carbon content of the U.S. imports. It is worth noting that, positive signs for variables *land area* and *bilateral distance measure*, however, are not expected and not usual within the gravity model estimation framework.

The NAFTA dummy variables are found to be statistically significant (generally at 1% level) with a positive sign except column (3) and therefore conclusive. This refers that, given the sector level carbon content information, the carbon dioxide content of the U.S. imports, simply carbon imports, from Canada and Mexico has

²⁸By definition, for the estimates of pooled OLS and panel FE estimation techniques, the coefficients of Table 6 are the sum of the coefficients reported in Table 4 and Table 5.

²⁹An increase in the real effective exchange rate ratio implies, the currency of the partner country appreciates relative to the U.S. dollar. This implicitly implies, the exports of the partner country become expensive, while imports becomes cheaper. However, interpreting the variable real effective exchange rate ratio is more intuitive to better understand the bilateral trade compared to the bilateral carbon trade.

Table 6: Regressions on Sector Level Data, CO_2 Content of the U.S. Imports, China included

DEPENDENT VARIABLE	Log CO_2 CONTENT				Log CO_2 CONTENT				CO_2 CONTENT			
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE	(6) FE	(7) FE	(8) FE	(9) PPML	(10) PPML	(11) PPML	(12) PPML
$Log(Output_o/Output_{US})$	0.896*** (0.115)	0.888*** (0.117)	1.103*** (0.188)	0.806*** (0.104)	0.413*** (0.063)	0.405*** (0.057)	0.071 (0.084)	0.552*** (0.057)	0.543** (0.209)	0.526* (0.219)	0.400 (0.243)	0.729*** (0.172)
$Log(REER_o/REER_{US})$	-0.938** (0.300)	-0.361 (0.397)	-8.755 (40.388)	-0.135 (0.369)	-1.329*** (0.175)	-0.995*** (0.164)	-1.528*** (0.227)	-1.189*** (0.149)	-0.739 (0.491)	-0.327 (0.661)	-1.679*** (0.347)	-0.886 (0.576)
$LogLandarea$	0.083 (0.042)	0.101* (0.045)	0.111 (0.439)	0.131** (0.044)					0.140*** (0.036)	0.154*** (0.039)	0.130 (0.152)	0.129** (0.041)
$LogDistcap$	1.545*** (0.344)	1.560*** (0.346)	2.032 (2.703)	1.505*** (0.363)					2.233*** (0.339)	2.225*** (0.345)	1.333 (0.871)	2.414*** (0.477)
$CommonLanguage$	0.692** (0.190)	0.689** (0.191)	0.467 (3.042)	0.599** (0.192)					0.412 (0.218)	0.399 (0.210)	0.840 (0.622)	0.735*** (0.195)
$MEXICO$	4.218*** (0.439)	4.192*** (0.426)	10.381 (36.280)	4.060*** (0.446)					3.508*** (0.350)	3.687*** (0.310)	3.476*** (0.827)	4.115*** (0.417)
$CANADA$	6.135*** (0.761)	6.250*** (0.763)	6.472 (13.782)	6.160*** (0.790)					6.584*** (0.625)	6.879*** (0.694)	5.014* (2.093)	7.118*** (1.034)
$MEXICO \times Year$	-0.019 (0.017)	-0.022 (0.016)	-0.361 (2.113)	-0.025 (0.017)	0.006 (0.016)	-0.004 (0.015)	0.031 (0.017)	-0.001 (0.015)	0.009 (0.011)	-0.020 (0.019)	0.038** (0.012)	-0.007 (0.014)
$CANADA \times Year$	-0.027 (0.014)	-0.031* (0.014)	0.068 (1.713)	-0.036* (0.014)	-0.004 (0.010)	-0.015* (0.007)	-0.002 (0.011)	-0.011 (0.008)	-0.011 (0.019)	-0.045 (0.032)	0.000 (0.016)	-0.029 (0.028)
CONSTANT	-14.935*** (3.328)	-15.491*** (3.372)	-19.865 (21.104)	-16.816*** (3.567)	-0.470* (0.168)	-0.603** (0.161)	-1.352*** (0.220)	-0.174 (0.162)	-21.113*** (3.286)	-21.512*** (3.446)	-14.431 (9.691)	-24.373*** (4.402)
$YearEffects$		x				x				x		
$CountryYearEffects$			x				x				x	
$SectorYearEffects$				x				x				x
NumberofObservations	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320
R^2	0.429	0.433	0.502	0.72	0.1	0.124	0.251	0.227	0.229	0.238	0.316	0.502

^a To obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis. *, **, *** present the statistical significance at 10%, 5% and 1% levels.

been greater than the carbon dioxide content of the U.S. imports from the non-NAFTA U.S. trading partners in the post-NAFTA era. The empirical results of year interactions of the NAFTA dummies, however, are rarely significant. *Mexico* x *Year* is only positively significant at a 5% level when the relation is estimated by PPML with country-year fixed effects. *Canada* x *Year*, on the other hand, negatively significant at 10% level in columns (2), (4) and (6). We have some weak evidence that, at a sector level, the carbon imports from Mexico have increased, while the carbon imports from Canada have diminished over time.

In this chapter, we reported our main results that we analyze the post-NAFTA U.S. imports, carbon dioxide intensity of the U.S. imports, and finally the U.S. carbon imports from major NAFTA member and non-NAFTA member U.S. importing partners. Our results indicate that, throughout the period 1995-2010, not only the value U.S. imports from Canada and Mexico but also the carbon content of the U.S. imports from Canada and Mexico have been larger than both the value and carbon content of the U.S. imports from other major non-NAFTA U.S. importing partners. Although the results for overtime change are less conclusive, we still have some evidence for the following results: (i) the value of the U.S. imports from Mexico has increased and the value of U.S. imports from Canada has decreased through 1995-2010; (ii) The carbon dioxide intensity has decreased for both Canada and Mexico through the specified period. (iii) the U.S. carbon imports from Mexico have increased and the U.S. carbon imports from Canada have diminished over time. Although our results for overtime impacts of NAFTA on Mexico and Canada remain non-conclusive, these results can be considered as a source of motivation for future research. In the following chapter, we present robustness checks done with alternative datasets.

CHAPTER VIII

ROBUSTNESS CONTROLS WITH ALTERNATIVE SAMPLES

We constructed additional datasets for all our dependent variables to provide a support to the earlier empirical findings that we presented in Table 4, Table 5 and Table 6. One such alternative is to exclude a country, which has a large share in the total U.S. imports, and repeat the same sequence of the analysis with the subsample to see whether the main empirical findings are robust. Another alternative is to construct a country level data by aggregating our sector level data across sectors and apply the adjusted sequence of the analysis at the aggregate level.

Table 7, Table 8 and Table 9 present the sector level data and the identical econometric strategy excluding China from our analyses. All tables present the results of the pooled Ordinary Least Squares, panel Fixed Effects and Poisson Pseudo Maximum Likelihood (PPML) estimation techniques for the U.S. imports, carbon dioxide intensity and carbon dioxide content of the U.S. imports from its major importing partners, respectively. For each model specification, we include

fixed effects in the same way and as follows: (i) *no fixed effects*, (ii) *year fixed effects*, (iii) *country-year fixed effects*, and finally, (iv) *sector-year effects*.³⁰ In addition, we aggregated our data across industries and obtained country level data to provide a support to our empirical findings. Table 10, Table 11 and Table 12 report the results of the aggregated sectoral data and similar economic models. All tables present the results of the pooled Ordinary Least Squares, panel Fixed Effects, panel Random Effects and Poisson Pseudo Maximum Likelihood (PPML) estimation techniques for the U.S. imports, carbon dioxide intensity and carbon dioxide content of the U.S. imports from its major importing partners, respectively. For each model specification, we include fixed effects in the same way and as follows: (i) *no fixed effects* and (ii) *year fixed effects*.³¹

8.1 An Alternative Sector Level Analysis

To begin with, we construct an alternative sector level data by excluding a country from our sample. Based on the the rank of China among the top four U.S. importing partners and the China share of the U.S. imports, we decide to exclude China from our sample. Over the period 1995-2010, China showed an increase in its trade performance and changed its status from being top fourth U.S. importing partner to the first place, while increasing share of the U.S. imports from 6% in 1995 to 19% in 2010.³² Therefore, we conducted a sensitivity test by excluding China from our sample to support our main findings presented in the previous chapter.

³⁰For the panel Fixed Effects estimation, these fixed effects are added in addition to the default *Country*×*Sector* fixed effects.

³¹For the panel Fixed Effects and panel Random Effects estimation techniques, these fixed effects are added in addition to the default *Country* fixed effects.

³²Author's calculation. Data on U.S. imports is obtained from UN COMTRADE.

We repeat the same procedure at a sector level for a relevant subset of our sample, where we exclude China, to see whether excluding China changes our test and regression results. Once again, we used model specification tests to determine our empirical strategy. The results of the F-test are consistently found in favor of the panel Fixed Effect estimation, the results of Breusch-Pagan Lagrange Multiplier tests are consistently found in favor of the panel Random Effects estimation, and finally, the results of Hausman model specification tests are consistently found in favor of the panel Fixed Effects estimation. The results of panel specification tests are reported in Table B.1 provided in Appendix B.

8.1.1 U.S. Imports

The estimates in Table 7 represents the results of the pooled OLS, panel FE and PPML estimation techniques for the U.S. imports. Columns (1)-(4) present the pooled OLS estimates, columns (5)-(8) present the FE estimates, and finally, columns (9)-(12) present the PPML estimates.

As shown in Table 7, the overall picture remains the same in terms of significance of the NAFTA dummies. Excluding China from the country set has not changed the results we have previously reported in Table 4. Simply, we still have strong evidence that, the value of the U.S. imports from Canada and Mexico have been more than the value of the U.S. imports from major non-NAFTA U.S. partners covering approximately 75% of the overall U.S. trade for the period 1995-2010. Also, the year interactions of NAFTA dummies remain rarely significant across different estimation techniques, implying that we have some evidence for overtime increase of the U.S. imports from Mexico and over time decrease from Canada compared to the other non-NAFTA U.S. partners. However, due to weak significance, results for year interactions of NAFTA dummies are not conclusive.

Table 7: Regressions on Sector Level Data, U.S. Imports, China excluded

DEPENDENT VARIABLE	Log IMPORTS			Log IMPORTS			IMPORTS					
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE	(6) FE	(7) FE	(8) FE	(9) PPML	(10) PPML	(11) PPML	(12) PPML
<i>Log(Output_o/Output_{US})</i>	0.851*** (0.113)	0.841*** (0.115)	1.145*** (0.184)	0.746*** (0.108)	0.406*** (0.072)	0.332*** (0.057)	0.081 (0.079)	0.493*** (0.071)	0.821*** (0.143)	0.821*** (0.140)	0.964*** (0.107)	0.762*** (0.147)
<i>Log(REER_o/REER_{US})</i>	-0.092 (0.314)	0.318 (0.414)	-5.008 (34.393)	0.578 (0.402)	-0.208 (0.173)	0.169 (0.172)	-0.424 (0.229)	-0.029 (0.149)	-0.038 (0.295)	0.392 (0.389)	-1.045*** (0.296)	0.555 (0.517)
<i>LogLandarea</i>	-0.209*** (0.041)	-0.195*** (0.042)	0.213 (0.369)	-0.164** (0.043)					-0.279*** (0.033)	-0.274*** (0.033)	-0.391*** (0.074)	-0.204*** (0.038)
<i>LogDistcap</i>	0.016 (0.323)	0.021 (0.324)	1.662 (2.284)	-0.059 (0.324)					0.358 (0.403)	0.400 (0.418)	-1.793* (0.785)	0.341 (0.329)
<i>CommonLanguage</i>	0.041 (0.225)	0.033 (0.228)	2.362 (2.530)	-0.073 (0.223)					0.194 (0.171)	0.190 (0.161)	0.206 (0.576)	0.211 (0.171)
<i>MEXICO</i>	2.568*** (0.490)	2.669*** (0.468)	9.601 (30.801)	2.509*** (0.459)					2.531*** (0.528)	2.507*** (0.474)	0.346 (0.724)	2.380*** (0.410)
<i>CANADA</i>	3.633*** (0.657)	3.832*** (0.629)	5.510 (12.045)	3.707*** (0.625)					3.764*** (1.100)	3.975*** (1.093)	-1.261 (2.074)	3.734*** (0.887)
<i>MEXICO</i> x <i>Year</i>	0.003 (0.016)	-0.015 (0.017)	-0.350 (1.800)	-0.018 (0.018)	0.022 (0.016)	-0.002 (0.017)	0.040* (0.016)	-0.001 (0.017)	0.020 (0.014)	0.025 (0.016)	0.034** (0.013)	0.014 (0.012)
<i>CANADA</i> x <i>Year</i>	-0.006 (0.011)	-0.026 (0.013)	-0.070 (1.459)	-0.031* (0.013)	0.009 (0.009)	-0.017* (0.007)	0.013 (0.010)	-0.014 (0.007)	0.002 (0.019)	-0.002 (0.019)	0.007 (0.015)	-0.014 (0.009)
CONSTANT	24.504*** (3.096)	24.014*** (3.078)	3.971 (18.129)	23.108*** (3.201)	21.250*** (0.197)	20.871*** (0.157)	20.296*** (0.226)	21.381*** (0.193)	23.303*** (3.741)	22.693*** (3.859)	44.309*** (7.354)	20.738*** (3.323)
<i>YearEffects</i>		x				x				x		
<i>CountryYearEffects</i>			x				x				x	
<i>SectorYearEffects</i>				x				x				x
<i>NumberofObservations</i>	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050
<i>R²</i>	0.386	0.389	0.461	0.714	0.058	0.101	0.195	0.231	0.349	0.354	0.379	0.847

^a To obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis. *, **, *** present the statistical significance at 10%, 5% and 1% levels.

8.1.2 CO_2 Intensity

Table 8 presents the results of the pooled OLS, panel FE and PPML estimation techniques for the carbon dioxide intensity. Columns (1)-(4) present the OLS estimates, columns (5)-(8) present the FE estimates, and finally, columns (9)-(12) present the PPML estimates.

The overall coefficient estimates for the NAFTA dummies remain unchanged in terms of statistical significance levels. Excluding China from our analysis has not influenced the conclusion that we obtained from Table 5. Simply, we still have strong evidence that, production in Canada and Mexico, therefore the U.S. imports from Canada and Mexico, have been more carbon intensive than the production in the non-NAFTA member partners. However, excluding China from the analysis strengthens the results for year interaction term for Mexico dummy. We have stronger evidence that, carbon dioxide intensity of the not only the Canadian but also the Mexican production has diminished over the period 1995-2010.

8.1.3 CO_2 Content of the U.S. Imports

Table 9 presents the results of the pooled OLS, panel FE and PPML estimation techniques for the carbon dioxide content of the U.S. imports.³³ Columns (1)-(4) present the OLS estimates, columns (5)-(8) present the FE estimates, and finally, columns (9)-(12) present the PPML estimates.

As shown in Table 9, once again, the NAFTA dummies' estimates remain unchanged in terms of significance. Excluding China from the analysis has not changed the result obtained in Table 6. We still have same strong evidence that, carbon content of the U.S. imports from Canada and Mexico have been greater than the

³³By definition, for the estimates of pooled OLS and panel FE estimation techniques, the coefficients of Table 6 are the sum of the coefficients reported in Table 7 and Table 8.

Table 8: Regressions on Sector Level Data, CO_2 Intensity, China excluded

DEPENDENT VARIABLE	Log CO ₂ INTENSITY			Log CO ₂ INTENSITY			CO ₂ INTENSITY					
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE	(6) FE	(7) FE	(8) FE	(9) PPML	(10) PPML	(11) PPML	(12) PPML
<i>Log(Output_o/Output_{US})</i>	0.017 (0.031)	0.017 (0.033)	-0.003 (0.049)	0.010 (0.018)	-0.099* (0.039)	-0.021 (0.033)	-0.034 (0.028)	-0.029 (0.035)	-0.073 (0.065)	-0.076 (0.067)	-0.025 (0.119)	-0.032*** (0.004)
<i>Log(REER_o/REER_{US})</i>	-0.742*** (0.112)	-0.546** (0.154)	-4.990 (14.947)	-0.526*** (0.124)	-1.009*** (0.034)	-1.055*** (0.051)	-1.087*** (0.041)	-1.045*** (0.044)	-0.594*** (0.141)	-0.310 (0.183)	-1.229*** (0.081)	-0.459*** (0.017)
<i>LogLandarea</i>	0.233*** (0.014)	0.239*** (0.015)	-0.104 (0.177)	0.241*** (0.013)					0.270*** (0.022)	0.278*** (0.023)	0.330*** (0.038)	0.257*** (0.006)
<i>LogDistcap</i>	1.237*** (0.108)	1.244*** (0.108)	0.518 (0.900)	1.237*** (0.120)					1.727*** (0.065)	1.729*** (0.065)	1.518*** (0.136)	1.481*** (0.033)
<i>CommonLanguage</i>	0.577*** (0.060)	0.579*** (0.061)	-1.846 (1.169)	0.571*** (0.059)					0.685*** (0.075)	0.680*** (0.076)	1.362*** (0.080)	0.695*** (0.017)
<i>MEXICO</i>	1.525*** (0.126)	1.401*** (0.126)	1.998 (13.327)	1.389*** (0.143)					1.795*** (0.132)	1.735*** (0.118)	2.083*** (0.096)	1.507*** (0.028)
<i>CANADA</i>	2.164*** (0.299)	2.089*** (0.312)	0.588 (5.202)	2.079*** (0.337)					3.105*** (0.131)	3.102*** (0.111)	2.331*** (0.335)	2.436*** (0.060)
<i>MEXICO x Year</i>	-0.023*** (0.004)	-0.009* (0.004)	-0.078 (0.777)	-0.009* (0.004)	-0.014*** (0.003)	0.002 (0.003)	-0.009* (0.004)	0.002 (0.003)	-0.023*** (0.000)	-0.018*** (0.002)	-0.007 (0.004)	-0.012*** (0.000)
<i>CANADA x Year</i>	-0.022*** (0.005)	-0.008 (0.007)	0.188 (0.634)	-0.009 (0.006)	-0.012* (0.004)	0.004 (0.004)	-0.014** (0.004)	0.004 (0.004)	-0.032*** (0.001)	-0.027*** (0.004)	-0.020*** (0.002)	-0.015*** (0.001)
<i>CONSTANT</i>	-36.177*** (1.045)	-36.274*** (1.073)	-25.128** (6.468)	-36.333*** (1.148)	-22.123*** (0.101)	-21.850*** (0.094)	-22.005*** (0.072)	-21.901*** (0.091)	-41.931*** (0.579)	-42.081*** (0.575)	-41.423*** (2.104)	-39.769*** (1.085)
<i>YearEffects</i>		x				x				x		
<i>CountryYearEffects</i>			x				x				x	
<i>SectorYearEffects</i>				x				x				x
<i>NumberofObservations</i>	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050
<i>R²</i>	0.469	0.482	0.565	0.735	0.451	0.537	0.669	0.57	0.291	0.294	0.308	0.601

^a To obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T11 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis. *, **, *** present the statistical significance at 10%, 5% and 1% levels.

Table 9: Regressions on Sector Level Data, CO_2 Content of the U.S. Imports, China excluded

DEPENDENT VARIABLE	Log CO_2 CONTENT				Log CO_2 CONTENT				CO_2 CONTENT			
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) FE	(6) FE	(7) FE	(8) FE	(9) PPML	(10) PPML	(11) PPML	(12) PPML
$Log(Output_o/Output_{US})$	0.869*** (0.116)	0.858*** (0.118)	1.142*** (0.181)	0.756*** (0.112)	0.307** (0.079)	0.312*** (0.070)	0.047 (0.087)	0.464*** (0.089)	0.391 (0.253)	0.385 (0.253)	0.521* (0.248)	0.477* (0.190)
$Log(REER_o/REER_{US})$	-0.834* (0.306)	-0.228 (0.413)	-9.998 (40.770)	0.052 (0.385)	-1.216*** (0.159)	-0.886*** (0.157)	-1.511*** (0.227)	-1.075*** (0.134)	-0.006 (0.770)	0.740 (1.169)	-1.753*** (0.346)	0.528 (1.108)
$LogLandarea$	0.025 (0.042)	0.044 (0.044)	0.109 (0.444)	0.077 (0.043)				-0.029 (0.057)	-0.029 (0.057)	-0.014 (0.064)	0.099 (0.152)	-0.023 (0.041)
$LogDistcap$	1.252** (0.346)	1.264** (0.347)	2.180 (2.714)	1.179** (0.365)				1.458*** (0.337)	1.458*** (0.337)	1.534*** (0.387)	1.195 (0.868)	1.647*** (0.459)
$CommonLanguage$	0.618** (0.199)	0.612** (0.201)	0.516 (3.088)	0.498* (0.203)				0.746* (0.302)	0.746* (0.302)	0.742* (0.293)	0.883 (0.620)	0.875** (0.330)
$MEXICO$	4.093*** (0.448)	4.071*** (0.437)	11.599 (36.613)	3.898*** (0.455)				3.309*** (0.357)	3.309*** (0.357)	3.409*** (0.380)	3.384*** (0.828)	3.640*** (0.504)
$CANADA$	5.797*** (0.754)	5.921*** (0.751)	6.099 (13.918)	5.786*** (0.777)				5.443*** (0.725)	5.443*** (0.725)	5.899*** (0.971)	4.691* (2.053)	6.110*** (1.162)
$MEXICO \times Year$	-0.020 (0.017)	-0.024 (0.016)	-0.428 (2.133)	-0.028 (0.017)	0.008 (0.016)	0.000 (0.016)	0.032 (0.017)	0.001 (0.016)	0.002 (0.011)	-0.008 (0.020)	0.034** (0.013)	-0.011 (0.014)
$CANADA \times Year$	-0.028 (0.014)	-0.034* (0.015)	0.118 (1.729)	-0.040* (0.015)	-0.003 (0.010)	-0.013 (0.007)	-0.001 (0.011)	-0.010 (0.008)	-0.022 (0.021)	-0.042 (0.038)	-0.002 (0.016)	-0.045 (0.031)
$CONSTANT$	-11.673** (3.340)	-12.260** (3.370)	-21.157 (21.130)	-13.226** (3.595)	-0.873*** (0.219)	-0.979*** (0.195)	-1.709*** (0.243)	-0.520* (0.240)	-12.490** (3.820)	-13.680** (4.523)	-12.483 (9.715)	-15.557** (4.888)
$YearEffects$		x				x				x		
$CountryYearEffects$			x				x				x	
$SectorYearEffects$				x				x				x
$NumberOfObservations$	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050	4050
R^2	0.401	0.406	0.468	0.715	0.076	0.098	0.216	0.205	0.213	0.215	0.238	0.359

^a To obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis. *, **, *** present the statistical significance at 10%, 5% and 1% levels.

carbon content of the U.S. imports from non-NAFTA major U.S. importing partners. The estimates for year interactions of NAFTA dummies, however, remain non-conclusive. We have some weak evidence for overtime increase in the carbon imports from Mexico and decrease in the U.S. carbon imports from Canada through the NAFTA implementation period 1995-2010.

8.2 An Alternative Aggregate Level Analysis

We construct an alternative country level data by aggregating our sector level data across sectors. Table 10, Table 11 and Table 12 report the results of our aggregate level analysis where we include China to our analysis.

We obtain similar results from F- and Breusch Pagan Lagrange Multiplier tests. The results for the F-Test are consistently obtained in favor of the panel Fixed Effects estimation, while the Breusch-Pagan Lagrange Multiplier tests are consistently obtained in favor of the panel Random Effects estimation. However, different than the sector level analysis, the Hausman model specification test results are consistently obtained in favor of panel Random Effects estimation method. The results of panel specification tests for the alternative aggregate-level samples, both including and excluding China, are reported in Table B.2 and provided in Appendix B.³⁴

8.2.1 U.S Imports

The estimates in Table 10 represent the results for the pooled OLS, panel FE, panel RE, and finally, PPML estimation techniques for the U.S. imports. Columns (1)-(2) present the pooled OLS estimates, columns (3)-(4) present the FE es-

³⁴Table B.4, Table B.5 and Table B.6 in Appendix B report the results for the aggregate level analysis where we exclude China from the country set. The results of panel specification tests for the alternative aggregate-level sample, where we exclude China, are presented in Table B.3 and provided in Appendix B.

timates, columns (5)-(6) present the RE estimates and finally, columns (7)-(8) present the PPML estimates.

There is a positive and significant relation between the U.S. imports and relative total output growth in all cases. The estimated coefficients are statistically significant at either 5% or 1% levels, implying that U.S. imports are from countries with relatively higher total output growth. The real effective exchange rate ratio is weakly significant with a negative sign as expected.

Estimates for land area, bilateral distance, common official language and NAFTA dummy variables (Canada and Mexico) are only available for pooled OLS, RE and PPML estimation techniques. As stated previously, the Hausman test results fail to reject the null hypothesis, implying that panel Random Effects estimation technique is favorable for country level panel study obtained by aggregated sectoral data. Even so, we report the estimated coefficients obtained from the panel Fixed Effects estimation method. Estimates for land area are negatively significant and consistent with the previous results. Bilateral distance is positively significant at 10% level for columns (7) and (8). It is worth noting once again that, although we have positive signs for bilateral distance, this is not common and unexpected in the gravity model literature. Common official language is found to be statistically insignificant.

In all specifications, the NAFTA dummy variables are found to be statistically significant at 1% with a positive sign. We have strong evidence supporting that, the value of the U.S. imports from Canada and Mexico have been more than the U.S. imports from major non-NAFTA U.S. partners for the period 1995-2010. The estimates of year interactions of the NAFTA dummies, however, are not robust across different estimation techniques. There is some weak evidence that,

Table 10: Regressions on Aggregate Level Data, U.S. Imports, China included

DEPENDENT VARIABLE	Log IMPORTS			Log IMPORTS			IMPORTS		
	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) RE	(6) RE	(7) PPML	(8) PPML	
$Log(Total\ Output_o/Total\ Output_{US})$	0.535** (0.167)	0.500** (0.164)	0.878** (0.270)	0.829** (0.280)	0.839** (0.258)	0.786** (0.261)	0.712*** (0.169)	0.694*** (0.167)	
$Log(REER_o/REER_{US})$	0.284 (0.594)	0.934 (0.730)	-0.800* (0.293)	-0.294 (0.383)	-0.753** (0.283)	-0.238 (0.371)	0.012 (0.549)	0.493 (0.775)	
$LogLandarea$	-0.189* (0.078)	-0.163* (0.076)			-0.287* (0.113)	-0.261** (0.099)	-0.155* (0.065)	-0.142* (0.065)	
$LogDistcap$	0.255 (0.342)	0.257 (0.348)			0.402 (0.388)	0.389 (0.394)	0.634* (0.304)	0.669* (0.305)	
$CommonLanguage$	-0.173 (0.339)	-0.195 (0.346)			0.075 (0.416)	0.035 (0.426)	0.097 (0.323)	0.077 (0.322)	
$MEXICO$	1.973*** (0.425)	2.121*** (0.421)			2.432*** (0.601)	2.455*** (0.596)	2.391*** (0.387)	2.506*** (0.406)	
$CANADA$	3.456*** (0.625)	3.757*** (0.635)			3.717*** (0.875)	3.857*** (0.841)	3.969*** (0.629)	4.322*** (0.715)	
$MEXICO \times Year$	0.028*** (0.007)	-0.001 (0.012)	0.034*** (0.006)	0.019 (0.010)	0.035*** (0.006)	0.019 (0.010)	0.024*** (0.004)	0.007 (0.013)	
$CANADA \times Year$	0.002 (0.009)	-0.030 (0.015)	0.015*** (0.004)	-0.003 (0.010)	0.015*** (0.003)	-0.004 (0.010)	0.002 (0.008)	-0.024 (0.019)	
$CONSTANT$	25.596*** (3.384)	24.870*** (3.519)	26.397*** (0.588)	26.146*** (0.610)	25.957*** (3.586)	25.486*** (3.620)	22.070*** (3.188)	21.307*** (3.289)	
$YearEffects$		X		X		X		X	
$NumberOfObservations$	240	240	240	240	240	240	240	240	
R^2	0.729	0.764	0.474	0.622	0.686	0.722	0.896	0.904	

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis.
*, **, *** present the statistical significance at 10%, 5% and 1% levels.

NAFTA's positive effect is increasing over time for both Mexico and Canada at aggregate level. For *Mexico x Year*, the coefficients are statistically significant at 1% level with positive sign in columns (1), (3), (5) and (7). Besides, *Canada x Year* is weakly significant with a positive sign. For *Canada x Year* interaction, signs of significant coefficients are opposite to the ones that we obtained from sector level analysis. However results are too weak to reach a conclusion for overtime change of the value of the U.S. imports from Canada at an aggregate level.³⁵

8.2.2 CO₂ Intensity

The estimates in Table 11 represent the results for the pooled OLS, panel FE, panel RE, and finally, PPML estimation techniques for the carbon dioxide intensity. Columns (1)-(2) present the pooled OLS estimates, columns (3)-(4) present the FE estimates, columns (5)-(6) present the RE estimates and finally, columns (7)-(8) present the PPML estimates.

As shown in Table 11, the NAFTA dummy variables are found to be statistically significant at 1% with a positive sign with the exception of the relation is estimated by the PPML. In our opinion, the data constructed at a sector level provides the possibility of a detailed empirical analysis about the production schemes. Therefore, we believe that, the results that we obtained as a result of sector level analysis are more reliable than the outcomes we obtained from the aggregate level analysis. Estimates of *Mexico x Year* are statistically significant with negative sign across different estimation techniques, except column (8). This implies, we have some evidence showing that, although the U.S. imports from Mexico has been relatively more carbon intensive than the other U.S. trading partners, the carbon

³⁵Excluding China from the sample changes the significance of *Mexico x Year* dummy to statistically significant at 10% level for panel RE and PPML estimation techniques. As we exclude China from the country set, the results become stronger and evidence that, the value of the U.S. imports from Mexico has increased more compared to the value of the U.S. imports from other major U.S. partners.

Table 11: Regressions on Aggregate Level Data, CO_2 Intensity, China included

DEPENDENT VARIABLE	Log CO ₂ INTENSITY			Log CO ₂ INTENSITY			CO ₂ INTENSITY	
	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) RE	(6) RE	(7) PPML	(8) PPML
<i>Log(Total Output_o/Total Output_{US})</i>	-0.024 (0.113)	-0.018 (0.123)	-0.293** (0.082)	-0.152 (0.109)	-0.276*** (0.078)	-0.140 (0.105)	0.061 (0.300)	0.083 (0.310)
<i>Log(REER_o/REER_{US})</i>	-0.760** (0.205)	-0.582 (0.289)	-0.881*** (0.112)	-0.993*** (0.156)	-0.895*** (0.108)	-1.001*** (0.150)	-0.856 (0.926)	-0.774 (1.339)
<i>LogLandarea</i>	0.223*** (0.045)	0.227*** (0.043)			0.278*** (0.059)	0.244*** (0.059)	0.256 (0.140)	0.250 (0.145)
<i>LogDistcap</i>	1.608*** (0.233)	1.618*** (0.244)			1.450*** (0.263)	1.529*** (0.224)	1.775* (0.738)	1.790* (0.739)
<i>CommonLanguage</i>	0.738*** (0.142)	0.745*** (0.148)			0.524** (0.198)	0.638*** (0.177)	0.828 (0.638)	0.839 (0.640)
<i>MEXICO</i>	2.064*** (0.320)	1.966*** (0.311)			1.590*** (0.330)	1.725*** (0.307)	2.102 (1.374)	1.953 (1.354)
<i>CANADA</i>	2.885*** (0.576)	2.831*** (0.593)			2.331*** (0.615)	2.465*** (0.524)	2.954 (2.160)	2.838 (2.163)
<i>MEXICO x Year</i>	-0.034*** (0.005)	-0.021* (0.010)	-0.020*** (0.002)	-0.011 (0.005)	-0.021*** (0.002)	-0.011* (0.005)	-0.037* (0.017)	-0.014 (0.025)
<i>CANADA x Year</i>	-0.021*** (0.005)	-0.010 (0.011)	-0.010*** (0.002)	0.000 (0.006)	-0.010*** (0.002)	0.001 (0.006)	-0.021 (0.019)	0.002 (0.031)
<i>CONSTANT</i>	-39.034*** (2.089)	-39.123*** (2.116)	-21.894*** (0.180)	-21.530*** (0.241)	-38.775*** (2.868)	-38.746*** (2.437)	-41.578*** (7.141)	-41.435*** (7.179)
<i>YearEffects</i>		x		x		x		x
<i>NumberofObservations</i>	240	240	240	240	240	240	240	240
<i>R²</i>	0.792	0.806	0.758	0.807	0.717	0.775	0.778	0.802

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis.
*, **, *** present the statistical significance at 10%, 5% and 1% levels.

dioxide intensity has diminished over the period 1995-2010. However, the estimates of *Canada* x *Year* dummy is found to be rarely significant across different estimation techniques with negative sign. In short, we have some weak evidence that, at an aggregate level, production of the U.S. imports in NAFTA member countries have been more carbon intensive and this difference in the intensity has been diminishing relative to the other U.S. importing partners.³⁶

8.2.3 CO₂ Content of the U.S. Imports

The estimates in Table 12 represent the results for the pooled OLS, panel FE, panel RE, and finally, PPML estimation techniques for the carbon dioxide content of the U.S. imports. Columns (1)-(2) present the pooled OLS estimates, columns (3)-(4) present the FE estimates, columns (5)-(6) present the RE estimates and finally, columns (7)-(8) present the PPML estimates.

In almost all specifications, the NAFTA dummy variables are found to be statistically significant at 1% with a positive sign and robust across different estimation techniques. This result strictly indicates that, the carbon dioxide content of the U.S. imports from its NAFTA partners in the post-NAFTA era, i.e. 1995-2010, have been greater than the carbon dioxide content of the U.S. imports from major non-NAFTA U.S. import partners. The estimates of year interactions of the NAFTA dummies are, however, weak relative to the NAFTA dummies, and therefore, not conclusive. For *Mexico* x *Year* dummy, estimates are statistically significant when the panel estimator is used, however, not significant when pooled OLS of PPML approach is used. *Canada* x *Year* have some contradictory results compared to our main findings. There is inadequate evidence for both interactions to

³⁶Excluding China from the sample, on the other hand, also have the same results in terms of significance of NAFTA dummies and year interaction terms of the NAFTA dummies.

Table 12: Regressions on Aggregate Level Data, CO_2 Content of U.S. Imports, China included

DEPENDENT VARIABLE	Log CO ₂ CONTENT			Log CO ₂ CONTENT			CO ₂ CONTENT	
	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) RE	(6) RE	(7) PPML	(8) PPML
<i>Log(Total Output_o/Total Output_{US})</i>	0.406 (0.293)	0.369 (0.300)	0.428 (0.252)	0.460 (0.316)	0.430 (0.251)	0.459 (0.312)	0.653* (0.288)	0.621* (0.300)
<i>Log(REE_{R_o}/REE_{R_{US}})</i>	0.244 (1.105)	1.263 (1.422)	-1.439*** (0.291)	-1.107* (0.424)	-1.431*** (0.292)	-1.092* (0.427)	-0.892 (0.861)	-0.462 (1.135)
<i>LogLandarea</i>	0.135 (0.116)	0.171 (0.110)			0.084 (0.114)	0.087 (0.094)	0.130 (0.112)	0.147 (0.113)
<i>LogDistcap</i>	2.083** (0.513)	2.097*** (0.501)			2.037** (0.629)	2.067*** (0.609)	2.309*** (0.465)	2.287*** (0.442)
<i>CommonLanguage</i>	0.566 (0.343)	0.544 (0.347)			0.570 (0.366)	0.598 (0.373)	0.436 (0.428)	0.412 (0.426)
<i>MEXICO</i>	3.738*** (0.649)	3.815*** (0.583)			3.621*** (0.831)	3.709*** (0.795)	3.724*** (0.618)	3.866*** (0.553)
<i>CANADA</i>	6.801*** (1.160)	7.121*** (1.126)			6.276*** (1.575)	6.454*** (1.493)	6.913*** (1.151)	7.160*** (1.100)
<i>MEXICO x Year</i>	-0.004 (0.011)	-0.027 (0.028)	0.027*** (0.006)	0.019* (0.009)	0.026*** (0.006)	0.019* (0.009)	0.007 (0.007)	-0.021 (0.024)
<i>CANADA x Year</i>	-0.028 (0.017)	-0.055 (0.035)	0.009* (0.004)	0.000 (0.010)	0.008* (0.003)	0.000 (0.010)	-0.011 (0.011)	-0.045 (0.031)
<i>CONSTANT</i>	-17.330** (4.633)	-18.340** (4.755)	3.677*** (0.547)	3.649*** (0.735)	-16.404** (4.996)	-16.764*** (4.951)	-18.647*** (4.533)	-18.973*** (4.335)
<i>YearEffects</i>		x		x		x		x
<i>NumberofObservations</i>	240	240	240	240	240	240	240	240
<i>R²</i>	0.629	0.668	0.399	0.53	0.582	0.608	0.729	0.754

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis.
*, **, *** present the statistical significance at 10%, 5% and 1% levels.

attribute a meaning to the estimated coefficients of the interaction terms.³⁷

In this chapter, we presented the results that we obtained from several alternative datasets that we constructed either at a sector or country level. Although there are little differences between the results obtained from sector and country level analyses, almost all results provide support to our main findings. We observe the same evidence that, both the value and the carbon content of the U.S. imports from Canada and Mexico have been larger relative to the non-NAFTA U.S. trading partners. Moreover, results indicate that, the carbon dioxide intensity of the domestic production in Canada and Mexico have relatively higher than those U.S. importing partners which are not NAFTA member for the specified period. Besides, we also have some evidence showing that, carbon dioxide intensity of the Canadian and Mexican production has diminished throughout the specified period compared to the other U.S. partners.

³⁷Excluding China from the model does not influence the significance of the variables, however, there is still inadequate evidence for both interactions to attribute a meaning to the estimated coefficients.

CHAPTER IX

CONCLUSION

In this thesis, the gravity model of international trade is employed at industry level to examine the post-NAFTA U.S. import levels and the carbon content of the U.S. imports from its NAFTA trading partners, i.e. Canada and Mexico, vis-à-vis non-NAFTA partners. To this end, datasets on carbon dioxide intensity of the production in the U.S. imports partner countries and carbon dioxide content of bilateral U.S. trade with these countries are constructed following the methodology proposed by Aichele and Felbermayr (2015).

At the first step, we calculated the total (direct and indirect) carbon dioxide emission coefficients for each sector and for each country in the sample. In order to do this, we used Leontief total requirements matrices to convert direct sectoral emission coefficients to total sectoral emission coefficients. This measure represents the direct and indirect emissions generated per dollar of sectoral output, therefore, this measure is defined as the carbon dioxide intensity. We calculated carbon dioxide intensity for each trading partner of the U.S. in our sample. As the second step, we employ carbon dioxide intensity measure to calculate the carbon dioxide content of U.S. imports. The data on U.S. imports is collected at product level

and then aggregated into industries. As we used the information on the carbon dioxide intensity of the production in the partner country and data on bilateral trade for the traded industries, we calculated the carbon dioxide embodied in the U.S. imports.

Investigating the value and the carbon dioxide content of the U.S. imports provide us tools to identify two main points: first, it allows us to explore whether there is a significant influence of NAFTA as a free trade agreement in distinguishing post-NAFTA U.S. trade patterns, specifically the U.S. imports, with NAFTA partners compared to the non-NAFTA partners. Second, it allows us to explore how the carbon content of imports evolves between NAFTA and non-NAFTA trading partners throughout the NAFTA implementation era.

Our results are based on three estimation techniques, which are pooled Ordinary Least Squares, panel Fixed Effects and the Poisson-Pseudo Maximum Likelihood estimation techniques, with additional sector, country and year fixed effect specifications. According to our results, all three variables show an increase in the post-NAFTA era. To be clear, both the value and carbon dioxide content of the U.S. imports from Canada and Mexico have been larger than the other major non-NAFTA U.S. importing partners. Moreover, we observed that, the carbon dioxide intensity of the Canadian and Mexican production schemes have been relatively more carbon intensive than those in non-NAFTA member partners of the U.S. through 1995-2010. However, our results for the overtime changes of the value of the U.S. imports, carbon dioxide intensity and carbon dioxide content of the U.S. imports from Canada and Mexico are found to be relatively weak and therefore non-conclusive.

In addition to our main findings, we also supported our results with alternative datasets. For each sequence of analysis, we obtained supportive results of our main sector level results. One such alternative was by excluding China from our sector level analysis. Due to the drastic increase in the share of the U.S. imports from 6% to 19% over the period 1995-2010, China could dominate our main findings. Excluding China from our sample, has not affected the significance of the NAFTA dummy variables. Another alternative was to construct a country level data by aggregating our industry level data across industries and apply the adjusted sequence of the analysis at the aggregate level. Our results for the value and the carbon dioxide content of the U.S. imports are found to be supportive to our main empirical findings. Only for carbon dioxide intensity measure, we obtained weaker results as we employed pooled sectoral data. However, in our opinion, an industry level analysis is a more detailed, therefore more suitable, way to draw a conclusion for the post-NAFTA comparison between the carbon intensity of the domestic production in NAFTA vis-à-vis non-NAFTA member countries.

In an empirical sense, our results indicate that, there is a significant difference in both three measures we employed our study for Canada and Mexico compared to the non-NAFTA member countries. To be more precise about our results, we first observed that, the value of the U.S. imports from Canada and Mexico are relatively larger than other non-NAFTA trading partners. Then, we explored Canadian and Mexican production and found that NAFTA countries production are relatively more carbon intensive than the production in other non-NAFTA U.S. import partners. These imply that, the U.S. imports from Canada and Mexico are more carbon intensive. To sum up, in those results, we observed that, U.S. has been importing more carbon from Canada and Mexico vis-à-vis other import partners since the implementation of NAFTA.

From policy making perspective, NAFTA is one of the largest free trade agreements with an environmental side agreement. Even though the member nations agreed to have environment specific acts under NAAEC, we observe that, there have been some limited effect of the enhanced intra-NAFTA trade on the environment. There is a difference between U.S. carbon imports from Canada and Mexico compared to the other non-NAFTA partners of the United States. Even though we have some evidence showing that carbon dioxide intensity of the U.S. imports from Canada and Mexico have declined throughout the period 1995-2010 relative to the non-NAFTA countries. This result is very strong. This may be attributed to the fact that although NAFTA is a multilateral free trade agreement between two developed and a developing country with environmental clauses, it is not an agreement solely about environment such as Kyoto Protocol and Paris Agreement, with specific environmental restrictions and regulations. We believe that, NAFTA did not play an important role in cleaning up the environment partly due to the fact that, the issue of environment is left to the individual countries own regulations such as each country is required to have their own environmental regulation and to abide by these rules on environment. If the free trade agreement, i.e. NAFTA, had direct and common environmental regulations like Kyoto and Paris Accord with improved pollution restrictions and/or quotas on trade-related pollution amounts, the outcome could have been different.

Our results strongly support that, there is no improved environmental performance in Canada and Mexico as the NAFTA members relative to the non-NAFTA members through the period 1995-2010. These results to a certain extent support the path dependency argument. The integrated markets of developing and developed economies with a free trade agreement is not conducive for creating major changes in production technologies. In some sense, the countries environmental performances are “path-dependent”. With path dependence we imply that, de-

spite the existence of improved products and technologies, the cost-effectiveness concerns lead to continue from the existing path rather than shifting through a new and more efficient one. Such studies address whether developing countries trading with high income countries may be path dependent to the existing policies and technologies or may not be open to the technological transfers which enable cleaner production. Other research could explore either clean or dirty industries are affected more by the path dependence. Such studies can address the relation between the increased carbon content of international trade and path dependence to shed light on the solutions to trade-offs between trade and environment.

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APPENDICES



APPENDIX A



Table A.1: Data-Variable Explanations and Data Sources

Data	Data Description	Data Source / Derivation of the Variable
Carbon Dioxide Emissions from Fuel Combustion	Refers to the measure of the direct carbon dioxide emissions from fossil fuel combustion, which are converted from IEA format to the International Standard Industrial Classification of All Activities (ISIC, Revision 3).	International Energy Agency, IEA
(Sectoral) Direct Carbon Dioxide Emission Coefficients	The direct carbon dioxide emission coefficients present the direct sectoral carbon dioxide emissions per dollar production.	Author's calculation: $\text{Sectoral } CO_2 \text{ Coefficients} = \frac{\text{Sectoral } CO_2 \text{ Emissions}}{\text{Sectoral Output}}$
Harmonised National Input-Output Tables	The input-output tables reflect the inter-industrial flows of domestic and imported goods and services in the current prices (OECD definition).	Harmonised National Input-Output Tables, OECD
Leontief Total Requirements Matrices	The Leontief Inverse matrices represent the direct and indirect inter-industrial transactions of the production of a unit of output.	Harmonised National Input-Output Tables, OECD $\text{Leontief Inverse Matrix} = (I - A)^{-1}, \text{ where } A \text{ represents the technical coefficients matrix}$
(Sectoral) Total, <i>i.e. Direct and Indirect, Carbon Dioxide Emission Coefficients</i> (In other words, <i>Sectoral Carbon Dioxide Intensity</i>)	The total carbon dioxide emission coefficients present the direct and indirect sectoral carbon dioxide emissions per dollar production.	Author's Calculation: $\text{Sectoral } CO_2 \text{ Intensity} = (\text{Sectoral Direct } CO_2 \text{ Coefficients}) \times (\text{Leontief Inverse Matrix})$

Sectoral Bilateral Trade Data (Reported in <i>Standard International Trade Classification, Revision 3</i>)	The dollar value of the bilateral trade between the trading partners.	United Nations Commodity Trade Database, UN-COMTRADE Database
Concordance Table: Between SITC, Rev. 3 and ISIC, Rev. 3	Concordance table enables conversion between the Standard International Trade Classification (Revision 3) and the International Standard Industrial Classification of All Activities (Revision 3).	Eurostat, RAMON Concordance Table (from SITC, Rev. 3 to ISIC, Rev. 3)
Sectoral Carbon Dioxide Content of Imports	The carbon dioxide content of imports is the measure of the carbon dioxide embodied in the U.S. imports from its trading partners at a sectoral level.	Author's calculation: $CO_2 \text{ Content of Imports} = (\text{Sectoral } CO_2 \text{ Intensity}) \times (\text{Sector Level Bilateral Trade})$
Consumer Price Index (CPI)	CPI presents the changes in the cost of the average consumer acquiring a basket of goods and services, which may be fixed or changed in a given period of time (World Bank definition)	World Development Indicators, World Bank
Real GDP (Constant 2010 U.S. Dollars)	The real value of the gross domestic product in millions of U.S. Dollars. The data is reported in constant 2010 U.S. Dollars.	World Development Indicators, World Bank
Real Effective Exchange Rate (REER)	REER reflects the real values of the geometric weighted averages of the bilateral exchange rates.	Bank of International Settlements, BIS
Gravity Variable: <i>Distance</i>	The measure of distance between the capital city of the exporting country with the capital city of the U.S.	French Centre d'Etudes Prospectives et d'Informations Internationales, CEPII

Gravity Variable: <i>Land Area</i>	Land area represents a country's total surface area.	French Centre d'Etudes Prospectives et d'Informations Internationales, CEPII
Gravity Variable: <i>Common Official Lan- guage</i>	Dummy with 1 if the exporting country shares the same official language with the U.S. and 0 otherwise.	French Centre d'Etudes Prospectives et d'Informations Internationales, CEPII
Dummy: MEXICO (CANADA)	Dummy with 1 if the exporting country is MEXICO (CANADA) and 0 otherwise.	-

Table A.2: List of International Energy Agency's Energy Flows

Long Name	Short Name
Main Activity Electricity Plants	MAINELEC
Main Activity CHP Plants	MAINCHP
Main activity heat plants	MAINHEAT
Own use in electricity, CHP and heat plants	EPOWERPLT
Unallocated autoproducers	AUTOPROD
Other energy industry own use	OTHER
Iron and steel	IRONSTL
Chemical and petrochemical	CHEMICAL
Non-ferrous metals	NONFERR
Non-metallic minerals	NONMET
Transport equipment	TRANSEQ
Machinery	MACHINE
Mining and quarrying	MINING
Food and tobacco	FOODPRO
Paper, pulp and printing	PAPERPRO
Wood and wood products	WOODPRO
Construction	CONSTRUC
Textile and leather	TEXTILES
Non-specified industry	INONSPEC
Road	ROAD
Domestic aviation	DOMESAIR
Rail	RAIL
Pipeline transport	PIPELINE
Domestic navigation	DOMESNAV
Non-specified transport	TRNONSPE
<i>Residential</i>	<i>RESIDENT</i>
Commercial and public services	COMMPUB
Agriculture/forestry	AGRICULT
Fishing	FISHING
Non-specified other	ONONSPEC
<i>Memo: International marine bunkers</i>	<i>MARBUNK</i>
Memo: International aviation bunkers	AVBUNK

Table A.3: Summary Statistics, Canada and Mexico

SECTOR	VARIABLE	CANADA		MEXICO		SECTOR	VARIABLE	CANADA		MEXICO	
		Mean	Sd. Dev.	Mean	Sd. Dev.			Mean	Sd. Dev.	Mean	Sd. Dev.
C01T05	Imports	5472.04	1026.7	5024.13	923.58	C27	Imports	18551.1	5175.76	5023.88	2411.99
	CO ₂ Intensity	0.62	0.05	0.52	0.06		CO ₂ Intensity	0.7	0.2	0.88	0.24
	CO ₂ Content	3354.97	512.2	2579.76	480.44		CO ₂ Content	12259.4	2225.32	4056.34	1212.39
C10T14	Imports	43556.2	23845	18797.2	9597.42	C28	Imports	5348.58	925.1	3996.9	1135.32
	CO ₂ Intensity	0.54	0.14	0.39	0.07		CO ₂ Intensity	0.67	0.15	0.76	0.2
	CO ₂ Content	20686.3	6497.94	6901.6	2797.27		CO ₂ Content	3527.23	764.95	2829.55	427.46
C15T16	Imports	10771.5	2196.54	4715.3	1445.48	C29	Imports	14402.1	2019.99	11981	4502.82
	CO ₂ Intensity	0.42	0.04	0.44	0.08		CO ₂ Intensity	0.33	0.06	0.35	0.08
	CO ₂ Content	4427.72	716.62	1988.57	396.73		CO ₂ Content	4642.32	671.41	3904.7	852.26
C17T19	Imports	3744.83	845.4	9445	2698.28	C30T33	Imports	17516.4	7169.24	44389.2	11187.9
	CO ₂ Intensity	0.26	0.02	0.32	0.05		CO ₂ Intensity	0.27	0.08	0.18	0.04
	CO ₂ Content	981.94	278.23	2937.6	786.51		CO ₂ Content	4911.71	2743.63	7538.23	1022.12
C20	Imports	11832.5	3598.03	489.45	144.06	C31	Imports	4671.11	633.54	21496.9	4061.22
	CO ₂ Intensity	0.52	0.03	0.39	0.06		CO ₂ Intensity	0.31	0.05	0.3	0.06
	CO ₂ Content	6147.06	1947.27	192.76	72.96		CO ₂ Content	1464.6	342.99	6244.16	969.35
C21T22	Imports	14892.3	2489.85	1402.23	199.09	C34	Imports	64116.6	11492.4	32191	7014.11
	CO ₂ Intensity	0.54	0.11	0.51	0.05		CO ₂ Intensity	0.21	0.04	0.26	0.06
	CO ₂ Content	8222.57	2800.7	710.85	83.84		CO ₂ Content	13506.6	3820.42	7971.77	778.2
C23	Imports	3748.03	1231.31	50.1	41.29	C35	Imports	8724.26	1490.03	1453.79	590.84
	CO ₂ Intensity	0.41	0.1	0.4	0.08		CO ₂ Intensity	0.28	0.04	0.34	0.06
	CO ₂ Content	1527.89	668.12	21.76	20.14		CO ₂ Content	2394.8	497.9	472.74	144.86
C24	Imports	16935.2	4910.89	3952.07	555.62	C36T37	Imports	6570.83	1345.73	5621.66	1238.48
	CO ₂ Intensity	0.45	0.09	0.46	0.1		CO ₂ Intensity	1.43	0.48	0.99	0.25
	CO ₂ Content	7258.52	796.38	1758.81	250.78		CO ₂ Content	9469.79	3519.36	5330.09	695.92
C25	Imports	7857.37	1480.04	3216.3	775.5	C40T41	Imports	2152.59	845.67	127.33	154.07
	CO ₂ Intensity	0.5	0.08	0.52	0.13		CO ₂ Intensity	3.77	0.85	5.46	1.77
	CO ₂ Content	3836.27	670.95	1571.42	172.74		CO ₂ Content	8057.37	3808.63	548.07	621.6
C26	Imports	2324.24	291.12	2194.79	428.34	TOTAL	Imports	13852	16370	9240.44	12356.4
	CO ₂ Intensity	0.82	0.17	1.09	0.09		CO ₂ Intensity	0.69	0.81	0.77	1.21
	CO ₂ Content	1901.21	455.23	2381.58	470.96		CO ₂ Content	6240.96	5421.4	3154.75	2636.49

^aUnits of Imports, CO₂ intensity and CO₂ Content are in terms of Million USD, kg per USD and Kt of CO₂, respectively.

Table A.4: Summary Statistics, Country Groups According to NAFTA Membership

SECTOR	VARIABLE	NAFTA		NON-NAFTA		SECTOR	VARIABLE	NAFTA		NON-NAFTA	
		Mean	Sd. Dev.	Mean	Sd. Dev.			Mean	Sd. Dev.	Mean	Sd. Dev.
C01T05	Imports	5248.08	987.21	219.86	283.47	C27	Imports	11787.5	7937.22	1384.81	1585.24
	CO ₂ Intensity	0.57	0.07	0.47	0.36		CO ₂ Intensity	0.79	0.24	1.29	1.97
	CO ₂ Content	2967.36	627.47	110.25	156.34		CO ₂ Content	8157.86	4524.66	2397.86	5978.27
C10T14	Imports	31176.7	21860.6	1309.84	4544.15	C28	Imports	4672.74	1228.52	911.31	1589.62
	CO ₂ Intensity	0.46	0.13	0.55	0.64		CO ₂ Intensity	0.71	0.18	1.3	2.11
	CO ₂ Content	13794	8558.85	524.23	1571.22		CO ₂ Content	3178.39	705.1	1407.24	4490.56
C15T16	Imports	7743.42	3579.23	1026.34	985.8	C29	Imports	13191.5	3646.61	4000.08	5758.17
	CO ₂ Intensity	0.43	0.06	0.47	0.38		CO ₂ Intensity	0.34	0.07	0.56	0.69
	CO ₂ Content	3208.14	1363.82	455.55	652.98		CO ₂ Content	4273.51	842.61	1851.87	4977.86
C17T19	Imports	6594.92	3500.54	3868.16	7089.61	C30T33	Imports	30952.8	16486.3	12180.9	16250.3
	CO ₂ Intensity	0.29	0.05	0.75	1.14		CO ₂ Intensity	0.22	0.08	0.44	0.59
	CO ₂ Content	1959.77	1150.55	2664.48	6787.77		CO ₂ Content	6224.97	2434.78	3997.97	9221.65
C20	Imports	6160.95	6283.12	240.19	449.39	C31	Imports	13084	9013.05	1838.29	2538.31
	CO ₂ Intensity	0.45	0.08	0.58	0.67		CO ₂ Intensity	0.31	0.06	0.55	0.71
	CO ₂ Content	3169.91	3314.62	184.48	567.54		CO ₂ Content	3854.38	2531.18	1024.64	3018.08
C21T22	Imports	8147.28	7069.8	422.9	444.48	C34	Imports	48153.8	18728.2	5797.38	13037.2
	CO ₂ Intensity	0.53	0.09	0.91	1.4		CO ₂ Intensity	0.23	0.06	0.54	0.7
	CO ₂ Content	4466.71	4284.9	259.02	475.3		CO ₂ Content	10739.2	3906.55	1459.32	2705.92
C23	Imports	1899.07	2064.79	117.31	222.55	C35	Imports	5089.03	3858.04	1727.8	2173.09
	CO ₂ Intensity	0.4	0.09	0.72	1.57		CO ₂ Intensity	0.31	0.06	0.53	0.63
	CO ₂ Content	774.83	895.31	95.8	649.93		CO ₂ Content	1433.77	1040.91	478.19	630.4
C24	Imports	10443.6	7437.64	3571.33	4262.11	C36T37	Imports	6096.25	1360.5	2451.21	4194.07
	CO ₂ Intensity	0.45	0.09	0.89	1.46		CO ₂ Intensity	1.21	0.44	4.37	9.81
	CO ₂ Content	4508.67	2853.59	1635.07	2339.52		CO ₂ Content	7399.94	3263.43	7338.04	16075.1
C25	Imports	5536.83	2628.6	1021.11	1515.17	C40T41	Imports	1139.96	1189.97	0.02	0.03
	CO ₂ Intensity	0.51	0.11	0.7	0.87		CO ₂ Intensity	4.62	1.61	6.01	5.56
	CO ₂ Content	2703.84	1247.4	803.63	2344.68		CO ₂ Content	4302.72	4664.55	0.08	0.13
C26	Imports	2259.52	366.21	511.2	663.17	TOTAL	Imports	11546.2	14673.4	2352	6380.04
	CO ₂ Intensity	0.95	0.19	1.86	2.23		CO ₂ Intensity	0.73	1.03	1.24	3.17
	CO ₂ Content	2141.4	516.86	917.35	2261.18		CO ₂ Content	4697.86	4530.62	1524.02	5557.32

^aUnits of Imports, CO₂ intensity and CO₂ Content are in terms of Million USD, kg per USD and Kt of CO₂, respectively.

APPENDIX B



Table B.1: Model Specification Tests for the Sector Level Data, China Excluded

Model and Test Specification	F-Test (F-Statistics)		Breusch-Pagan LM Test (Chibar-Squared)		Hausman Test (Chi-Squared)	
	H0: Pooled OLS H1: Fixed Effects Model		H0: Pooled OLS H1: Random Effects Model		H0: Fixed Effects Model H1: Random Effects Model	
Imports, No Fixed Effect	Prob > F = 0.0000		chibar2 = 23874.76 Prob > chibar2 = 0.0000		chi2 = 24.90 Prob > chi2 = 0.0000	
Imports, Year Fixed Effect	Prob > F = 0.0000		chibar2 = 24009.96 Prob > chibar2 = 0.0000		chi2 = 30.72 Prob > chi2 = 0.0000	
Intensity, No Fixed Effect	Prob > F = 0.0000		chibar2 = 22396.19 Prob > chibar2 = 0.0000		chi2 = 27.61 Prob > chi2 = 0.0000	
Intensity, Year Fixed Effect	Prob > F = 0.0000		chibar2 = 23196.37 Prob > chibar2 = 0.0000		chi2 = 12.47 Prob > chi2 = 0.0020	
Content, No Fixed Effect	Prob > F = 0.0000		chibar2 = 23743.93 Prob > chibar2 = 0.0000		chi2 = 39.15 Prob > chi2 = 0.0000	
Content, Year Fixed Effect	Prob > F = 0.0000		chibar2 = 23872.81 Prob > chibar2 = 0.0000		chi2 = 36.41 Prob > chi2 = 0.0000	

Table B.2: Model Specification Tests for the Aggregate Level Data, China Included

Model and Test Specification	F-Test (F-Statistics)		Breusch-Pagan LM Test (Chibar-Squared)		Hausman Test (Chi-Squared)	
	H0: Pooled OLS H1: Fixed Effects Model		H0: Pooled OLS H1: Random Effects Model		H0: Fixed Effects Model H1: Random Effects Model	
Imports, No Fixed Effect	Prob > F = 0.0000		chibar2 = 932.05 Prob > chibar2 = 0.0000		chi2 = 5.26 Prob > chi2 = 0.0722	
Imports, Year Fixed Effect	Prob > F = 0.0000		chibar2 = 1056.74 Prob > chibar2 = 0.0000		chi2 = 3.87 Prob > chi2 = 0.1444	
Intensity, No Fixed Effect	Prob > F = 0.0000		chibar2 = 1170.97 Prob > chibar2 = 0.0000		chi2 = 5.65 Prob > chi2 = 0.0595	
Intensity, Year Fixed Effect	Prob > F = 0.0000		chibar2 = 1278.61 Prob > chibar2 = 0.0000		chi2 = 2.34 Prob > chi2 = 0.3097	
Content, No Fixed Effect	Prob > F = 0.0000		chibar2 = 1161.86 Prob > chibar2 = 0.0000		chi2 = 4.90 Prob > chi2 = 0.0861	
Content, Year Fixed Effect	Prob > F = 0.0000		chibar2 = 1158.76 Prob > chibar2 = 0.0000		chi2 = 4.24 Prob > chi2 = 0.1202	

Table B.3: Model Specification Tests for the Aggregate Level Data, China Excluded

Model and Test Specification	F-Test (F-Statistics)			Breusch-Pagan LM Test (Chibar-Squared)		Hausman Test (Chi-Squared)	
	H0: Pooled OLS H1: Fixed Effects Model			H0: Pooled OLS H1: Random Effects Model		H0: Fixed Effects Model H1: Random Effects Model	
Imports, No Fixed Effect	Prob > F = 0.0000			chibar = 799.36 Prob > chibar2 = 0.0000		chi2 = 4.49 Prob > chi2 = 0.1058	
Imports, Year Fixed Effect	Prob > F = 0.0000			chibar = 901.59 Prob > chibar2 = 0.0000		chi2 = 2.76 Prob > chi2 = 0.2515	
Intensity, No Fixed Effect	Prob > F = 0.0000			chibar = 946.28 Prob > chibar2 = 0.0000		chi2 = 5.13 Prob > chi2 = 0.0770	
Intensity, Year Fixed Effect	Prob > F = 0.0000			chibar = 1019.09 Prob > chibar2 = 0.0000		chi2 = 2.23 Prob > chi2 = 0.3285	
Content, No Fixed Effect	Prob > F = 0.0000			chibar = 936.47 Prob > chibar2 = 0.0000		chi2 = 9.56 Prob > chi2 = 0.0084	
Content, Year Fixed Effect	Prob > F = 0.0000			chibar = 890.56 Prob > chibar2 = 0.0000		chi2 = 8.37 Prob > chi2 = 0.0152	

Table B.4: Regressions on Aggregate Level Data, U.S. Imports, China excluded

DEPENDENT VARIABLE	Log IMPORTS			Log IMPORTS			IMPORTS		
	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) RE	(6) RE	(7) PPML	(8) PPML	
$Log(Total\ Output_o/Total\ Output_{US})$	0.432* (0.181)	0.398* (0.181)	0.596* (0.246)	0.496* (0.195)	0.571** (0.213)	0.484** (0.169)	0.605** (0.201)	0.587** (0.194)	
$Log(REER_o/REER_{US})$	0.462 (0.581)	1.155 (0.714)	-0.531* (0.241)	0.032 (0.297)	-0.494* (0.222)	0.060 (0.292)	0.292 (0.556)	0.884 (0.751)	
$LogLandarea$	-0.211** (0.069)	-0.186* (0.064)			-0.263** (0.097)	-0.232** (0.080)	-0.211** (0.069)	-0.199** (0.066)	
$LogDistcap$	-0.004 (0.289)	-0.006 (0.286)			0.071 (0.292)	0.022 (0.282)	0.272 (0.346)	0.307 (0.341)	
$CommonLanguage$	-0.290 (0.223)	-0.314 (0.215)			-0.178 (0.270)	-0.249 (0.245)	-0.098 (0.268)	-0.119 (0.264)	
$MEXICO$	1.745*** (0.411)	1.870*** (0.388)			1.915*** (0.524)	1.894*** (0.474)	2.083*** (0.489)	2.087*** (0.467)	
$CANADA$	3.080*** (0.664)	3.363*** (0.644)			3.062*** (0.802)	3.148*** (0.760)	3.530*** (0.773)	3.835*** (0.783)	
$MEXICO\ \times\ Year$	0.029** (0.008)	0.002 (0.012)	0.041*** (0.007)	0.023 (0.011)	0.041*** (0.006)	0.023* (0.011)	0.023*** (0.005)	0.020* (0.009)	
$CANADA\ \times\ Year$	0.001 (0.010)	-0.029 (0.014)	0.018*** (0.004)	-0.003 (0.011)	0.018*** (0.004)	-0.003 (0.011)	-0.002 (0.009)	-0.017 (0.018)	
$CONSTANT$	27.998*** (2.374)	27.315*** (2.365)	25.798*** (0.570)	25.409*** (0.427)	28.136*** (2.451)	27.842*** (2.435)	25.877*** (3.144)	25.148*** (3.069)	
$YearEffects$		x		x		x		x	
$NumberofObservations$	225	225	225	225	225	225	225	225	
R^2	0.783	0.821	0.299	0.522	0.756	0.797	0.913	0.927	

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis.
*, **, *** present the statistical significance at 10%, 5% and 1% levels.

Table B.5: Regressions on Aggregate Level Data, CO_2 Intensity, China excluded

DEPENDENT VARIABLE	Log CO ₂ INTENSITY			Log CO ₂ INTENSITY			CO ₂ INTENSITY	
	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) RE	(6) RE	(7) PPML	(8) PPML
<i>Log(Total Output_o/Total Output_{US})</i>	-0.086 (0.087)	-0.087 (0.091)	-0.263* (0.117)	-0.096 (0.148)	-0.238* (0.098)	-0.091 (0.131)	-0.050 (0.322)	-0.049 (0.330)
<i>Log(REER_o/REER_{US})</i>	-0.628** (0.164)	-0.389 (0.236)	-0.908*** (0.130)	-1.014*** (0.176)	-0.926*** (0.114)	-1.012*** (0.157)	-0.647 (0.947)	-0.399 (1.379)
<i>LogLandarea</i>	0.198*** (0.039)	0.204*** (0.036)			0.218*** (0.050)	0.188*** (0.047)	0.236 (0.144)	0.242 (0.148)
<i>LogDistcap</i>	1.402*** (0.182)	1.409*** (0.188)			1.272*** (0.216)	1.384*** (0.212)	1.568* (0.784)	1.576* (0.785)
<i>CommonLanguage</i>	0.660** (0.160)	0.661** (0.162)			0.524* (0.239)	0.652** (0.202)	0.859 (0.642)	0.857 (0.644)
<i>MEXICO</i>	1.916*** (0.259)	1.841*** (0.253)			1.600*** (0.325)	1.765*** (0.333)	2.036 (1.395)	1.970 (1.376)
<i>CANADA</i>	2.611*** (0.448)	2.593*** (0.462)			2.170*** (0.507)	2.364*** (0.513)	2.663 (2.206)	2.651 (2.207)
<i>MEXICO x Year</i>	-0.033*** (0.004)	-0.026** (0.008)	-0.021*** (0.003)	-0.013* (0.005)	-0.022*** (0.003)	-0.013* (0.006)	-0.038* (0.017)	-0.031 (0.027)
<i>CANADA x Year</i>	-0.022*** (0.004)	-0.016 (0.009)	-0.010*** (0.002)	-0.001 (0.006)	-0.011*** (0.002)	-0.001 (0.006)	-0.024 (0.019)	-0.017 (0.032)
<i>CONSTANT</i>	-36.999*** (1.674)	-37.165*** (1.717)	-21.951*** (0.270)	-21.519*** (0.353)	-36.396*** (2.246)	-36.716*** (1.851)	-39.809*** (7.555)	-39.948*** (7.578)
<i>YearEffects</i>		x		x		x		x
<i>NumberofObservations</i>	225	225	225	225	225	225	225	225
<i>R²</i>	0.811	0.828	0.749	0.806	0.766	0.810	0.933	0.942

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis.
*, **, *** present the statistical significance at 10%, 5% and 1% levels.

Table B.6: Regressions on Aggregate Level Data, CO_2 Content of U.S. Imports, China excluded

DEPENDENT VARIABLE	Log CO_2 CONTENT			Log CO_2 CONTENT			CO_2 CONTENT		
	(1) OLS	(2) OLS	(3) FE	(4) FE	(5) RE	(6) RE	(7) PPML	(8) PPML	
$Log(Total\ Output_o/Total\ Output_{US})$	0.254 (0.281)	0.210 (0.273)	0.118 (0.178)	0.104 (0.208)	0.137 (0.186)	0.126 (0.219)	0.140 (0.268)	0.118 (0.253)	
$Log(REE_{R_o}/REE_{R_{US}})$	0.541 (1.084)	1.662 (1.386)	-1.145*** (0.219)	-0.736* (0.340)	-1.148*** (0.229)	-0.738* (0.354)	0.297 (0.729)	1.166 (1.022)	
$LogLandarea$	0.092 (0.111)	0.130 (0.102)			0.068 (0.111)	0.081 (0.094)	0.047 (0.091)	0.071 (0.092)	
$LogDistcap$	1.658** (0.494)	1.663** (0.460)			1.505* (0.660)	1.511* (0.641)	1.212** (0.430)	1.260** (0.409)	
$CommonLanguage$	0.386 (0.280)	0.357 (0.265)			0.266 (0.363)	0.261 (0.372)	0.513* (0.213)	0.494* (0.220)	
$MEXICO$	3.393*** (0.721)	3.467*** (0.633)			3.009*** (0.882)	3.057*** (0.830)	2.734*** (0.659)	2.835*** (0.589)	
$CANADA$	6.209*** (1.335)	6.543*** (1.268)			5.370** (1.837)	5.515** (1.779)	4.822*** (1.161)	5.291*** (1.084)	
$MEXICO \times Year$	-0.003 (0.013)	-0.028 (0.027)	0.034*** (0.005)	0.023* (0.008)	0.033*** (0.005)	0.022** (0.008)	0.007 (0.008)	-0.012 (0.020)	
$CANADA \times Year$	-0.030 (0.018)	-0.060 (0.033)	0.012** (0.003)	-0.001 (0.009)	0.011*** (0.003)	-0.001 (0.010)	-0.020* (0.010)	-0.050 (0.030)	
$CONSTANT$	-13.286** (4.112)	-14.315** (4.021)	2.864*** (0.409)	2.710*** (0.514)	-12.003* (5.643)	-12.381* (5.685)	-8.760* (3.449)	-9.887** (3.298)	
$YearEffects$		x		x		x		x	
$NumberOfObservations$	225	225	225	225	225	225	225	225	
R^2	0.636	0.695	0.396	0.55	0.547	0.585	0.859	0.879	

^aTo obtain the same number of observations for all of our dependent variables, we exclude Philippines, Russia, Saudi Arabia and sector C40T41 due to data availability. Standard errors are clustered to correct for heteroskedasticity and reported in parenthesis.
*, **, *** present the statistical significance at 10%, 5% and 1% levels.