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Abstract

The current study empirically investigates and shows that on average, the possible implementation of the Transatlantic Trade and Investment Partnership (TTIP) would generally help in the fight against global warming. In particular, the study finds that a one percent increase in the bilateral trade between the U.S. and the typical EU member would reduce annual per capita emissions of CO_2 and *GHGs* in the typical TTIP member by about 2.7 and 2.4 percent, respectively. However, results also show that TTIP may increase annual per capita emissions of *GHGs* in the U.S. by about 2.5 percent per year. These results stand because the factor endowment hypothesis (FEH) and the pollution haven hypothesis based on population density variations (PHH2) appear to dominate the pollution haven hypothesis based on national income differences (PHH1).

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1 Introduction

The possible creation of a free trade agreement between the U.S. and EU (so far the biggest common free trade area in the world), the so-called Transatlantic Trade and Investment Partnership (TTIP), has generated a lot of debate on both sides of the Atlantic. During their ongoing negotiations, both the U.S. and EU have been evaluating the pros and cons that such an agreement would have on both regions.[1] These pros and cons concern not only the economic and political implications but also the environmental impact of the agreement.[2] This paper attempts to shed some light on the latter by considering the TTIP impact on its members' pollution emissions of CO_2 and *GHGs*, the two most important air pollutants associated with global warming.

There is a burgeoning literature on the effects of trade liberalization on the environment. Following this literature, one would expect, at least in theory, a GDP increase on both sides of the Atlantic as a result of TTIP. Assuming that everything else remains constant, a boost in production would then raise pollution levels in all TTIP members. This phenomenon is known as the scale effect. However, opposite to the scale effect, the technique effect suggests that the implementation of TTIP could simultaneously be beneficial to the environment. The later effect works through the upgrades in the production methodology, through the adoption of environmentally friendly technologies, and through the increased public awareness towards the consumption of pollution-intensive goods. In addition, the TTIP implementation may produce a composition effect. This effect refers to the changes in pollution levels due to the changes in the relative share of different goods

[1]TTIP has also been known as the Transatlantic Free Trade Agreement (TAFTA)

[2]According to the Office of the United States Trade Representative, "TTIP is an is an ambitious, comprehensive, and high-standard trade and investment agreement being negotiated between the United States and the European Union. T-TIP will help unlock opportunity for American families, workers, businesses, farmers and ranchers through increased access to European markets for Made-in-America goods and services. This will help to promote U.S. international competitiveness, jobs and growth". According to the European Commission, TTIP could be responsible for creating millions of jobs in both sides of Atlantic and promote growth by boosting the U.S. and EU economies by 90 and 120 billions of Euro respectively. TTIP is still under negotiations (there have been so far, 14th rounds of negotiations between a high official of the U.S. and EU) despite the efforts of President Obama to reach an agreement before the end of his second term in the White House. In various reports published by the respective officials in the U.S. (available online at https://ustr.gov/ttip) and EU (available online at http://ec.europa.eu/trade/policy/in-focus/ttip/), there is a chapter entitled "Raw Materials and Energy" that discusses the environmental issues and goals associated with the implementation of TTIP. In particular, according to Article 9 of this chapter entitled "Cooperation on Energy and Raw Materials", they claim that TTIP "would promote research, development, and innovation in the areas of energy efficiency, sustainable renewable energy, and raw materials", or it would "promote internationally high standard of safety and environmental protection for offshore oil, gas, and mining operations, by increasing transparency, sharing information, including on industry safety and environmental performance". For more details see the technical report available online at http://trade.ec.europa.eu/doclib/docs/2016/august/tradoc_154837.pdf.

in the aggregate national production. According to the composition effect, the adoption of TTIP may denigrate (improve) the environment if the production of capital-intensive (labor-intensive) goods increases due to the higher accumulation of physical capital.[3]

On the other hand, the TTIP implementation could increase pollution in the low-income and/or sparsely populated countries due to the existence of lax environmental regulations in these countries, following a typical Heckscher-Ohlin framework. These economic phenomena stem from trade liberalization and fall under the pollution haven hypothesis. Trade liberalization may also create a factor endowment hypothesis (henceforth, FEH). According to the Heckscher-Ohlin theory, the FEH states that a capital-abundant country has a comparative advantage in the production of capital-intensive goods. Therefore, the FEH consequently implies that the TTIP implementation could be beneficial for the environment only in the labor-abundant countries.

However, the most recent literature pioneered by Antweiler et al. (2001), focuses on determining the comparative advantage in a country by simultaneously analyzing the pollution haven motives and the FEH. A typical TTIP member is poorer, more densely populated, and more labor-abundant than the U.S. Consequently, at least theoretically, the adoption of TTIP should produce ambiguous effects. This is because, in line with the pollution haven hypothesis based on national income differences (henceforth, PHH1), one should observe an environmental degradation in the relatively poor countries such as Romania, Bulgaria, and Greece to name a few. On the other hand, since the latter three countries tend to be more densely populated and more labor-abundant than the U.S., the pollution haven hypothesis based on national population density variations (henceforth, PHH2) and the FEH dictate that one should observe an increase (decrease) of the production of pollution-intensive goods in the U.S (above three countries). The latter effect then implies a positive impact of TTIP on the environment of Bulgaria, Romania and Greece, and a negative one for the environment of the U.S., respectively. Thus, the implementation of TTIP, at least theoretically, should denigrate the environment in a typical EU member (the U.S.), only if PHH1 dominates (is dominated by) FEH and PHH2.[4]

Whether on average the implementation of TTIP benefits or denigrates the environment remains an empirical question. This paper aims to provide a definite answer to this question. Therefore, using data over the 1989-2013 time period and for the current 28 EU members and the U.S., this study empirically investigates the possible impact of TTIP on the per capita pollution emissions of CO_2 and *GHGs*, respectively. The study focuses on

[3]The empirical evidence suggests that capital-intensive (labor-intensive) goods are pollution-intensive (environmentally-friendly) goods in relative terms, holding everything else constant.

[4]This is true since a typical EU member is poorer, more densely populated and more labor-abundant than the U.S.

these two air pollutants not only because of data availability but also because environmentalists consider *CO_2* and *GHGs* as the two main sources of man-made global warming.

The present work uses several panel data econometric techniques to evaluate the effects of the implementation of TTIP on the environment. The approach follows the work of Antweiler et al. (2001). Thus, the empirical analysis employs not only fixed and random effects but also fixed effects where the errors are robust to cross-sectional dependence and serial correlation, respectively. In addition, the study acknowledges the potential endogeneity problems between per capita emissions and trade and between per capita emissions and income per capita, respectively. Thus, to avoid the endogeneity between per capita emissions and income as well as the contemporaneous collinearity between trade and income, the base specification uses the second lag of income instead of its contemporaneous value. Next, the empirical analysis performs two robustness checks. First, one robustness check uses the second lag of trade as an instrument to avoid the potential endogeneity between per capita emissions and trade. Consequently, this specification uses the third lag of income. Further, similar to Frankel and Rose (2005), a second robustness check instruments trade with a set of exogenous variables including lagged income, exchange rate, capital to labor ratio, price of export, price of imports, land per capita, and four dummies (for whether a country uses the Euro, or has sea access, or uses English as its official language, or is poor). The main results remain surprisingly strong independent of the employed empirical strategy.

Overall, the study finds robust and statistically significant evidence suggesting that the implementation of TTIP may help reduce per capita emissions of *CO_2* and *GHGs*. More specifically, holding all other factors constant, the paper shows that, on average, a one percent increase in the bilateral trade between the U.S. and the typical EU member may help reduce per capita emission of *CO_2* and *GHGs* in the typical TTIP country by about 2.7 and 2.4 percent, respectively. This represents an important result because of its implications on the ongoing discussions and negotiations between the high-ranking officials of the EU and the U.S. It is also a surprising result since most of the literature provides empirical evidence that free trade is generally associated with higher per capita emissions of *CO_2*. Moreover, historical evidence has shown that it is very unlikely for the *CO_2* or *GHGs* based pollution issues to be addressed only by enforcing regulations at the national level. Thus, many environmental economists perceive *CO_2* or *GHGs* based pollution as a pure global externality.

However, the possible TTIP adoption may not have a uniform impact on the environment of each treaty member. This is more apparent in the case of *GHGs*. For instance, the empirical evidence shows that the implementation of TTIP could be associated with lower

GHGs emissions in a typical EU country, but with higher *GHGs* emissions in the U.S. In particular, one percent increase of trade (imports plus exports over GDP) between the U.S. and EU could lead to about 2.5 percent higher per capita emissions of *GHGs* in the U.S. In contrast, the evidence shows an across the board reduction of *GHGs* for almost all EU members (see Table 9 for more details). This result indicates that the implementation of TTIP may shift per capita emissions of *GHGs* from the EU towards the U.S. Interestingly, this result contradicts the popular belief (or fear) that EU members have towards the impact of TTIP. One can easily confirm the European public concern about the environmental impact of TTIP in the general media coverage as compared to the one in the U.S.[5] In general, Europeans believe that the environmental standards imposed in their countries, or at least in each of the original EU15 members, are more stringent than those in the U.S. Therefore, the EU seems concerned that the implementation of TTIP may force its members to reduce their standards. However, empirical evidence in this study suggests the opposite.

Further, for the case of CO_2 , the empirical exercise confirms a beneficial impact of TTIP because the FEH appears to dominate the PHH1. As mentioned, a typical EU member is more labor-abundant, poorer and more densely populated than the U.S. In the case of CO_2, on average, the results show that PHH2 is not generally statistically significant.[6] The reasoning for this finding has to do with the fact that the U.S. is richer and applies environmentally friendlier technologies as compared to a typical EU member. At the same time, according to the FEH and given that the average EU member is labor-abundant compared to the U.S., the implementation of TTIP reduces the production of capital-intensive goods and increases the production of labor-intensive goods in the typical EU country. Thus, despite the fact that a typical EU member may not use environmentally friendly technologies due to PHH1, its overall per capita emissions of CO_2 fall because of its national reduction of domestic production of capital-intensive goods. Further, since labor-intensive goods are considered relatively clean-goods, the use of backward and non-environmentally friendly technologies may not be associated with very high per capita CO_2 emissions.

Moreover, the results highlight that the implementation of TTIP, on average, will reduce per capita emissions of *GHGs*. The effect comes from the observation that FEH and PHH2 dominate PHH1.[7] The accompanying figures in the empirical section confirm this

[5] For instance, one can compare the information provided in http://ec.europa.eu/trade/policy/in-focus/ttip/ vs the one in https://ustr.gov/ttip.

[6] On the other hand, the Appendix Figures show that PHH2 could possibly verify for only four countries, which are to the right of Lithuania (Estonia, the U.S., Sweden, and Finland). This result is more apparent when comparing Finland and Sweden on one side with the U.S. on the other.

[7] Note that a typical EU member country is poorer and more densely populated as compared to the U.S. Thus, a poor country may act as pollution haven because it adopts lax environmental laws. On the other hand, the U.S. may act as pollution haven because it is sparsely populated as compared to an average EU

observation. One may note the much stronger evidence for PHH1 and PHH2 in the case of *GHGs*.[8]

In addition, the empirical results provide robust and statistically significant evidence suggesting that the implementation of TTIP on average, may benefit more the environment of the poor countries than that of the rich ones. The intuition for this result stems from the fact that the poor countries may see a more rapid adoption of environmentally friendly technologies due to the foreign direct investment spillover effects. Further, an increased public awareness of the risks of pollution may also play a role. Furthermore, all the poor EU members are more labor abundant than the rich EU members are relative to the U.S. Thus, increased trade between the poor EU members and the U.S. may benefit the former (despite the existence of lax environmental regulations in those countries) because TTIP would relocate the production of the capital-intensive goods towards the U.S.[9]

The empirical exercise focuses on the importance of PHH2 by omitting the variables associated with this motive (see model M1) in the first regression and then introducing those variables in the second regression (see Model M2). For the case of *GHGs*, the results show that PHH2 is very important for Belgium, Finland, Germany, Italy, Malta, the Netherlands, Sweden, the U.K., and the U.S. In particular, in the absence of PHH2, it may seem that in the U.S., the implementation of TTIP could be beneficial to the environment because PHH1 dominates FEH. However, when model M2 introduces the PHH2, the evidence shows that the implementation of TTIP could, in fact, denigrate the environment in the U.S.

Additional findings indicate that the implementation of TTIP in countries that use English as an official language and/or Euro as the official currency reduces per capita emissions of CO_2 less than in countries that do not do so. Moreover, evidence suggests that for countries with sea or ocean access, TTIP reduces per capita emissions of CO_2 and *GHGs* more than in countries that are landlocked.[10]

member. In conclusion, in the case of *GHGs*, the U.S. may act as a pollution haven if PHH1 is dominated by PHH2. Moreover, if this is the case, then FEH may further denigrate the environment in the U.S. since the latter is a capital-abundant country as compared to a typical EU member. The empirical results confirm this argument since they show statistically significant evidence suggesting that one percent increase in the bilateral trade between the U.S. and EU increases per capita emission of GHGs by about 2.5 percent per year in the U.S.

[8]This may be related to the fact that *GHGs* contain other air pollutants in addition to CO_2. In particular, *GHGs* also contain CH_4(methane), NO_2 (nitrogen dioxide), *CFCs* (chlorofluorocarbons), *HFCs* (hydrofluorocarbons), *PFCs* (perfluorocarbons), and SF_6 (sulfur hexafluoride). The online appendix to the paper entitled "Other Pollutants" shows that in a typical TTIP member, the implementation of TTIP will reduce per capita emissions of *HFCs/PFCs/*SF_6 (fluorinated gases) and NO_2.

[9]The Figures in the empirical section show that for *GHGs* and CO_2 and for the countries that are more developed than the typical TTIP member, the FEH starts to vanish after a certain point. In addition, in certain countries, the opposite situation occurs when PHH1 dominates FEH.

[10]However, it should be noted that, on average, countries that use English as the official language and/or Euro as the official currency are more developed than countries that do not do so. Therefore, this result may

Finally, an additional empirical exercise calculates the changes in social costs related to the changes in total CO_2 emissions due to one percent increase in bilateral trade. We provide statistically significant evidence suggesting that on average, an increase of one percent in annual bilateral trade between the U.S. and a typical EU member, could reduce social costs by approximately 220 million U.S. Dollars per year (or by about 8 dollars per person each year). The empirical section details the computation of these social costs for each participating country both in absolute value and as a percentage of GDP.

The rest of this paper is organized as follows. Section 2 provides a literature review. Section 3 describes our dataset and its sources. Section 4 presents the three main regression designs. Section 5 discusses the empirical methodology. Section 6 presents our empirical results. Section 7 provides some robustness checks. Finally, section 8 concludes.

2 Literature Review

Copeland and Taylor (2004) provide an excellent comprehensive review of the international trade and environmental literature. According to them, the recent burgeoning literature on the effects of international trade on the environment has its roots in the pioneering work of Grossman and Krueger (1993). Other important papers in this literature include among others, Anderson et al. (1992), Antweiler et al. (2001), Chichilnisky (1994), Cole and Elliott (2003), Copeland and Taylor (1994), Copeland and Taylor (1995), Dean (2002), Frankel and Rose (2005), Grossman and Krueger (1995), and (Mani and Cunha, 2011).

One can interpret the adoption of TTIP as a reduction of the geographical distance between North America and Europe, and therefore, as an intensification of the volume of international trade between them. Consequently, one would expect an increase in production, with cheaper prices for traded goods, and therefore with increased consumption in both the U.S. and the EU Thus, pollution levels in all TTIP member countries may increase due to the increased national production and higher national per capita income, respectively. The environmental economics literature calls this phenomenon the scale effect. Antweiler et al. (2001), Frankel and Rose (2005), Grossman and Krueger (1993), Grossman and Krueger (1995) among others provide robust empirical evidence of the existence of the scale effect in the case of SO_2.

At the same time, the adoption of TTIP may change the production methods for many goods via the technique effect. The latter effect works in two ways. First, trade liberaliza-

be more related to the level of development than to the use of the same currency or language. However, this is not the case for countries that have sea access relative to landlocked countries.

tion could create positive technological spillover effects. This is especially seen in developing countries, where domestic firms might take advantage of cleaner available technologies. Second, consumers may see environmental quality as a normal good. This, in turn, may lead to an increase in per capita income and to higher preferences for goods with better environmental quality. Antweiler et al. (2001), Frankel and Rose (2005), Grossman and Krueger (1993), Grossman and Krueger (1995) among others provide robust empirical evidence for the existence of the technique effect in the case of SO_2.

In addition to the scale and technique effects, trade liberalization may create a composition effect. This refers to changes in pollution levels due to changes in the relative shares of different goods in the aggregate national production. The composition effect relates to the empirical evidence that relative capital-intensive goods are pollution-intensive goods (see, for example, Mani and Wheeler (1997), Antweiler et al. (1998) , Antweiler et al. (2001), and Cole and Elliott (2003)). Thus, trade liberalization generates economic growth, which in turn generates more physical (human) capital accumulation and thus increases the national physical (human) capital. The latter will increase the overall production of the capital-intensive (labor-intensive) goods and therefore increase (decrease) national pollution emissions.

Grossman and Krueger (1995) find that while national income per capita increases, NAFTA raises SO_2 emission levels via the combination of the above three effects in the case of low-income countries, but lowers them in the case of high-income countries. This finding provides a unique relationship between trade liberalization and pollution levels and aligns with the claim that NAFTA produces an inverted-U shaped environmental Kuznets curve (EKC), between economic growth and SO_2 emission levels (see Copeland and Taylor (2004) and Dean (1992) for a comprehensive review on comparing the scale, technique and composition effects).

One part of the trade and environment literature agrees with either a Ricardian and/or Heckscher-Ohlin theory of international trade. In other words, liberalized trade forces a country to produce more of the goods at which they are relatively better suited and to import the rest of the goods from foreign countries. This changes the composition of national aggregate production, whereby each country increases the production of goods at which they enjoy a comparative advantage. Thus, if a country has a comparative advantage in goods that are produced with relatively cleaner technologies, trade liberalization would expand these cleaner industries and lead to lower pollution levels. As indicated earlier, since the pollution-intensive goods tend to be capital-intensive goods, one would expect an increase of national pollution levels in the capital-abundant countries (e.g., Italy, Austria, and Luxembourg are capital-abundant when compared to the U.S.). Consequently, one would expect a fall of pollution levels in labor-abundant countries (e.g., Bulgaria, Romania, Greece, and Portugal to name a few). The trade and environmental literature call this the FEH. Grossman and Krueger (1993) use data on SO_2 to provide empirical evidence that the implementation of NAFTA is consistent with the FEH. In particular, Grossman and Krueger (1993) show a decrease in SO_2 emission levels in Mexico, which is relatively labor-abundant, at least when compared to the U.S. Antweiler et al. (2001), Cole and Rayner (2000), Jaffe et al. (1995), Low and Yeats (1992), Tobey (1990), Xu (1999), and Walter (1973) provide more empirical evidence in support of the FEH.

Another branch of the trade and environment literature examines what is known as the PHH1. According to this hypothesis, the adoption of TTIP increases pollution in low-income countries because the latter tend to have lax environmental standards or non-effective implementation policies towards clean industries. For example, the group of former communist EU countries and of some southern European ones could have a comparative advantage in a dirty industry and thus export pollution-intensive goods to the U.S. since the former has lower incomes than the latter (i.e., the U.S.). Baumol and Oates (1988), Chichilnisky (1994), Copeland and Taylor (1994), Copeland and Taylor (1995), Grossman and Krueger (1995), McGuire (1982), Pethig (1976), and Siebert et al. (1980) provide robust and simple theoretical models in the support of PHH1. Thus, at least theoretically, PHH1 implies that the U.S. should expect a reduction of pollution levels due to its participation in TTIP, while Slovenia and Greece among others should expect an increase in pollution levels. However, not many papers in the trade and environment literature support the PHH1. For example, the literature review in Jaffe et al. (1995) concludes there is little empirical support for PHH1 and that only a few studies appear to contradict this conclusion. However, Ederington et al. (2004) claims that the lack of evidence for PHH1 could be related to the possible existence of simultaneity between the stringency of environmental regulations and pollution and to the issue of unobserved heterogeneity. More recently, empirical studies that control for the last two econometric issues, find empirical evidence in support of PHH1.[11]Muradian et al. (2002), Cole (2003), Ederington and Minier (2003), Levinson (2003), Brunnermeier and Levinson (2004) and Levinson and Taylor (2008) are some examples.

A different stream of the literature tests the pollution haven hypothesis using a differ-

[11]The present paper does not distinguish between the terms “effect” and “hypothesis” when referring to PHH1, even though some other studies do. The current study refers to PHH1 as the situation where the implementation of TTIP increases the production of dirty goods in the relatively poorer trade partners. This study proxies the latter by using the interaction of the trade variable with the relative income variable and with its covariables. However, the classical PHH1 simply claims that the implementation of a trade agreement (such as TTIP) would relocate the dirtiest firms from the rich trading partners to the poor ones. The present study proxies the latter with a measure of FDI.

ent approach. For example, Frankel and Rose (2005) use an inverted density measure that they call land per capita in order to test PHH2. They claim that trade liberalization may increase the production of pollution-intensive goods in low density populated areas and decrease it in high-density populated areas via the classical comparative advantage argument. Therefore, the low-density populated areas that may have less stringent environmental standards have the potential to become pollution havens.[12] However, Frankel and Rose (2005) find no empirical evidence in support of PHH2.

Antweiler et al. (2001) claims that previous empirical studies have found conflicting evidence not only because of data limitation and/or quality but also because these studies were trying to establish a unique relationship between international trade and environment across all countries. However, a country's comparative advantage, as shown above, could result both from the pollution haven and from the FEH. Both of these effects produce pollution levels that move in opposite directions and/or cancel out in the case of the relatively rich and capital-intensive countries. Thus, the implementation of TTIP, at least theoretically, reduces the pollution emissions in Luxembourg (Lithuania) for instance, if PHH1 dominates (is being dominated by) FEH. Antweiler et al. (2001) breaks down the composition effects of international trade into FEH and PHH1 and shows empirically that trade liberalization lowers pollution emissions. The dataset in this paper includes for the most part countries that are relatively poorer and more labor-abundant than the U.S. Therefore, for these countries, PHH1 should increase their national pollution emissions while FEH should reduce their national pollution emissions.

In the context of the impact of trade liberalization on global warming, environmental economists focus more on the effects of additional trade on per capita emissions of CO_2 (e.g., since the latter is considered to be the most important air pollutant associated with global warming), or *GHGs,* in general. In the case of CO_2 various empirical papers such as (Cole, 2003) or (Shapiro, 2016) provide robust evidence that trade liberalization increases per capita emissions of CO_2. While Managi et al. (2009) arrive at the same conclusion, they also provide empirical evidence that trade may help reduce per capita emissions of CO_2 for OECD countries.

3 Data Description and their Sources

The current study employs a dataset that covers the current 28 EU member countries and the U.S. over a period of 25 years from 1989 until 2013. Table 1 lists these countries.

[12]The dataset in this study includes only two countries, namely Finland and Sweden, that have relatively higher land per capita than the U.S.

Our models denote Carbon Dioxide with *CO_2,* which is probably the most discussed and often cited indicator of climate change and global warming. According to NRC (2010), *CO_2* is the primary *GHGs* contributor.[13] The Edgar database supplies the data for *CO_2*.[14] The Edgar database measures *CO_2* in metric tons (*Mg*) per capita emissions. According to NRC (2010) *"CO_2 is the primary greenhouse gas emitted through human activities. In 2013, CO_2 accounted for about 82% of all of GHGs emissions from human activities in the U.S. CO_2 is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle—both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere.* [15]

While *CO_2* is the largest contributor to *GHGs*, it is only one of several poisonous gases emitted into the atmosphere. Others include methane (*CH_4*), nitrous oxide (*N_2O*), chlo-

[13]NRC (2010) claims that *"human activities currently release over 30 billion tons of CO_2 into the atmosphere every year. This build-up in the atmosphere is like a tub filling with water, where more water flows from the faucet than the drain can take away... When sunlight reaches Earth's surface, it can either be reflected back into space or absorbed by Earth. Once absorbed, the planet releases some of the energy back into the atmosphere as heat (also called infrared radiation). GHGs like H_2O, CO_2, and CH_4 absorb energy, slowing or preventing the loss of heat to space. In this way, GHGs act like a blanket, making Earth warmer than it would otherwise be. This process is commonly known as the greenhouse effect."* Moreover, *CO_2* is also a significant contributor to ocean acidification as it dissolves into water carbonic acid is created.

[14]EDGAR v4.2, European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. http://edgar.jrc.ec.europe.eu, 2011; EDGARv4.2FT2012, European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. http://edgar.jrc.ec.europe.eu, 2014; BP (2011-2014) BP Statistical Review of World Energy 2011-2014. Internet: http://www.bp.com/en/global/corporate/about-bp/energy-economics/statisticalreview-of-world-energy.html, June 2014.

[15]According to the U.S. Environmental Protection Agency (EPA), the main human sources for emissions of *CO_2* come from the combustion of coal, natural gas, and oil for energy and transportation. Other important human sources concern various land use changes and industrial processes. In particular, in the U.S. in 2013 fossil fuel combustion from certain industrial processes accounted for about 15% of its total *CO_2* emissions and 12% of total *GHGs* emissions. A significant source of *CO_2* emissions caused by industrial processes comes from the cement manufacturing process. Other important human industrial sources of *CO_2* emissions come from the production process of several chemicals, or from the production of metals such as steel and iron. The second largest human source of *CO_2* emissions (which in the U.S. in 2013 accounted for about 31% of total *CO_2* emissions and 26% of total U.S. *GHGs* emissions) is represented by various modern methods of goods and human transportation means such as marine (ships), rail (trains), air (airplanes) and land (cars, trucks, buses) means. However, the most significant human source of *CO_2* emissions is the combustion of fossil fuels to generate electricity, which is generally used to power homes, businesses, and various industries. For example, in the U.S. in 2013 this source accounted for about 37% of total *CO_2* emissions and 31% of total U.S. *GHGs* emissions. According to NRC (2010), atmospheric *CO_2* concentrations have increased by almost 40% since pre-industrial times, from approximately 280 parts per million by volume (ppmv) in the 18th century to 390 ppmv in 2010. The current *CO_2* level is higher than it has been in at least 800,000 years. In the U.S. during the 1989-2013 time period, *CO_2* emissions have increased by about 7%. The U.S. EPA claims that the increase in *CO_2* emissions is mainly due to two main factors: 1) an increase in energy use by an expanding economy and population and an overall growth in emissions from electricity generation and 2) an increase in miles traveled by motor vehicles.

rofluorocarbons (*CFCs*), hydro-fluorocarbons (*HFCs*), per-fluorocarbons (*PFCs*) and sulfur hexafluoride (SF_6). These gases can have significant impacts on human health, global warming, ecosystems, volatile weather and economic output. We obtain the data for *GHGs* from UNFCCC. They are in *Tg* in CO_2 equivalent per capita emissions.

A measure of trade intensity, which is similar to Antweiler et al. (2001) constitutes the main variable of interest. The IMF database provides data on the volume of bilateral trade (imports and exports) between each EU member and the U.S. and on each country's real GDP measured in 2005 U.S. Dollars. In particular, the paper denotes this measure of trade intensity with *T* and measures it by dividing the sum of exports and imports to GDP. In the case of the U.S., *T* sums each EU country's exports to the U.S. to find the imports of the US from the EU, and each EU country's imports from the U.S. to find the exports of the U.S. towards the EU.[16]

The study finds real *GDP* per capita by dividing a country's real *GDP* to its population. In order to avoid the possible dual causality problem between pollution and income, the paper constructs and employs the three-year moving average of lagged real *GDP* per capita instead of a contemporaneous measure. We simply call this measure income per capita and denote it with *I*.[17] The IMF (2015) database supplies the data for real *GDP* per capita.[18] The paper uses bilateral nominal exchange rates to measure *GDP* in real 2005 U.S. Dollars. Relative real *GDP* per capita, denoted as *RI*, is found by dividing each country's real *GDP* per capita to the corresponding U.S. real *GDP* per capita. Table (3) provides more detailed information about this measure, while the Appendix figures provide a visual description. Both Table (3) and the figures show that with the exception of Denmark, Luxembourg, and Sweden, all countries in the sample are poorer than the U.S.[19]

The PENN World Tables 8.0 supply the capital to labor ratio data.[20] The paper denotes it with *KL* and measures it in current PPPs 2005 billion U.S. Dollars by dividing the physical capital stock to the labor force (the latter being measured in thousands).[21] The relative

[16]Thus, for each EU member i, $T_i = \left(\frac{X_i+M_i}{GDP_i}\right)$, where X_i and M_i denote each EU country's exports and imports with the U.S., respectively. In the case of the U.S., $X_{U.S.} = \sum_i M_i$ and $M_{U.S.} = \sum_i X_i$, respectively. Thus, the measurement unit is as a percentage of *GDP*.

[17]More specifically, the paper constructs it as: $I_{it} = 0.6 * I_{it-2} + 0.3 * I_{it-3} + 0.1 * I_{it-4}$. The empirical section demonstrates the better measurement properties of this weighting scheme over an equally weighted one.

[18]The IMF has since January 2015 made all of its data available at www.imf.org.

[19]Since the U.S. is the benchmark, *RI* will be 1 for the U.S. Only Denmark, Luxembourg, and Sweden have *RI*>1. This means that in the figures of interest, the rest of the countries will be to the left of the vertical line, which corresponds to the *RI* of the U.S.

[20]Feenstra et al. (2015) provides a statistical overview and analysis of the data in PENN Tables 8.0.

[21]Alternative measures exist. In particular, one could measure the national labor force by using the national persons engaged or the national working hours or an education index (i.e., the latter comes from

capital to labor ratio variable, denoted by *RKL*, computes by dividing each country's capital to labor ratio to that of the U.S. Table (3) and the Appendix figures provide more detailed information on this measure.[22] Both Table (3) and the figures confirm that with the exception of Austria, Italy, and Luxembourg, all other countries in the sample have a KL ratio lower than that of the U.S.

The annual ratio of the stock of inward Foreign Direct Investment to the physical stock of capital in each country provides a relative *FDI* measure. The IMF (2015) database supplies again the data for the stock of inward *FDI*, measured in real 2005 U.S. Dollars. The PENN World Tables 8.0 provide the data for the physical stock of capital, also expressed in 2005 constant U.S. Dollars.

LPC denotes land area per capita. The CIA World Factbook (2015) sources the land information in square kilometers.[23] The population, on the other hand, varies over time and across countries. The IMF (2015) database provides the population in millions. *LPC* writes as the annual log-ratio of the land area of each country to its population. The relative land area per capita variable, denoted by *RLPC*, writes as the ratio of each country's land per capita to the land area per capita in the U.S.[24] Table (3) and the Appendix figures show that only Finland and Sweden are more sparsely populated than the U.S. (i.e., *RLPC* >1).

Sea dummy denotes a dummy variable that is 1 for landlocked countries, while *T(Sea Dummy)* interacts *Trade* with this dummy variable. The sample in the study includes only five countries that are landlocked (i.e., Austria, Czech Republic, Hungary, Luxembourg, and Slovakia, respectively). *English* refers to a dummy variable that is 1 for the countries that have English as an official language. Only four countries in the dataset score a 1 for this variable (i.e., the U.S., the UK, Ireland and Malta). *Euro* denotes a dummy variable that switches to 1 beginning with the year in which a country has officially adopted the Euro.[25] *T(Euro)* refers to the interaction between *Trade* and this dummy variable.

Table (4) provides the summary statistics of our variables of interest. In particular, one may note that on average the relative *KL*, *I* and *LPC* ratios are at 71.1%, 56.2%, and 43.7%

Barro/Lee data set in the PENN World Tables). However, irrespective of the alternatives measure one could use, the main results stand. These are available upon request from the authors.

[22]The labor-abundant countries locate to the left of the U.S., while the capital-abundant countries locate to the right of the U.S. For the latter, *RKL* > 1.

[23]The CIA World Factbook is public and available online at https://www.cia.gov.

[24]Thus, $RLPC_i = LPC_i/LPC_{U.S.}$. The countries that are more densely populated than the U.S. have $RLPC<1$.

[25]The Euro was officially launched on January 1, 1999. Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain were the initial members of the Eurozone. Greece followed in 2001, Slovenia in 2007, Slovakia in 2009, Cyprus and Malta in 2008, and finally Estonia in 2011.

of those of the U.S., respectively. Bilateral trade with the U.S. is on average 3.71% of the GDP of the typical EU country. The stock of *FDI* is 13.2% of the stock of capital. The average annual income per capita is 22,716 real 2005 U.S. Dollars per capita, while the *KL* ratio is on average 158,455 real 2005 U.S. Dollars. Overall, the means are relatively close to their median, which indicates a low degree of skewness.

4 Three Estimating Equations

Throughout, subscripts t and i indicate the year (1989 through 2013) and country, respectively. Z_{it} denotes per capita emissions of the two pollutant measures (i.e., $CO_{2_{it}}, GHGs_{it}$). The construction of the three econometric models follows the works of Antweiler et al. (2001) and Frankel and Rose (2005). First, following Antweiler et al. (2001), the paper investigates the relationship between per capita emissions of each pollutant and: 1) the trade effect, which is split into *(i)* the FEH and *(ii)* the PHH1, 2) levels and squares of per capita income levels to investigate the existence of an environmental Kuznets curve (i.e., EKC), 3) the direct composition effect of growth, and 4) the composition effect of growth. Model 1 (*M1*) writes in the following way

$$\begin{aligned} E\left(Z_{it}\right) &= \theta_i + \xi_t + \alpha_1 T_{it} + \alpha_2 T\left(RKL\right)_{it} + \alpha_3 T\left(RKL\right)_{it}^2 + \alpha_4 T\left(RI\right)_{it} + \alpha_5 T\left(RI\right)_{it}^2 \\ &\quad + \beta_1 I_{it} + \beta_2 I_{it}^2 + \beta_3 KL_{it} + \beta_4 KL_{it}^2 + \beta_5 I\left(KL\right)_{it} + \epsilon_{it} \end{aligned} \tag{1}$$

where θ_i denotes the country-specific constant term, ξ_t denotes the time-specific constant term, and ϵ_{it} denotes an idiosyncratic measurement error term. Model 1 employs a set of five trade-based explanatory variables. In particular, M1 uses 1) the trade variable, T as a measurement of trade intensity, 2) the interaction of trade intensity with the relative capital to labor ratio, denoted by *T(RKL),* in order to detect the FEH, 3) the interaction of trade intensity with the squared relative capital to labor ratio denoted by $T(RKL)^2$ in order to account for the diminishing FEH at the margin, 4) the interaction of trade intensity with relative per capita income, denoted by *T(RI)*, in order to investigate PHH1 and 5) the interaction of trade intensity with squared relative per capita income, denoted by $T(RI)^2$, in order to account for diminishing PHH1 at the margin.

The lagged national income per capita I captures the effect of economic growth on the environment. The above specification does not separate the scale from the technique effects of growth since the pollution data are in terms of per capita emission levels. Therefore, the income per capita variable measures both the scale and technique effects. The specialized literature calls this the scale-technique effect (see Cole (2003) and Managi et al. (2009), among others).[26] The inclusion of the squared lagged income denoted by I^2 allows for the investigation of the possible existence of an EKC. Thus, a positive and statistically significant β_1 and a negative and statistically significant β_2 would confirm the empirical validity of the EKC.

To measure the direct composition effect of growth or the importance of national capital-abundance, *M1* adds the level and the square of the capital to labor ratio *(i.e., KL* and $(KL)^2$*,* respectively*)*. $(KL)^2$ accounts for the diminishing effect of capital accumulation at the margin. The cross-product of income per capita and capital to labor ratio (i.e., *I(KL)*) measures the general composition of growth.

Further, the slopes $\alpha_2\, and\, \alpha_3$ measure the *FEH* and the slopes $\alpha_4\, and\, \alpha_5$ measure the *PHH1*, respectively. Theoretically, according to the *FEH*, TTIP should produce a positive sign of α_2 for a relatively capital-abundant country, as compared to the U.S. For example, since Italy, Austria, and Luxembourg are relatively capital-abundant countries, while Poland and Slovenia are relatively-labor-abundant countries, the U.S. should import capital-intensive goods from Italy, Austria, and Luxembourg and labor-intensive goods from Poland and Slovenia. Consequently, the implementation of TTIP will increase per capita pollution levels in Italy, Austria, and Luxembourg, but decrease them in Poland and Slovenia.

On the other hand, along with the lines of *PHH1*, TTIP should theoretically produce a positive sign of α_4 for Bulgaria and Romania, because relatively poorer countries design and implement lax environmental regulations as compared to their trading partner, the U.S. (see for example Dasgupta et al. (2001)). Analogously, TTIP should theoretically produce a negative sign of α_4 for Denmark, Luxembourg, and Sweden because relatively richer countries design and implement stringent environmental regulations as compared to the U.S. Most EU members are poorer than the U.S., and therefore, potential pollution havens when compared to the U.S.[27] The existence of the *PHH1* in this setting falls under the Heckscher-Ohlin model as described in Antweiler et al. (2001), Copeland and Taylor (2004), Pethig (1976)and Siebert et al. (1980).[28]

[26]To separately identify the two effects, one would need data on concentrations of pollution. Using the latter, some studies separate the scale from the technique effect by using GDP per square kilometer for major cities to capture the scale effect (see for example, Antweiler et al. (2001), and Panayotou (1997)) and per capita income to measure the technique effect. Unfortunately, the data collection process did not find the required concentrations for the countries under study.

[27]Some countries, such as the former Communist countries have always been much poorer than the U.S. However, other countries in the sample, such as the majority of the first EU15 members for instance, are just slightly poorer than the U.S.

[28]Thus, the implementation of TTIP would theoretically force the poor countries to increase the production

The trade intensity variable T together with its interactions with the other variables in the model (i.e., the slopes of α_1 to α_5) measures the overall impact of trade on pollution. Theoretically, one would expect to find that TTIP reduces per capita emissions of CO_2 and *GHGs* in the U.S. if the rise of emissions per capita due to the FEH is outweighed by the fall of per capita emissions due to PHH1. According to Antweiler et al. (2001), one would unambiguously expect that TTIP increases per capita pollution emissions for a relatively capital-abundant and poor country (such as Italy or Austria when compared to the U.S.) because FEH goes in the same direction as PHH1. Similarity, TTIP should unambiguously decrease per capita pollution emissions for a relatively labor-abundant and rich country (such as Denmark or Sweden when compared to the U.S.) because FEH and PHH1 move in the same direction. However, for the rest of the countries, the implementation of TTIP should lead to an ambiguous effect of trade on the per capita emission levels. Since most countries in this study are labor-abundant and poor relative to the U.S., the implementation of TTIP should reduce pollution in the labor-abundant countries according to the FEH and simultaneously increase pollution in the poor countries due to the PHH1. Whether *FEH* dominates or not *PHH1* remains an empirical question.

Following the work of Frankel and Rose (2005), model 2 *(M2)* adds another proxy to capture the pollution haven hypothesis. In particular, *M2* adds levels and squares of an inverse measure of national population density such as the land per capita (i.e., total square kilometers per number of inhabitants). *M2* uses the coefficients associated with these terms to test the validity of *PHH2*. In addition to these two variables, *M2* adds the inward stock of *FDI* as a percentage of overall national physical capital. *M2* then writes in the following way

$$
\begin{aligned}
E\left(Z_{it}\right) &= \theta_i + \xi_t + \alpha_1 T_{it} + \alpha_2 T\left(RKL\right)_{it} + \alpha_3 T\left(RKL\right)^2_{it} + \alpha_4 T\left(RI\right)_{it} + \alpha_5 T\left(RI\right)^2_{it} \\
&\quad + \alpha_6 T\left(RLPC\right)_{it} + \alpha_7 T\left(RLPC\right)^2_{it} + \beta_1 I_{it} + \beta_2 I^2_{it} + \beta_3 KL_{it} + \beta_4 KL^2_{it} \\
&\quad + \beta_5 I\left(KL\right)_{it} + \beta_6 FDI_{it} + \beta_7 LPC_{it} + \beta_8 (LPC)^2{}_{it} + \epsilon_{it}
\end{aligned} \tag{2}
$$

M2 proposes to investigate the existence of the pollution haven hypothesis using a different channel than *M1* does. In this setting, the relatively low (as compared to the trading partner) national population density can trace the origins of lax environmental standards. In particular, the signs of the two slopes α_6 *and* α_7 (i.e., the slope coefficients of the cross

of pollution-intensive goods due to the existence of lax environmental regulations (as a consequence of being poor). In other words, relative income works in an analogous way to the relative capital to labor ratio. Models 2 and 3 use the FDI measure to test for the existence of a delocation of production from a rich country to a poor one.

product of trade and of the relative land area per capita and its square, respectively) test the empirical validity of *PHH2*. Table (3) underlines that with the exception of Finland and Sweden, most countries in this dataset are more densely populated than the U.S. Therefore, the PPH2 according to Frankel and Rose (2005) suggests that Finland and Sweden should have laxer environmental standards than the U.S. Therefore, holding everything else constant, TTIP should increase per capita emissions in Finland and Sweden and decrease them in the U.S. On the other hand, PHH2 also suggests that all other EU member countries will have relatively more stringent environmental standards than the U.S. Thus, the implementation of TTIP should decrease per capita emission of CO_2 and *GHGs* in these EU countries but increase them in the U.S.

Moreover, TTIP may affect per capita emission levels because of a globalization effect. For instance, a country's degree of openness or globalization should affect the way in which TTIP affects the environment. Following this reasoning, model 3 (*M3*) writes in the following way

$$\begin{aligned} E\left(Z_{it}\right) \quad = \quad & \theta_i + \xi_t + \alpha_1 T_{it} + \alpha_2 T\left(RKL\right)_{it} + \alpha_3 T\left(RKL\right)^2_{it} + \alpha_4 T\left(RI\right)_{it} + \alpha_5 T\left(RI\right)^2_{it} \\ & +\alpha_6 T\left(RLPC\right)_{it} + \alpha_7 T\left(RLPC\right)^2_{it} + \alpha_8 T(Sea\, dummy)_{it} + \alpha_9 T(Euro\, dummy)_{it} \\ & +\alpha_{10} T(English\, dummy)_{it} + \beta_1 I_{it} + \beta_2 I^2_{it} + \beta_3 KL_{it} + \beta_4 KL^2_{it} + \beta_5 I\left(KL\right)_{it} \\ & +\beta_6 FDI_{it} + \beta_7 LPC_{it} + \beta_8 (LPC)^2{}_{it} + \epsilon_{it} \end{aligned} \quad (3)$$

More specifically, *M3* includes a dummy for sea access denoted *Sea dummy* and interacts it with *T*. The international trade literature argues that a major regional free trade agreement such as TTIP will intensify bilateral trade more for the countries that have sea or ocean access. Only five countries in this dataset do not have sea access. These are Austria, Czech Republic, Hungary, Luxembourg, and Slovakia, respectively. Similarly, whether some countries adhere to a currency union such as the euro may matter too. Theoretically, *ceteris paribus*, one would expect more trade between the U.S. and the EU countries that are also part of the Eurozone. Therefore, in order to capture the Euro effect, *M3* adds the euro dummy denoted with *Euro dummy* and interacts it with *T*. Analogously, the use of English as an official language may also be important. Thus, *M3* proposes an English dummy simply denoted with *English dummy* and interacts it with *T*. Theoretically, holding everything else constant one would expect more trade between the U.S. and the three EU countries where English is an official language. These countries are the UK, Ireland, and Malta, respectively.

5 Empirical Methodology

Since some of the dependent and independent variables lack observations for all entities and all years, the empirical exercise requires imputing some of the missing data. To this end, this study uses the Amelia II program available in R. This program performs multiple imputations whereby several different "completed" datasets are obtained to reflect the uncertainty in the data. The results are then recombined to obtain the final dataset. The estimations in the study generally follow the default specifications (i.e., bootstrap five different datasets which are then averaged to get the final series). However, in other cases whereby the missing observations occur either at the very end or at the very beginning of the sample and the series exhibits a clear monotonic trend, we employ a simple trend regression to fill in the missing observations. Further, for the cases where there is only one missing observation in the middle of the series, a simple averaging to fill in the data suffices. Moreover, for the countries like the Czech Republic and Slovakia that did not become independent until 1993, we impute the data by using the information for Czechoslovakia and using a "proportional" approach based on a counterfactual analysis. The Appendix provides further details on the data imputation methods for the main variables employed in the analysis.[29]

The tables of the next section present results that employ the usual random and fixed effects approaches. However, in addition to the usual heteroskedastic robust standard errors, the empirical section employs specifications that are robust to contemporaneous cross-sectional dependence and serial correlation effects, respectively. In particular, for the latter, the paper uses a fixed effects regression with Driscoll-Kraay serial correlation robust standard errors that employ an MA(2) component. As indicated in the environmental literature, the serial correlation effects should be considered because the pollution and macroeconomic variables usually display monotonic trends. Further, the Breusch-Pagan Lagrange Multiplier (BP/LM) test rejects a simple pooled OLS approach. Thus, to economize on space we omit the OLS results.

Concerning the main results, the evidence suggests that in most cases the estimators across the random and fixed effects specifications, respectively are very similar in terms of sign, significance, and magnitude. Finally, the study corrects for the possibility of cross-sectional dependence by using such robust standard errors in a standard fixed effects framework.

[29]For instance, for one of the main variables in the study, namely the trade measure, Amelia fills in the missing observations by using a set of macro factors like GDP, employment, total population and the unemployment rate that do not have any missing observations.

The current study also investigates for the possible existence of unit roots. Thus, the last column of Table 4 shows the results from applying the Im-Pesharan-Shin panel unit root test. After controlling for a deterministic time trend, both pollutants and the explanatory variables appear stationary.

6 Empirical Results

The empirical section shows the main results for each pollutant in separate tables. Tables 5 and 6 show the "base" results for *GHGs* and CO_2, respectively. Each table reports the estimation results using fixed effects for *M1*, *M2* and *M3* in the first, second and third columns respectively and the estimation results of the same models, using random effects in the fourth, fifth, and sixth columns, respectively. Further, the seventh, eighth and ninth columns report the estimation results of the three models using cross-sectional fixed effects, while the tenth, eleventh and twelfth columns, respectively show the results using serial correlation fixed effects (i.e., with Driscoll-Kraay standard errors).

Scale-Technique Effects and EKC: The 6^{th} row of Tables 5 and 6 indicates the proxy of the scale-technique effect as measured by the two period lagged three-year moving average of income (real *GDP*) per capita. The 7^{th} row reports its squared value in order to investigate the existence of an EKC.[30] Both rows show statistically significant evidence across most of our models and estimation methods, consistent with the EKC argument.

Composition Effects: The 8^{th} and 10^{th} rows of Tables 5 and 6 report the direct composition effect of growth, as measured by the capital-labor ratio, and the composition effect of growth, as measured by the cross product of income per capita and capital-labor ratio, respectively. The 9^{th} row includes the square of the capital-labor ratio in order to capture the diminishing effect of capital accumulation at the margin. The evidence suggests that the accumulation of capital decreases per capita emissions of CO_2 and *GHGs,* respectively. This evidence appears strong especially in the case of the fixed effects and cross-section specification of *M3* in the case of *GHGs,* and almost in all specifications in the case of CO_2.

Population Density Effects: The 14^{th} row of Tables 5 and 6 reports the relationship between the inverse measurement of population density, as proxied by land per capita and pollution. Consistent with the environmental literature, the statistically significant evidence confirms that population density (land per capita) reduces (increases) per capita

[30] We further analyze the existence of the EKC in a separate paper, where we also report the turning points. This separate paper shows that for the two air pollutants above, the existence of the EKC is verified even when adding variables from the political economy literature such as the GINI coefficient and various national institutional measures. For more details see Pascalau and Qirjo (2017)

pollution of *GHGs* and CO_2, respectively. The second order effect appears especially strong when the dependent variable is *GHGs*. This result is strongest for *M2*.

FDI Effects: *M2* and *M3* present the impact of *FDI* on pollution in the 13th row and for each estimation method. Both models report a statistically significant and positive relationship between the extent of FDI in an economy and per capita emissions of CO_2 and *GHGs*. This may imply that multinational corporations may have chosen to move their production to the poorer (relative to the U.S.) TTIP members because of the lax environmental standards. This is consistent with the classical pollution haven hypothesis (abbreviated PHH). PHH argues that some of the firms in rich countries choose to move up entire plants (or just the dirtiest ones) to the relatively poor countries to take advantage of their relatively lax environmental standards. In order to confirm the PHH, unreported results employ a dummy variable with a value of 1 if the country is not part of the original EU-15 countries, to find statistically significant evidence that one percentage point increase in *FDI* from the U.S. to a typical non-EU-15 member is associated with an increase of per capita emissions of *GHGs* of 5.8 percentage points.[31] On the other hand, there is no significant evidence indicating a relationship between *FDI* from the U.S. to a typical EU-15 member and per capita emissions of our pollutants.[32]

Factor Endowment Effects: The cross-product of trade intensity and relative capital to labor ratio captures the FEH. The 2nd row of Tables 5 and 6 informs on the FEH via the *T(RKL)* coefficient. The 3rd row has the squared term of the cross-product of trade and relative capital to labor ratio to account for the diminishing FEH at the margin. Theoretically, the FEH suggests that the implementation of TTIP would denigrate the environment in capital-abundant countries and be beneficial to the environment in labor-abundant countries. The signs and significance of the *T(RKL)* and $T(RKL)^2$ coefficients support the FEH for both CO_2 and *GHGs*. This implies that assuming that capital-intensive goods are pollution-intensive goods, a higher capital to labor ratio of a country relative to that of the U.S. associates with higher per capita emissions of the two pollutants. However, this result applies on average. In order to get a better taste of the FEH, one needs to focus on each EU member's trade elasticity and their capital to labor ratios relative to the U.S. Table 9

[31] However, this exercise does not yield statistically significant evidence in the case of CO_2 emissions.

[32] Moreover, one would expect that PHH aligns with an increase in FDI in the non-EU-15 members due to the existence of relatively lax environmental standards, not only because of higher poverty in those countries relative the U.S. but also relative to the EU-15 members. For example, investigative articles comment on the severity of deforestation in Romania to supply the global chain of IKEA (for more details see an WSJ article available at https://www.wsj.com/articles/ikea-gets-deeper-into-the-woods-1438310691). Therefore, an additional source for the PHH may stem from the reallocation of dirty industries from the EU-15 to the non-EU-15 members as a direct outcome of the higher trade between EU-15 members and the U.S., respectively.

shows trade elasticity coefficients.[33] Thus, irrespective of the model used, it appears that in the case of CO_2 and for the countries to the left of Sweden, the higher the capital to labor ratio, the higher the per capita emissions of CO_2. The trade elasticities are markedly negative for the poorer countries from the former Eastern European block (e.g., Lithuania, Latvia, Poland, and Bulgaria). However, for the more advanced countries in the former Eastern European block (e.g., Czech Republic, Hungary), the elasticities appear positive albeit small. Similarly, the set of figures corresponding to *GHGs* shows a positive relationship between per capita emissions of *GHGs* and the relative to the U.S. capital-labor ratios, for the countries to the left of Croatia. In this case, however, the relationship stays negative for most of the countries in the analysis.

Pollution Haven Effects: The cross-product of trade intensity and relative income per capita captures the PHH1. The 4^{th} row in Tables 5 and 6 reports the coefficient of *T(RI)*, while the 5^{th} reports the squared value to account for the diminishing PHH1 at the margin. PHH1 argues that low-income countries adopt lax environmental standards, and therefore, produce dirtier goods, while rich countries can afford to accommodate stringent environmental laws and consequently produce cleaner goods. Thus, the implementation of TTIP should increase exports of dirty goods from poor countries and increase exports of clean goods from rich countries. On average, the statistically significant coefficients support the PHH1 for both CO_2 and *GHGs,* respectively. Therefore, on average, per capita emissions of these two pollutants go down as countries get richer. Further, the elasticities of CO_2 with respect to trade conditioning on relative income show that for the countries to the right of Slovenia and as countries get richer, their trade elasticity coefficients decrease slightly. The poorest countries in the sample, such as Bulgaria and Romania appear to have the lowest trade elasticities. However, this fact does not necessarily invalidate PHH1. It simply indicates that in most TTIP members, either the FEH and/or the PHH2 dominate PHH1. The evidence for *GHGs* also confirms the existence of PHH1. In particular, for the countries in the sample richer than Croatia, one percent increase in the bilateral trade with the U.S. produces a negative relationship between relative income and per capita emission of *GHGs*.[34]

As indicated above, an alternative method to test for the existence of the pollution

[33] To make sure the results are consistent, the Appendix figures (the ones in the middle) graph some of these trade elasticity coefficients, where in the vertical axes, there are trade elasticities of each TTIP member and the horizontal axes, there are the capital to labor ratios relative to the U.S. In particular, these figures show the elasticities produced by the random effects specification of each of the three models.

[34] The polynomial fitting curve under *M2* appears to have a different pattern than the ones in *M1* and *M3*, respectively. However, a closer inspection of the figure reveals that the trade elasticity coefficients are roughly similar across the three models with several minor exceptions. See three figures on the top for CO_2 and *GHGs* respectively.

haven hypothesis uses the cross-product of trade intensity and relative land per capita. Under this scenario, the implementation of TTIP may reallocate the production of dirty goods from the densely populated trade partner towards the sparsely populated one. Consequently, the less densely population countries may act as a pollution heaven. The evidence in Tables 5 and 6 supports the PHH2, at least for *GHGs*. The corresponding elasticities figures show that while in the case of CO_2 there is initially a negative relationship between the CO_2 trade elasticity coefficient and the relative land per capita, this trade elasticity coefficient is positive as predicted for Sweden and Finland. These two countries are the only ones with more land per capita than the U.S. Further, the corresponding figures for *GHGs* demonstrate that for almost all countries on average, higher land per capita associates with higher trade elasticities of per capita emissions.

Race to the bottom or gains from trade hypothesis: The trade intensity term T together with all of its interactions with the other variables captures the overall impact of TTIP on the environment. The evidence supports the existence of the gains from trade argument for both pollutants. This constitutes the most important result of the paper. Moreover, especially in the case of CO_2, historical evidence has shown that regulation at the national level may not be sufficient to reduce emissions levels. In the case of *GHGs*, a closer inspection of Table 6 shows that the beneficial effect of TTIP lies in the empirical fact that FEH and PHH2 dominate PHH1. Consequently, the implementation of TTIP reduces per capita emissions of *GHGs* because of the reduction of pollution levels in the low income and densely populated countries. Further, Table 6 suggests that the implementation of TTIP reduces per capita emissions of CO_2 because FEH dominates PHH1. The explanation for the latter result lies with the delocation of the production of the capital-intensive goods towards the U.S.

Trade Elasticity of CO_2 and GHGs: While so far the focus has been on the slopes of Trade and its interaction terms, a next step in the analysis seeks a better understanding of the impact of trade on pollution. For this, Table 9 shows the elasticities of *GHGs* and CO_2 with respect to trade (i.e., the percentage response of CO_2 or *GHGs* due to a 1% increase in Trade) for each country in the sample. The last row in this table reports the average total response across all countries. The paper evaluates the trade elasticities at sample means using the delta method. Focusing on CO_2, the results show robust and statistically significant evidence that on average, 1% increase in the share of trade to *GDP* will reduce per capita emissions of CO_2 anywhere from 0.93% in *M1* to 2.7% in *M3*. Note that while the coefficients from *M1* and *M2* display a smaller magnitude than that of those from *M3*, the coefficients are still negative and significantly different from zero. This is a surprising and interesting result since it shows that the implementation of TTIP may be really helpful in the fight against global warming by reducing per capita emissions of CO_2 by about 2.7% per year in the average TTIP country.[35] Moreover, Table 9 shows robust and statistically significant evidence that on average, 1% increase in the share of trade to GDP will reduce per capita emissions of *GHGs* by 2.4% when using *M3*, by 1.3% when using *M2* or by about 2.3% when using *M1*, respectively. Again, this is a very important result because it implies that the implementation of TTIP may reduce per capita emissions of *GHGs* by around 2.4% per year in the average TTIP member country.

However, this does not mean that every TTIP member country will benefit from this agreement. As explained in the previous section, the role of TTIP on pollution for each specific TTIP country member depends on one's comparative advantage in pollution-intensive versus clean-intensive goods. Therefore, we may find countries that are poorer than the U.S., but also more labor-abundant relative to the U.S., or countries that are more densely populated than the U.S., but also more capital-abundant than the U.S., or countries that are simultaneously poorer and more densely populated as compared to the U.S. Therefore, it is quite possible theoretically to find that some countries in our dataset have negative trade elasticities while others have positive trade elasticities. For a visual comparison, the Appendix figures plot the country-specific elasticities from Table 9 as a function of income relative to the U.S. (located on the top), with respect to the capital to labor ratios relative to the U.S. (located in the middle), and finally with respect to the U.S. land per capita (located at the bottom), respectively.

Overall, the results show that a TTIP member's specific trade elasticity estimates are negative for most of the countries under the analysis. However, the evidence also highlights positive and statistically significant estimates for Finland, Ireland, and Malta in the case of CO_2 per capita emissions. Further, at least when using *M3,* Ireland and the U.S. display positive and significant trade elasticities of *GHGs* per capita emissions. In some cases, while the coefficients appear negative, they are not statistically different from zero. These countries are Austria, Finland, Lithuania and Estonia in the case of *GHGs* and Austria and Sweden in the case of CO_2. The reader should keep in mind that these results are slightly different when changing the models or the specification method.[36]

As mentioned above, the country specific elasticities may cast a different light on the stated hypotheses and in particular on PHH1 and PHH2. For instance, the elasticities with respect to relative income provide weak support for PHH1 that claims that rich countries adopt stringent environmental laws and therefore pollute the environment less than the

[35]We focus on the results from *M3* since we believe it is the most complete and less prone to omitted variable bias.

[36]In each case, we focus on the results from *M3*. The results from *M1* and *M2* are relatively similar, even though on average the latter appear slightly less significant.

poor ones. As the figures show, there appears a positive relationship between relative income and trade elasticities for most countries. This is in contrast with PHH1 since one would expect a negative relationship between a TTIP member's trade-elasticity of CO_2 and its relative income level. However, there appears some support for PHH1 for several countries. In particular, for countries with a relative income higher than that of Spain (i.e., *RI* higher than 0.7 approximately), one can note a negative relationship between their relative income and trade elasticities of CO_2. In other words, for this set of countries, one may claim that the poorer ones adopt lax environmental regulations, and therefore, have higher per capita emissions of CO_2 due to the implementation of TTIP.

The evidence consistent with PHH1 appears stronger in the case of *GHGs* than in the case of CO_2. Focusing on the figures on the top, *M1* and *M3* show that for the majority of countries, the relative richer ones have lower *GHGs* emissions. In particular, countries that are richer then Croatia (located to the right of Croatia in the graph) reduce per capita emissions of *GHGs* more as they get richer as a result of more trade.

Further, looking at the figures, the trade elasticities with respect to land per capita show even more support for PHH2. The latter claims that the less densely populated countries may become pollution havens. In particular, in the case of CO_2 and for the countries roughly to the right of Latvia (i.e., to the right of a ratio of approximately 0.8), there appears to be a positive correlation between relative land per capita and the magnitude of a country's trade elasticity. This finding appears to be stronger for the case of *GHGs* (this is more apparent under *M2* and *M3*). Thus, for a land per capita in excess of about 0.1 (relative to the U.S.), there is a clear upward trend in the scatterplot of *GHGs* trade elasticities and relative land per capita.

The figures in the middle show the compositional effects of trade with respect to the FEH. For our sample, this hypothesis appears to be verified for the countries to the left of Slovenia (i.e., for a relative capital to labor ratio less than around 0.65) in the case of CO_2 and to the left of Croatia in the case of *GHGs* (i.e., for a relative capital to labor ratio less than approximately 0.54), respectively. In other words, we find a positive relationship between relative capital abundance and the magnitude of a country's trade elasticity for countries to the left of Slovenia for CO_2 and to the left of Croatia for *GHGs*, respectively. For the rest of the countries, there appears no evidence that more capital-abundant countries pollute the environment more.

In the case of *GHGs,* the average trade elasticity appears negative, indicating that PHH2 and FEH dominate PHH1. This is something that one may expect since most countries in our dataset are more labor-abundant, poorer, and more densely populated as compared to the U.S. Therefore, for a country like Romania, the implementation of TTIP, *Ceteris Paribus*, decreases per capita emissions of *GHGs*. The reasoning is that Romania is poorer, more labor-abundant, and more densely populated than the U.S. Therefore, the implementation of TTIP may push Romania towards a comparative advantage in labor-intensive goods and may pressure the U.S. to follow the PHH2, since Romania is more densely populated than the U.S. Therefore, the FEH and PHH2 promote the production of dirty (clean) goods in the U.S. (Romania). On the other hand, Romania is relatively much poorer than the U.S., which may force Romania to pursue the PHH1 due to the implementation of TTIP and increase per capita emission of *GHGs* there.[37]

An interesting case is Sweden, which is more labor-abundant but richer than the U.S. Thus, one may theoretically expect a negative trade elasticity for Sweden. However, a closer look at Table 3 and at the Appendix figures located at the bottom, shows that Sweden has a much lower density of population than the U.S., and therefore, the implementation of TTIP may force Sweden to chase the PHH2 due to its higher land per capita. The trade elasticity coefficient for Sweden appears positive but not significant for both *GHGs* and CO_2. Consequently, in the case of Sweden, PHH2 balances FEH and PHH1. This argument may explain the insignificant effect of trade elasticity on Sweden's per capita emission of *GHGs* and CO_2.

Another good example is, of course, the U.S. Table 3 clarifies that the U.S. is capital and land abundant and richer than most EU members. Thus, the implementation of TTIP could increase per capita emissions of *GHGs* and CO_2 in the U.S. if FEH and PHH2 dominate PHH1. In other words, if the latter argument is true, then the U.S. will raise the production of pollution-intensive goods due to the implementation of TTIP, despite the fact that it may have stringent environmental regulations as a result of enjoying a higher income. Thus, the U.S. may act as a pollution heaven because it is sparsely populated. Moreover, it has a comparative advantage in capital-intensive goods since it is a capital abundant country. However, none of the three models finds significant coefficients for the U.S. trade elasticities for CO_2 per capita emissions. Consequently, this may indicate that PHH2 and FEH even out PHH1. However, in the case of *GHGs*, *M3* yields a positive and statistically significant trade elasticity coefficient for the U.S. This may imply that in the U.S., PHH2 and FEH dominate PHH1.[38]

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[37]However, this is not the case for Malta, which is more labor abundant, poorer but more densely populated than the U.S. Thus, we conclude that the implementation of TTIP could help denigrate the environment in Malta because it may help increase per capita emissions of *GHGs* by about 1.6 percent per year. This result may hold because in the case of Malta, PHH1 dominates PHH2 and FEH.

[38]In the case of the U.S., the difference of the significance levels of coefficients of trade elasticities between *GHGs* and CO_2 could be related to our findings in our online Appendix entitled "Other Pollutants". There, we employ the same empirical techniques used in this paper to find statistically significant evidence of changing per capita emissions of two other air pollutants that are part of *GHGs* as a result of more trade. In particular,

In the case of *GHGs*, comparing the trade elasticities using *M1* (as shown in the 2nd column) with the trade elasticities using *M2* (as shown in the 3rd column), may highlight the importance of PHH2. For example, Germany has a positive trade elasticity coefficient when we employ *M1*, but it has a negative one when we use *M2*. The positive coefficient of trade elasticity using *M1* may indicate that in Germany, PHH1 dominates FEH since Germany is poorer and more labor abundant when compared to the U.S. However, the introduction of PHH2 gives Germany a negative trade elasticity coefficient. This may emphasize the importance of PHH2 in Germany since the latter is more densely populated than the U.S.

Using the same argument one can compare the signs, significance levels, and values of the trade elasticity coefficients of *M1* and *M2* for the rest of the countries. It turns out that PHH2 plays a very significant role in changing per capita emissions of *GHGs* due to the implementation of TTIP for Belgium, Finland, Germany, Italy, Malta, the Netherlands, Sweden, the UK, and the U.S. In particular, in the case of the U.S., *M1* yields a negative and statistically significant coefficient. This finding indicates that the implementation of TTIP may decrease per capita emissions of *GHGs* in the U.S. because PHH1 dominates FEH. However, *M2* reports a positive but not statistically significant coefficient of the trade elasticity in the U.S. Therefore, one may suspect that the significance loss of the trade elasticity coefficient when employing *M2* instead of *M1*, emphasizes the importance of PHH2 in the U.S. since the latter is a relative land abundant country as compared to all EU member except for Finland and Sweden.

In light of the above results, Table 10 calculates the change in social costs in each country due to changes in total CO_2 emissions as a result of one percent increase in bilateral trade between the U.S. and each EU country member. Following the literature, the empirical exercise assumes a social cost of about 26.57 dollars (in 2013 U.S. dollars, or 20 Euros) for each metric ton increase of total CO_2 emissions per year. The value of social costs represents an aggregate estimate of damages caused by global warming that may affect mainly human health, the agriculture sector, and the energy sector. However, environmentalists believe that the social costs are much higher even though it is very difficult to calculate them accurately due to data limitations.[39] Table 10 shows these results, whereby the parentheses report the per capita values of the social costs of CO_2. Table 10 indicates that in a typical TTIP country, an increase of one percent in bilateral trade

we show that in a typical TTIP member, the implementation of TTIP will reduce per capita emissions of *HFCs/PFCs/*SF_6 (fluorinated gases) and NO_2 (Nitrogen Dioxide).

[39]For more details on the value of social costs, please see the latest technical report from TTIP and its annexes available online at http://trade.ec.europa.eu/doclib/docs/2016/august/tradoc_154837.pdf. See also https://www3.epa.gov/climatechange/EPAactivities/economics/scc.html

between trade partners will reduce social costs associated with CO_2 by about 75 million dollars under *M1*, or 106 million dollars under *M2*, or 220 million dollars under *M3*. Note that *M3* yields social costs that are statistically significant for 21 out of the 29 countries in the dataset. It is important to note that the economic significance of the reduction of social costs varies in different countries. Therefore, one may want to compare the first column of Table 3 (relative income) and the values in parentheses (that represents the change of the environmental costs per person) reported in Table 10, in order to get a better grasp of the economic significance of the social costs' reduction. For example, looking at the estimates from *M3*, Luxembourg saves the most in social costs (a reduction of about 36 dollars per person in a year), while France saves the least (about 4 dollars per person reduction in a year) among the rich countries. Focusing on the poor countries, Poland saves the most (about 15 dollars per person each year), while Slovakia saves the least (about 4 dollars per person a year). In terms of economic growth, saving more in terms of social costs could be more important in countries that are at relatively earlier stages of economic development. For example, using *M3* for Bulgaria and Germany, an increase of one percent of bilateral trade per year between the U.S. and each of the former countries will reduce social costs associated with CO_2 by about 7 and 8 dollars per person for a year in Bulgaria and Germany, respectively. However, one may speculate that 7 more dollars in the pockets of every Bulgarian may mean much more for the Bulgarian economy than what 8 more dollars in the pockets of every German may mean for the German economy.

Further Globalization Effects: Bilateral trade between the U.S. and a subset of EU countries in our dataset may also be affected by geographical, cultural, or political reasons. For instance, some EU countries use English as an official language, or have sea or ocean access or use the same currency. Therefore, especially for cases where we found a unique relationship between liberalized trade and each one of our pollutants, it may be of particular interest to see if there is any evidence of a stronger relationship between the implementation of TTIP and the environment in countries that are more open to trade with the U.S. In order to capture these effects, the paper employs three dummies: 1) the cross-product of trade with a dummy that is 1 if the official language is English (English=1) reported in the 15^{th} row, 2) the cross-product of trade with the Sea dummy (Sea=1) reported in the 16^{th} row, and 3) the cross-product of trade with the Euro dummy (where Euro=1) reported in the 17^{th} row of Tables 5 and 6.

The results yield statistically significant evidence, implying that the implementation of TTIP in countries that use English as an official language would increase per capita emissions of both CO_2 and *GHGs,* relative to countries where English is not an official language. Further, the results show that the implementation of TTIP in countries that have sea or ocean access would, in turn, reduce per capita emissions of CO_2 and *GHGs* relative to countries that are landlocked. Finally, the tables report robust and statistically significant evidence, indicating that the implementation of TTIP in countries that use Euro as their common currency would increase per capita emissions of CO_2 and *GHGs* relative to countries where Euro is not an official currency. This finding may be related to the development stage of the Euro versus the non-Euro member countries and to the fact that CO_2 and *GHGs,* which are related to energy and transportation needs, may be facilitated by the use of the same currency.

7 Robustness Checks

7.1 Instrumenting Trade and Income with lags

The environmental literature has highlighted the potential endogeneity problems involving the possible double causation among the pollutant measures, trade, and income, respectively. For instance, the Porter hypothesis (see Porter and Van der Linde (1995)) claims that stringent environmental regulations are not only beneficial to the environment, but they may also act as incentives to promote or demote future growth through technological innovations. In other words, stringent environment regulations may create a technological revolution, (for example, absorbing energy from solar panels, or vehicles that operate with hybrid or electric engines vehicles) that reduces pollution and simultaneously increases or decreases productivity. Consequently, from the very beginning, the "base" specification employs the first lag of a three lag moving average of income per capita in order to avoid the dual causality between each pollutant measure and per capita income and also the contemporaneous correlation between income and trade. Specifically, the "base" specification uses the first lag of income per capita following the weighting scheme, where$I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * I_{it-3}$. Results not reported in the paper, show that this measure performs better out of sample in terms of a lower root mean squared forecast error relative to an equally weighted scheme.[40]

However, this section performs additional robustness checks. Thus, a first alternative specification instruments the potential endogeneity between trade and each pollutant, by using the first lag of trade instead of its contemporaneous value. For instance, instead of employing the contemporaneous value, this approach uses $T_{it} = 0.6T_{it-1} + 0.3T_{it-2} +$

[40]Separate unreported regressions use the level of $I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * 3$. These results are very similar to the ones reported in Tables 5 and 6 of this paper. For more details see Tables 5 and 6 of our previous version of this paper, Pascalau and Qirjo (2016)

$0.1T_{it-3}$. Consequently, this approach requires using the second lag of income per capita (i.e., $I_{it} = 0.6 * I_{it-2} + 0.3 * I_{it-3} + 0.1 * I_{it-4}$). Overall, the results are surprisingly similar to those presented above. Tables 7 and 8 display the robustness results using the instrumental variables approach outlined above. In general, the coefficients in Tables 7 and 8 have approximately the same magnitude and level of significance. However, some differences exist. For instance, the coefficients on *I* and *KL* are now significant at the 5% level when using fixed effects in both *M1* and *M2*, unlike the corresponding ones in Table 5. Further, in the case of CO_2, Table 8 yields minor differences. For instance, the fixed effects of *M3* specification does not any longer produce a significant coefficient for the interaction of *T* and *RI*. Thus, it appears that PHH1 weakens when instrumenting trade and income, respectively. Nevertheless, the reader should be aware that the trade elasticities reported in Table 9 and the Appendix figures are based on the results from Tables 7 and 8. Therefore, the main interpretation of the results stands.

In addition, multicollinearity issues may occur between the *KL* and *T* variables and/or between *LPC* and *T* variables due to the effect of trade on *KL* and *LPC*, respectively via the income effect (Chisik et al. (2016) provide details on the relationship between trade and population aging via the income channel). In order to avoid this additional issue, one may pursue an instrumental variable approach, where one uses the first lag of *KL* and the first lag of *LPC* instead of their contemporaneous values respectively (i.e., $KL_{it} = 0.6KL_{it-1} + 0.3KL_{it-2} + 0.1KL_{it-3}$ and $LPC_{it} = 0.6LPC_{it-1} + 0.3LPC_{it-2} + 0.1LPC_{it-3}$). Those results, while not reported here but available upon request from the authors, provide similar results.

7.2 Instrumenting Trade with Observables

A second robustness check follows Frankel and Rose (2005) to instrument trade with a set of exogenous variables including lagged income, exchange rate, capital to labor ratio, price of export, price of imports, land per capita, and four dummies for whether a country uses euro, or has sea access, or uses English as its official language, or was a poor country at the start of the sample, respectively.[41] This exercise considers a country poor if its first reported annual income was less than the EU average for that year, respectively. Tables

[41]Under this scenario, we proceed with the following two-stage least squares approach. First, we estimate a reduced form for our trade variable using all the exogenous variables and we get the fitted values for trade. Next, we construct instruments (not regressors) using the interaction between the predicted values and relative income, relative capital to labor ratio and relative land per capita respectively. Finally, we estimate the structural equation using all interacted instruments in addition to all the exogenous variables. As Wooldridge (2010) argues in chapter 20 of the 2nd edition of his textbook entitled "Econometric Analysis of Cross Section and Panel Data": There is no need to adjust the standard errors asymptotically.

11 and 12 report similar results to those in the "base" specifications. For instance, PHH1 verifies again. Thus, both in the case of CO_2 and *GHGs* the interaction of *Trade* and *RI* yields a negative and significant coefficient, with the second order effect being positive and highly significant, respectively. However, some differences also appear. Thus, in the case of *GHGs,* the interaction of *T* and *RLPC* appears now negative and significant, even though as before a higher *LPC* has a positive and increasingly diminishing impact on pollution.

In addition, one result that stands out is that the CO_2 reduction that trade appears to cause is mainly coming from the poorer EU members. This result reinforces the previous findings in the text.

Moreover, in order to control for the existence of potential different environmental standards in the highly industrialized EU15 members versus the non-EU-15 members, this second robustness check employs a dummy variable similar to the poor and rich dummy variable above. However, the difference, in this case, consists in using a dummy that is one if a country is an EU-15 member or the U.S. and a value of zero if a country is a non-EU-15 member. A possible additional dummy variable assigns a value of one if a country was not under a Communist regime before 1990 and a value of zero if it was. In general, the results from these separate exercises approximate those in Tables 11 and 12. Due to the space limitations, they are not included but are available upon request from the authors.

Additional specifications include the use of various institutional variables of worldwide governance indicators to control for the potential differences in environmental standards (for details on these variables see Kaufmann et al. (2011)). However, these specifications do not yield significant coefficients. While not included in this study, Pascalau and Qirjo (2017) include them in Tables 14 and 20 of a follow-up to this project.

Furthermore, one may use a weighted value of trade intensity that is expressed as a ratio of *T* to the world trade (where, $WT = \frac{WE+WI}{WGDP}$, where WT, WE, WI, and $WGDP$ stands for the world trade, world exports, world imports, and world GDP, respectively). In other words, we divide *T* with WT. The results remain the same in terms of their sign and statistical significance, albeit with smaller economic coefficients. These results are also available upon request from the authors.

The literature on growth and trade reports a reverse causality from income to trade which in our case implies a potential collinearity problem. However, from the very beginning, the "base" specification has employed lags of Income to alleviate this issue. In addition, the volume of trade with the U.S. as a share of GDP is small at around 3.7%. Also, the contemporaneous correlation between trade and income per capita in this sample is relatively small at only 9.17% on average. Therefore, the collinearity problem does not appear to be a severe issue in our dataset.

Finally, separate results may be obtained where instead of using a country's labor force, one may use a country's labor force multiplied by its average hours of labor (taken from the World PENN Tables 8.0), or a country's labor force multiplied with its human capital (taken again from the World PENN Tables 8.0), or a country's labor force multiplied with its average hours of labor and then multiplied by its human capital. All of these additional results are very similar to the main results in the paper.[42] Again, to save space we omit these additional results but they are available upon request from the authors.[43]

8 Conclusion

This paper empirically investigates the effects that the implementation of TTIP may have on CO_2 and *GHGs,* respectively. The present study employs a panel dataset of 28 EU members and the U.S. over the 1989-2013 time period. The evidence suggests that for a typical TTIP member, trade liberalization may indeed have a consistently beneficial impact on the environment. In particular, holding all the other factors constant, the results yield robust and statistically significant evidence suggesting that one percent increase in the bilateral trade between the U.S. and an average EU member reduces per capita emissions of CO_2 by about 2.7 percent. This reduction generates average social costs savings of about 220 million dollars per year (or 7.70 dollars per person per year). Similarly, the results yield robust and statistically significant evidence that the implementation of TTIP may help reduce per capita emissions of *GHGs* by around 2.4 percent per year in a typical TTIP member. However, the implementation of TTIP may not provide a beneficial impact on the environment of all TTIP members. For instance, evidence in the paper implies that one percent bilateral trade increase may raise per capita emissions of *GHG*s per capita in the U.S. by about 2.5 percent per year. The reasoning for this increase appears related to the fact that in the U.S., FEH and PHH2 dominate PHH1 since the U.S. is more capital abundant, more sparsely populated and richer than an average EU member.

[42] For more on the data of human capital as reported in the World PENN Tables 8.0 see Feenstra et al. (2015)

[43] We have also attempted a GMM approach to alleviate potential concerns about endogeneity. Thus, we have experimented with both a difference and a system GMM, where we used both a one-step and a two-step estimator, respectively. However, since in our sample T is not small relative to N, we run into an instrument proliferation problem. Thus, while trying to instrument both *Trade* and *Income* with previous lags, even though the coefficient signs and magnitudes appear similar to our original results, we get a perfect Hansen statistic of 1. This is indicative of the fact that the instruments in this case over fit the endogenous variables and/or that the instruments outnumber the individual countries. Therefore, we refrain from posting these additional results. However, with a large T, we argue that the potential endogeneity problem due to the correlation between a shock to a country's error and a country's fixed effects dwindles over time, which alleviates the endogeneity problem.

In the case of both pollutants, the paper provides robust evidence consistent with PHH1, which claims a negative relationship between national pollution and national income per capita. Moreover, the results yield statistically significant evidence consistent with PHH2 in the case of *GHGs*. PHH2 claims a negative relationship between national pollution and national population density as a result of TTIP. Further, the study reports strong statistically significant evidence consistent with the FEH in the case of both air pollutants, implying that the implementation of TTIP may help reduce pollution in labor-abundant countries and increase it in capital-abundant ones.

Since the typical EU member is poorer, more labor-abundant, and more densely populated than the U.S., one can not unambiguously predict the impact of TTIP on the environment. However, at least in the case of CO_2, the paper provides statistically significant evidence that FEH dominates PHH1. In addition, the evidence suggests that in the cases of *GHGs,* FEH and PHH2 dominate PHH1.

Moreover, the results of this paper suggest that the implementation of TTIP benefits the environment of the poor countries more than it does that of the rich ones. The intuition for this result possibly relates to the fact that all the poor EU members are more labor abundant than the rich EU members are relative to the U.S. Thus, based on the FEH, the poor EU members produce less capital-intensive goods and export more labor-abundant goods to the U.S. than the rich EU members do. In addition, the poor countries may see a more rapid adoption of environmentally friendly technologies due to the foreign direct investment spillover effects. The poor EU members may also benefit more from the increased public awareness of the pollution risks resulting from the implementation of TTIP.

Further, results show that countries with sea or ocean access have lower per capita emissions of both CO_2 and *GHGs* than landlocked ones as a result of TTIP. Additional evidence suggests that countries that use the Euro (English) as the common currency (official language) experience higher per capita emissions of CO_2 and *GHGs* due to TTIP than countries that do not. However, the latter result could be more related to the level of development that EU members have relative to the U.S. than the use of the same currency or language.

Overall, this study concludes that on average the adoption of TTIP may surprisingly truly help in the fight against global warming because of the reduction in per capita emissions of *GHGs* and CO_2, respectively. However, this is not the case for all TTIP members. For instance, evidence suggests that the implementation of TTIP may denigrate the environment in the U.S. because of the net increase in per capita emissions of *GHGs*. We suggest that the implementation of TTIP may denigrate the environment in the U.S., at least in the case of *GHGs*, because it may shift some *GHGs* emissions from most of the EU members towards the U.S. This suggestion is based on the robust and statistically significant evidence implying that PHH2 and FEH dominate PHH1.

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Table 1: *List of Countries in our dataset*

Austria	Germany	Poland
Belgium	Greece	Portugal
Bulgaria	Hungary	Romania
Croatia	Ireland	Slovakia
Cyprus	Italy	Slovenia
Czech Republic	Latvia	Spain
Denmark	Lithuania	Sweden
Estonia	Luxembourg	United Kingdom
Finland	Malta	United States of America
France	Netherlands	

Table 2: *Data Sources and their unit of measurement*

Variable	*Source*	*Unit of Measurement*
CO_2 (Carbon Dioxide)	EDGAR (2015)	Mg per Capita
GHGs (Greenhouse Gases)	UNFCCC (2015)	Tg in CO_2 equiv. per capita
Real GDP per capita (I)	IMF (2015)	Real (2005) U.S. Dollars
Capital to Labor Ratios (KL)	PENN World Tables 8.0	Real (2005) PPPs U.S. Dollars
Trade Intensity (T)	IMF (2015)	Percentage (0-100)
FDI Stock/Capital Stock (FDI)	IMF (2015)	Percentage (0-100)
Land area per capita (log) (LPC)	CIA World Factbook (2015)	log of (Km^2per capita)
Dummy for Landlocked {T(Sea dummy)}	CIA World Factbook (2015)	Percentage (0-100]=access to sea, 0=landlocked
Dummy for Language {T(English dummy)}	CIA World Factbook (2015)	Percentage (0-100]=English, 0=otherwise
Dummy for Euro {T(Euro dummy)}	Eurostat (2015)	Percentage (0-100]=using Euro, 0=otherwise

Table 3: Relative (to the U.S.) Measures of Income, Capital/labor and Land per Capita ratios

Country	Relative Income	Relative KL ratio	Relative LPC ratio
Austria	0.882	**1.183**	0.318
Belgium	0.827	0.935	0.091
Bulgaria	0.087	0.263	0.428
Croatia	0.199	0.539	0.388
Cyprus	0.356	0.828	0.304
Czech Republic	0.255	0.589	0.233
Denmark	**1.078**	0.874	0.247
Estonia	0.179	0.294	0.963
Finland	0.865	0.969	**1.825**
France	0.822	0.920	0.332
Germany	0.827	0.909	0.131
Greece	0.442	0.776	0.376
Hungary	0.197	0.467	0.275
Ireland	0.859	0.706	0.545
Italy	0.699	**1.176**	0.158
Latvia	0.142	0.296	0.842
Lithuania	0.139	0.239	0.581
Luxembourg	**1.681**	**1.689**	0.1822
Malta	0.322	0.659	0.024
Netherlands	0.871	0.978	0.066
Poland	0.162	0.333	0.248
Portugal	0.397	0.581	0.277
Romania	0.092	0.246	0.321
Slovakia	0.193	0.421	0.279
Slovenia	0.374	0.653	0.313
Spain	0.546	0.837	0.372
Sweden	**1.025**	0.660	**1.426**
UK	0.813	0.603	0.127
U.S.	1	1	1

Descriptive Statistics

Table 4: Summary Statistics and Unit Root Tests

Variable	Dimension	N	Mean	SD	Min	Max	Unit Root Tests
CO_2	Level	725	9.159	4.660	3.059	34.770	-4.094***
GHG	Level	725	10.435	4.786	0.562	34.807	-2.151**
Trade	% - (X+M)/GDP	725	3.712	5.005	0.272	103.540	-3.957***
Rel. K/L	U.S. = 1	725	0.711	.346	0.095	1.936	0.753***
Rel. I	U.S. = 1	725	0.562	0.406	0.014	2.289	0.856*
Rel. LPC	U.S. = 1	725	0.437	0.407	0.023	1.955	0.996*
I	Level	637	22.716	16.762	0.474	100.816	-1.917**
K/L	Level	725	158.455	84.453	16.616	522.945	-1.559*
FDI/K	Level	725	0.132	0.189	0	1.263	-3.665***
LPC	Log	725	9.184	0.890	6.602	11.021	-1.171*

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. For all series, with the exception of the "relative" series, we use the *Z-t-tilde-bar* statistic of the Im-Pesaran-Shin unit-root test where the AR parameter is panel specific. In all cases, we also include a time trend. For the "relative" series, we compute the Harris-Tzavalis unit-root test since the Im-Pesaran-Shin test did not meet the required assumptions. The null states that all panels contain unit roots, while the alternative states that some panels are stationary.

Main results

Table 5: Dependent Variable (Y) - GHGs Base Results

Estimation Method	Fixed Effects			Random Effects			Cross Section Dependence			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Trade	–38.963***	–57.198***	–84.446***	–36.292***	–53.090***	–72.601***	–38.963**	–57.198***	–84.446***	–33.386	–48.749***	–68.212
Trade × RKL	105.787***	159.956***	203.566***	94.601***	154.526***	187.656***	105.787**	159.956***	203.566***	92.189*	143.706***	179.289
Trade × $(RKL)^2$	–88.961***	–121.607***	–133.846***	–81.979***	–107.579***	–117.772***	–88.961***	–121.607***	–133.846***	–88.938**	–119.268***	–130.937
Trade × RI	12.501	–38.804	–79.234***	20.618	–48.229*	–60.226**	12.501	–38.804	–79.234	22.299	–31.267	–54.430
Trade × $(RI)^2$	–7.324	28.197**	43.941***	–13.011	21.929	25.941*	–7.324	28.197	43.941	–6.753	30.484**	40.403
I	.032	.053	.071**	.058*	.116***	.122***	.032	.053	.071	–.029	–.008	–.006
I^2	.001**	.000	.000	.001	.000	.000	.001	.000	.000	.001**	.000	.000
KL	–.008	–.010	–.012*	–.005	–.008	–.009	–.008	–.010	–.012*	.003	–.001	–.004
$(KL)^2$	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000**	.000***	.000
KL × I	–.001***	–.001***	–.000***	–.001***	–.001***	–.001***	–.001***	–.001**	–.000**	–.001**	–.000*	–.000
Trade × RLPC		49.607**	96.544***		69.897***	104.260***		49.607*	96.544***		31.954	70.252
Trade × $(RLPC)^2$		–12.885	–30.870*		–25.264	–39.187**		–12.885	–30.870*		.327	–14.456
FDI/K		1.491**	1.508**		2.164***	2.287***		1.491	1.508		1.924*	1.932*
LPC		32.831**	35.046**		2.337	1.428		32.831***	35.046***		37.729**	38.042
$(LPC)^2$		–1.402**	–1.480**		–.116	–.071		–1.402**	–1.480***		–1.622**	–1.616
English × Trade			41.038***			32.919***			41.038***			32.960
Sea × Trade			–24.823*			–25.372*			–24.823*			–23.821
Euro × Trade			9.508***			3.539			9.508**			5.866
Constant	11.578***	–171.070***	–184.450***	10.800***	–1.591	3.289	12.076***	–172.110***	–186.222***	11.842***	–196.903***	–199.648
N	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000
r2	.401	.456	.491				.963	.966	.968			
r2_a	.338	.394	.429									
bic	1732.164	1704.942	1684.261	.	.	.	.	.	.	.	.	.

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. M1, M2, and M3 correspond to the three models outlined in equations (1), (2), and (3), respectively. Cross Section Dependence represents a fixed effects regression where we allow for cross-section dependence among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay standard errors where we allow for an MA(2) component to account for the serial correlation effects in the residuals. GDP per capita is denoted by I and it is calculated as the three-year moving average of the lagged value of GDP per capita, $I_{it} = 0.6 * I_{it-2} + 0.3 * I_{it-3} + 0.1 * I_{it-4}$. All the other variables are in their contemporaneous values. Trade is the sum of exports and imports (between trading partners, the US on one side and each EU member on the other side) over GDP. All relative variables denoted by R in front of them are constructed relative to the US. KL denotes the capital to labor ratio that also measures the direct composition of growth. FDI/K is the ratio of the stock of inward FDI to the physical stock of capital. It is also used as a proxy to measure PHH. LPC denotes the land area per capita. KL × I denotes the general composition of growth. Trade × RKL and Trade × $(RKL)^2$ measure FEH. Trade × RI and Trade × $(RI)^2$ measure PHH1. Trade × RLPC and Trade × $(RLPC)^2$ measure PHH2. English × Trade is a dummy variable. If a country uses English as one of their official languages, we put the value of our Trade variable otherwise we put zero. Sea × Trade is a dummy variable. If a country has access to the sea or the ocean, we put the value of our Trade variable otherwise we put zero. Euro × Trade is a dummy variable. If the country uses Euro as its national currency, we put the value of our Trade variable otherwise we put zero.

Table 6: Dependent Variable (Y) - CO2 Base Results

Estimation Method	Fixed Effects			Random Effects			Cross Section Dependence			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Trade	–43.940***	–35.893***	–56.315***	–38.896***	–32.909**	–47.700***	–43.940**	–35.893**	–56.315***	–37.141	–26.020	–40.895*
Trade × RKL	146.104***	144.195***	194.615***	130.519***	140.860***	181.195***	146.104***	144.195***	194.615***	130.880**	127.082***	167.350***
Trade × $(RKL)^2$	–104.781***	–112.945***	–128.177***	–94.985***	–100.303***	–112.411***	–104.781***	–112.945***	–128.177***	–104.134***	–108.282***	–121.531***
Trade × RI	2.559	–13.227	–63.071**	5.711	–25.416	–47.432*	2.559	–13.227	–63.071	6.670	–12.448	–49.317**
Trade × $(RI)^2$	.667	21.689*	39.584***	–3.047	16.958	22.952	.667	21.689	39.584	5.312	27.019**	41.271***
I	.145***	.121***	.148***	.173***	.179***	.198***	.145***	.121***	.148***	.064	.049	.060
I^2	–.000	–.001	–.001*	–.000	–.001*	–.001**	–.000	–.001	–.001	.000	–.000	–.001
KL	–.017***	–.013**	–.016***	–.013**	–.010	–.012*	–.017***	–.013**	–.016**	–.008	–.008	–.011
$(KL)^2$	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000**	.000***	.000***
KL × I	–.000***	–.000*	–.000	–.000**	–.000*	–.000	–.000**	–.000	–.000	–.000	–.000	–.000
Trade × RLPC		–59.331***	–15.993		–30.940	4.496		–59.331**	–15.993		–73.005**	–38.771
Trade × $(RLPC)^2$		46.797***	33.247**		25.983	13.350		46.797***	33.247*		56.863**	46.436*
FDI/K		1.771**	1.748**		2.363***	2.517***		1.771	1.748*		2.188**	2.121**
LPC		24.235*	29.248**		–3.062	–3.312		24.235*	29.248**		25.635	28.624
$(LPC)^2$		–.844	–1.055		.276	.276		–.844	–1.055		–.899	–1.016
English × Trade			41.001***			35.007***			41.001***			32.548***
Sea × Trade			–32.672***			–33.446***			–32.672**			–27.434**
Euro × Trade			12.514***			6.348*			12.514***			9.591**
Constant	8.979***	–142.000**	–169.792***	8.112***	12.313	14.803	8.875***	–143.240**	–172.140***	9.520***	–149.244	–166.142*
N	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000
r2	.303	.381	.428				.962	.966	.969			
r2_a	.229	.310	.359									
bic	1693.171	1652.518	1623.697	.	.	.	.	.	.	.	.	.

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. M1, M2, and M3 correspond to the three models outlined in equations (1), (2), and (3), respectively. Cross Section Dependence represents a fixed effects regression where we allow for cross-section dependence among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay standard errors where we allow for an MA(2) component to account for the serial correlation effects in the residuals. GDP per capita is denoted by I and it is calculated as the three-year moving average of the lagged value of GDP per capita, $I_{it} = 0.6 * I_{it-2} + 0.3 * I_{it-3} + 0.1 * I_{it-4}$. All the other variables are in their contemporaneous values. Trade is the sum of exports and imports (between trading partners, the US on one side and each EU member on the other side) over GDP. All relative variables denoted by R in front of them are constructed relative to the US. KL denotes the capital to labor ratio that also measures the direct composition of growth. FDI/K is the ratio of the stock of inward FDI to the physical stock of capital. It is also used as a proxy to measure PHH. LPC denotes the land area per capita. KL × I denotes the general composition of growth. Trade × RKL and Trade × $(RKL)^2$ measure FEH. Trade × RI and Trade × $(RI)^2$ measure PHH1. Trade × RLPC and Trade × $(RLPC)^2$ measure PHH2. English × Trade is a dummy variable. If a country uses English as one of their official languages, we put the value of our Trade variable otherwise we put zero. Sea × Trade is a dummy variable. If a country has access to the sea or the ocean, we put the value of our Trade variable otherwise we put zero. Euro × Trade is a dummy variable. If the country uses Euro as its national currency, we put the value of our Trade variable otherwise we put zero.

Instrumenting Trade and Income with Lags

Table 7: Dependent Variable (Y) - GHGs Robustness Results

Estimation Method	Fixed Effects			Random Effects			Cross Section Dependance			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Trade	–47.836***	–58.993***	–85.808***	–45.265***	–56.153***	–75.059***	–47.836***	–58.993***	–85.808***	–43.406**	–51.528***	–72.735
Trade × RKL	129.373***	154.910***	213.316***	119.151***	155.474***	205.048***	129.373***	154.910***	213.316***	121.996***	144.558***	200.887
Trade × $(RKL)^2$	–103.132***	–120.576***	–140.388***	–97.222***	–111.270***	–130.092***	–103.132***	–120.576***	–140.388***	–105.585***	–119.565***	–140.139
Trade × RI	7.840	–15.851	–58.710**	15.083	–32.953	–47.419*	7.840	–15.851	–58.710	13.598	–14.716	–54.436
Trade × $(RI)^2$	–8.884	11.661	30.624**	–13.294	11.769	18.111	–8.884	11.661	30.624	–4.675	17.499	36.248
I	.066**	.065**	.066**	.086***	.116***	.115***	.066	.065	.066	–.023	–.018	–.026
I^2	.001**	.001*	.000	.001*	.000	–.000	.001	.001	.000	.001**	.001**	.001
KL	–.015**	–.016***	–.017***	–.012*	–.012*	–.014**	–.015**	–.016***	–.017***	–.004	–.006	–.008
$(KL)^2$	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000
KL × I	–.001***	–.001***	–.000***	–.001***	–.001***	–.000***	–.001***	–.001***	–.000**	–.001**	–.001**	–.000
Trade × RLPC		35.026	89.565***		58.193***	99.237***		35.026	89.565***		19.320	67.655
Trade × $(RLPC)^2$		–7.736	–29.674*		–21.314	–38.491**		–7.736	–29.674		4.129	–14.787
FDI/K		.298	.297		1.380*	1.488**		.298	.297		.944*	.999
LPC		10.981	13.016		–4.058	–5.391		10.981	13.016		17.372	19.303
$(LPC)^2$		–.237	–.292		.242	.313		–.237	–.292		–.545	–.600
English × Trade			43.220***			34.005***			43.220***			38.476
Sea × Trade			–32.867***			–33.336***			–32.867***			–33.065
Euro × Trade			9.645***			3.646			9.645***			8.742
Constant	11.910***	–69.018	–82.541	11.218***	27.184	33.801	12.422***	–69.019	–83.370	12.423***	–100.976	–113.298
N	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000
r2	.444	.498	.538				.968	.971	.973			
r2_a	.384	.438	.480									
bic	1549.135	1521.793	1492.735	.	.	.	.	.	.	.	.	.

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. M1, M2, and M3 correspond to the three models outlined in equations (1), (2), and (3), respectively. Cross represents a fixed effects regression where we allow for cross-section dependence among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay standard errors where we allow for an MA(2) component to account for the serial correlation effects in the residuals. This table shows a first set of robustness results, where we use an instrumental variable approach by instrumenting *Trade* with its lag (i.e. $T_{it} = 0.6T_{it-1} + 0.3T_{it-2} + 0.1T_{it-3}$) and consequently instrumenting *Income* with its second lag (i.e. $I_{it} = 0.6I_{it-3} + 0.3I_{it-4} + 0.1I_{it-5}$) to avoid the potential endogeneity issues arising from the Porter hypothesis. All the other variables are in their contemporaneous values. We use these results to compute the coefficients of elasticities of our pollution measures with respect to *Trade*.

Table 8: Dependent Variable (Y) - CO2 Robustness Results

Estimation Method	Fixed Effects			Random Effects			Cross Section Dependance			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Trade	−56.885***	−40.950***	−62.522***	−51.175***	−39.747***	−55.595***	−56.885***	−40.950***	−62.522***	−51.884*	−32.361**	−48.691***
Trade × RKL	180.378***	146.247***	205.875***	163.213***	149.572***	202.793***	180.378***	146.247***	205.875***	170.577***	135.228***	189.738***
Trade × $(RKL)^2$	−125.699***	−114.866***	−136.102***	−115.490***	−107.071***	−127.745***	−125.699***	−114.866***	−136.102***	−127.172***	−112.376***	−132.890***
Trade × RI	4.424	15.730	−25.581	7.365	−4.905	−19.423	4.424	15.730	−25.581	7.898	11.776	−26.266
Trade × $(RI)^2$	−2.882	.682	18.477	−5.704	2.760	8.586	−2.882	.682	18.477	4.041	9.443	26.996**
I	.171***	.144***	.147***	.193***	.188***	.190***	.171***	.144***	.147***	.061*	.050*	.044*
I^2	.000	.000	−.000	−.000	−.000	−.001*	.000	.000	−.000	.001	.000	.000
KL	−.023***	−.020***	−.021***	−.019***	−.015**	−.017***	−.023***	−.020***	−.021***	−.012**	−.013**	−.015**
$(KL)^2$	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***	.000***
KL × I	−.001***	−.001***	−.000***	−.000***	−.000***	−.000**	−.001***	−.001***	−.000**	−.001**	−.000**	−.000*
Trade × RLPC		−72.669***	−22.160		−40.954*	−.402		−72.669***	−22.160	−.038	−84.770**	−42.028
Trade × $(RLPC)^2$		50.625***	31.415*		28.860*	12.557		50.625***	31.415*		59.909**	44.120*
FDI/K		.574	.609		1.673**	1.828***		.574	.609		1.208**	1.279*
LPC		−1.908	1.140		−8.556	−9.557*		−1.908	1.140		1.475	4.206
$(LPC)^2$		.534	.429		.580*	.630**		.534	.429		.368	.274
English × Trade			42.090***			35.265***			42.090***			36.095***
Sea × Trade			−37.635***			−39.083***			−37.635***			−35.041***
Euro × Trade			9.755***			3.972			9.755***			8.782*
Constant	9.252***	−18.804	−37.429	8.437***	37.255	42.552	9.223***	−18.843	−38.475	9.912***	−34.753	−51.145
N	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000	580.000
r2	.350	.432	.481				.967	.972	.974			
r2_a	.279	.364	.416									
bic	1509.964	1463.615	1429.869	.	.	.	.	.	.	.	.	.

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. M1, M2, and M3 correspond to the three models outlined in equations (1), (2), and (3), respectively. Cross represents a fixed effects regression where we allow for cross-section dependence among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay standard errors where we allow for an MA(2) component to account for the serial correlation effects in the residuals. This table shows a first set of robustness results, where we use an instrumental variable approach by instrumenting *Trade* with its lag (i.e. $T_{it} = 0.6T_{it-1} + 0.3T_{it-2} + 0.1T_{it-3}$) and consequently instrumenting *Income* with its second lag (i.e. $I_{it} = 0.6I_{it-3} + 0.3I_{it-4} + 0.1I_{it-5}$) to avoid the potential endogeneity issues arising from the Porter hypothesis. All the other variables are in their contemporaneous values. We use these results to compute the coefficients of elasticities of our pollution measures with respect to *Trade*.

Table 9: Elasticity Coefficients

Estimation Method	GHGs			CO2		
Specification	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)
	RE (M1)	RE (M2)	RE (M3)	RE (M1)	RE (M2)	RE (M3)
Trade						
Austria	-3.894***	-3.323***	-1.259	-2.076***	-2.918***	-.266
Belgium	-1.803***	-2.634***	-6.651***	.126	-.049	-3.828***
Bulgaria	-2.053***	-.457	-3.413**	-2.328**	-2.995**	-7.540***
Croatia	-.734**	.812	-1.274*	.428	-.524	-3.464***
Cyprus	-1.292***	-.295	-2.129***	.183	-.615	-3.224***
Czech Republic	-.588**	.167	1.098	.797**	.285	2.147
Denmark	-1.593***	-1.506***	-3.821***	.240	-.329	-2.923***
Estonia	-1.592***	1.107	-.433	-1.479**	-1.667*	-3.637***
Finland	-1.903***	.297	-.528	-.102	1.543	.987
France	-1.554***	-1.053*	-2.608***	.126	-.772	-2.577***
Germany	1.166***	-1.763***	-4.498***	.481	.203	-3.047***
Greece	-.713***	.353	-1.136*	.871**	-.187	-2.076***
Hungary	-.847***	.103	.929	.175	-.463	1.267
Ireland	-1.143*	.074	1.405***	.486	-.547	.991*
Italy	-3.834***	-4.065***	-6.071***	-2.301***	-3.088***	-5.698***
Latvia	-1.949***	-.099	-2.619**	-2.195**	-2.879***	-6.439***
Lithuania	-1.624***	1.004	-.747	-1.548**	-1.942**	-4.033***
Luxembourg	-25.548***	-20.259***	-16.019***	-18.551***	-15.600***	-11.527***
Malta	-.775**	-1.213***	-.641*	.685**	1.113**	1.606**
Nederlands	-2.152***	-3.188***	-6.961***	-.156	-.276	-4.189***
Poland	-1.397***	-.896	-4.229***	-1.109*	-1.684**	-6.843***
Portugal	-.524***	-.015	-2.141***	.771**	.023	-2.831***
Romania	-2.075***	-1.131	-4.575***	-2.400***	-3.079***	-8.508***
Slovakia	-.572**	.315	-1.631***	.916***	.042	-2.611***
Slovenia	-1.182***	-.255	-1.613***	.403	-.622	-2.302***
Spain	-1.034***	-.225	.505	-.319	-.958	.667
Sweden	-.691	1.176	.208	.608	.682	-.182
UK	-.527	-1.480***	-1.229*	.651	.475	.670
USA	-2.124***	.324	2.506**	-.175	-.906	1.224
Average	-2.306***	-1.315***	-2.399***	-.924**	-1.301**	-2.696***

The results in this table show the percentage response in the GHGs and CO2 measures for a 1% increase in Trade, respectively. Columns (1), (2), and (3) show coefficients of Trade elasticities for GHGs using Model 1, 2, and 3 respectively. Columns (4), (5), and (6) indicate Trade elasticities for CO2 using Models 1, 2, and 3 respectively. ***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. The study employs the Delta method to compute the Trade elasticities. The last row reports the average Trade elasticity across all countries for each air pollutant under all Models. We use the results of Tables 7 and 8 to compute our Trade Elasticities. Note that the coefficients of Trade elasticities are generally very similar in terms of their significance level and sign when we use the results of Tables 5 and 6 instead of Tables 7 and 8. We do not report these results here, but they are available upon request to the authors. Note that all negative and statistically significant Trade elasticities are in blue color implying a beneficial impact on the environment as a consequence of the implementation of TTIP. All positive and statistically significant Trade elasticities are in red color indicating a degradation of the environment due to the implementation of TTIP.

Table 10: CO_2-based Environmental Social Costs

	Δ Social Costs (% Δ) (M1)	Δ Social Costs (% Δ) (M2)	Δ Social Costs (% Δ) (M3)
Trade			
Austria	-40,909,415 (-4.8)***	-57,493,163 (-6.8)***	-5,243,064 (-0.6)
Belgium	3,532,395 (0.3)	-1,386,452 (-0.1)	-10,6735,350 (-9.6)***
Bulgaria	-15,352,150 (-2.1)**	-19,750,388 (-2.7)**	-49,713,262 (-6.9)***
Croatia	5,663,683 (1.3)	-6,923,500 (-1.6)	-45,773,307 (-10.7)***
Cyprus	498,593 (0.4)	-1,675,924 (-1.5)	-8,785,457 (-7.7) ***
Czech Republic	16,051,880 (1.5)**	5,741,337 (0.5)	43,191,039 (4.0)
Denmark	2,128,530 (0.4)	-2,917,405 (0.5)	-25,881,265 (4.6)***
Estonia	-7,287,088 (-5.7)**	-8,208,812 (-6.4)*	-17,911,498 (-13.9)***
Finland	-1,167,591 (-0.2)	17,561,220 (3.2)	11,235,037 (2.1)
France	12,178,875 (0.2)	-74,188,303 (-1.2)	-247,424,625 (-3.8)***
Germany	99,310,233 (1.2)	41,971,844 (0.5)	-629,246,661 (-7.6)***
Greece	18,607,278 (1.7)**	-4,003,955 (-0.4)	-44,351,201 (-4.0)***
Hungary	2,279,102 (0.2)	-6,030,230 (-0.6)	16,485,369 (1.7)
Ireland	5,771,816 (1.2)	-6,499,796 (-1.4)	11,764,998 (2.5)*
Italy	-213,480,589 (-3.5)***	-286,544,153 (-4.7)***	-528,731,864 (-8.7)***
Latvia	-1,281,385 (-0.6)**	-1,680,468 (-0.8)***	-3,758,274 (-1.8)***
Lithuania	-6,104,820 (-2.0)**	-7,659,768 (-2.5)**	-15,904,408 (-5.3)***
Luxembourg	-30,557,122 (-57.6)***	-25,696,028 (-48.4)***	-18,986,576 (-35.8)***
Malta	448,552 (1.0)**	728,838 (1.7)**	1,051,526 (2.5)**
Nederlands	-6,739,745 (-0.4)	-11,923,612 (-0.7)	-180,342,598 (-10.8)***
Poland	-91,010,773 (-2.4)*	-138,137,716 (-3.6)**	-561,273,714 (-14.7)***
Portugal	9,874,943 (0.9)**	294,820 (0.0)	-36,223,618 (-3.4)***
Romania	-74,442,625 (-3.4)***	-95,501,038 (-4.4)***	-263,822,669 (-12.2)***
Slovakia	7,813,275 (1.4)***	356,859 (0.1)	-22,272,201 (-4.1)***
Slovenia	1,594,291 (0.8)	-2,457,673 (-1.2)	-9,098,671 (-4.4)***
Spain	-21,478,600 (-0.5)	-64,457,182 (-1.4)	44,872,538 (1.0)
Sweden	8,031,757 (0.8)	9,008,286 (0.9)	-2,407,289 (-0.3)
UK	72,581,499 (1.1)	52,906,867 (0.8)	74,625,560 (1.2)
USA	-249,989,194 (-0.8)	-1,288,106,971 (-4.0)	173,980,8977 (5.4)
Average	-75,127,132 (-2.6)**	-105,830,765 (-3.7) **	-219,259,834 (-7.7)***

***, **, * denote significance at 1%, 5%, and 10% significant level. The results of this table show the change in environmental social costs in response to a 1% increase of bilateral trade between the US and the respective EU member. The environmental social costs are assumed to be 26.57 in 2013 US dollars per ton of total CO_2 emissions. All the changes in the environmental social costs for CO_2 emissions are shown for 2013 (the most recent year in our dataset). Furthermore, in parenthesis and in italic, we show the respective per capita values of environmental social costs' change. A negative value of the environmental social costs' change indicates the value of social environmental gains as a result of trade.

Instrumenting Trade with Observables

Table 11: Dependent Variable (GHG) Instrumental Variable Results

Estimation Method	Fixed Effects			Random Effects			Cross Section Dependance			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\hat{Trade}$	17.007	46.917*	36.870	24.404	51.877*	64.429**	17.007	46.917	36.870	16.096	30.393	36.277*
$\hat{Trade}$ × RKL	56.965*	76.503**	34.627	48.566	70.606**	34.165	56.965	76.503	34.627	21.079	50.231	14.451
$\hat{Trade} \times (RKL)^2$	–36.143**	–43.847***	–37.309**	–31.685**	–35.617**	–28.204*	–36.143	–43.847	–37.309	–27.527	–39.960	–33.442
$\hat{Trade}$ × RI	–83.146**	–65.715*	–30.968	–92.519***	–79.429**	–46.296	–83.146	–65.715	–30.968	–36.596	–22.449	1.775
$\hat{Trade} \times (RI)^2$	76.582***	76.181***	69.432***	78.952***	78.377***	69.684***	76.582**	76.181**	69.432**	60.358**	60.787*	57.066
I	.093*	.079	.103*	.123***	.144***	.138***	.093*	.079	.103*	.013	.015	.025
I^2	–.003***	–.004***	–.004***	–.004***	–.004***	–.004***	–.003**	–.004***	–.004***	–.003**	–.004**	–.004**
KL	–.026***	–.024***	–.020**	–.024***	–.025***	–.021***	–.026***	–.024***	–.020***	–.015	–.015	–.011
$(KL)^2$	.000***	.000***	.000**	.000**	.000***	.000***	.000***	.000***	.000***	.000	.000*	.000
KL × I	.000	–.000	.000	.000	–.000	.000	.000	–.000	.000	.000	.000	.000
Poor × $\hat{Trade}$	–56.999***	–36.027**	–26.965*	–64.457***	–41.642***	–38.932***	–56.999***	–36.027*	–26.965	–60.417***	–36.585**	–30.713*
$\hat{Trade}$ × RLPC		–133.184***	–131.477***		–170.415***	–176.431***		–133.184***	–131.477***		–125.132***	–125.721**
$\hat{Trade} \times (RLPC)^2$		60.163***	62.099***		78.897***	82.734***		60.163***	62.099***		56.320**	58.807**
FDI/K		2.016***	2.104***		2.510***	2.321***		2.016*	2.104*		2.444**	2.507**
LPC		25.986*	43.627***		9.873	7.022		25.986*	43.627***		30.860*	44.916***
$(LPC)^2$		–1.217*	–2.083***		–.499	–.334		–1.217*	–2.083***		–1.466	–2.136**
English× $\hat{Trade}$			–55.377***			–40.752***			–55.377***			–51.316***
Sea × $\hat{Trade}$			–.223			–2.592			–.223			1.154
Euro × $\hat{Trade}$			7.819*			3.678			7.819*			6.872
Constant	12.742***	–123.477*	–211.447***	12.227***	–36.909	–24.756	13.138***	–123.726*	–213.620***	13.263***	–146.172**	–218.162***
N	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000
r2	.410	.446	.464				.963	.966	.967			
r2_a	.347	.380	.397									
bic	1729.200	1723.389	1722.192	.	.	.	.	.	.	.	.	.

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. M1, M2, and M3 correspond to the three models outlined in equations (1), (2), and (3), respectively. Cross represents a fixed effects regression where we allow for cross-section dependence among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay standard errors where we allow for an MA(2) component to account for the serial correlation effects in the residuals. We use an instrumental variable approach where we instrument trade with a set of exogenous variables including lagged income, exchange rate, capital to labor ratio, price of export, price of imports, land per capita, and four dummies for whether a country uses Euro, has access to the sea or ocean, whether it uses English as its official language, and whether it was a poor country at the start of the analysis period, respectively. We classify a country as poor if at the start of the sample its income was less than that of the European Average. Thus, Poor × $\hat{Trade}$ is a dummy variable. If a country is poor, we put the value of our trade value, otherwise we put zero. We use a two-stage least squares approach. First, we estimate a reduced form for our trade variable using all the exogenous variables and we get the fitted values for trade. Next, we construct instruments (not regressors) using the interaction between the predicted values and relative income, relative capital to labor ratio and relative land per capita respectively. Finally, we estimate the structural equation using all interacted instruments in addition to all the exogenous variables. As Wooldridge (2010) argues in chapter 20 of the 2nd edition of his textbook entitled âEconometric Analysis of Cross Section and Panel Dataâ: There is no need to adjust the standard errors asymptotically.

Table 12: Dependent Variable (CO2) Instrumental Variable Results

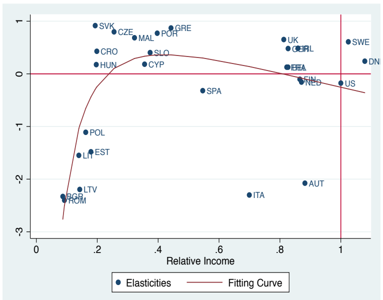
Estimation Method	Fixed Effects			Random Effects			Cross Section Dependance			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\hat{Trade}$	21.484	60.955**	51.772*	31.156	63.602**	52.113*	21.484	60.955*	51.772	22.949	33.423	14.432
$\hat{Trade}$ × RKL	55.942*	69.337**	108.975***	46.652	66.806**	107.175***	55.942	69.337	108.975*	19.898	44.027	80.756
$\hat{Trade} \times (RKL)^2$	–44.529***	–56.061***	–60.421***	–37.855**	–45.531***	–54.815***	–44.529	–56.061	–60.421	–35.710	–52.731	–56.648
$\hat{Trade}$ × RI	–79.566**	–55.939*	–100.735***	–87.320**	–70.151**	–110.112***	–79.566*	–55.939	–100.735**	–31.510	–9.310	–47.569
$\hat{Trade} \times (RI)^2$	76.181***	74.236***	84.157***	78.882***	77.152***	86.338***	76.181***	74.236***	84.157***	60.456**	57.945*	66.441**
I	.171***	.123***	.129**	.204***	.183***	.198***	.171***	.123**	.129**	.068	.048	.060
I^2	–.005***	–.005***	–.004***	–.005***	–.006***	–.005***	–.005***	–.005***	–.004***	–.005***	–.005***	–.004***
KL	–.019***	–.012*	–.019**	–.017**	–.014*	–.020**	–.019**	–.012	–.019***	–.010	–.004	–.011
$(KL)^2$	.000	.000	.000**	.000	.000	.000**	.000	.000	.000***	–.000	–.000	.000
KL × I	.000	.000**	.000	.000**	.000*	.000	.000	.000*	.000	.001***	.001***	.000
Poor × $\hat{Trade}$	–42.773***	–20.381	–20.734	–52.197***	–27.423**	–28.999**	–42.773***	–20.381	–20.734	–45.485***	–18.859*	–15.026
$\hat{Trade}$ × RLPC		–109.423***	–112.832***		–139.137***	–126.156***		–109.423***	–112.832***		–97.899**	–103.027***
$\hat{Trade} \times (RLPC)^2$		54.841***	56.081***		69.216***	63.599***		54.841**	56.081***		48.646**	51.614***
FDI/K		2.074***	1.837***		2.342***	2.312***		2.074**	1.837*		2.548**	2.287**
LPC		28.733**	17.320		3.870	7.805		28.733**	17.320		33.767*	23.563
$(LPC)^2$		–1.183*	–.630		–.085	–.305		–1.183	–.630		–1.459	–.972
English × $\hat{Trade}$			53.028***			48.131***			53.028***			54.175**
Sea × $\hat{Trade}$			1.659			–8.962			1.659			1.001
Euro × $\hat{Trade}$			–.180			–1.541			–.180			.895
Constant	9.219***	–155.959**	–98.010	8.442***	–21.232	–38.298	8.907***	–156.831**	–97.587	9.961***	–177.263**	–124.703
N	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000	609.000
r2	.307	.372	.388				.962	.966	.967			
r2_a	.233	.298	.312									
bic	1695.933	1667.769	1671.353	.	.	.	.	.	.	.	.	.

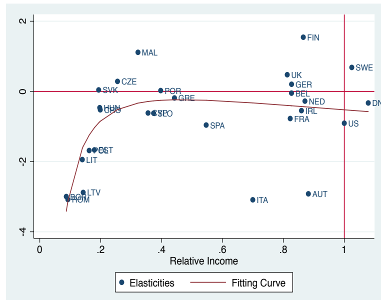
***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. M1, M2, and M3 correspond to the three models outlined in equations (1), (2), and (3), respectively. Cross represents a fixed effects regression where we allow for cross-section dependence among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay standard errors where we allow for an MA(2) component to account for the serial correlation effects in the residuals. We use an instrumental variable approach where we instrument trade with a set of exogenous variables including lagged income, exchange rate, capital to labor ratio, price of export, price of imports, land per capita, and four dummies for whether a country uses Euro, has access to the sea or ocean, whether it uses English as its official language, and whether it was a poor country at the start of the analysis period, respectively. We classify a country as poor if at the start of the sample its income was less than that of the European Average. Thus, Poor × $\hat{Trade}$ is a dummy variable. If a country is poor, we put the value of our trade value, otherwise we put zero. We use a two-stage least squares approach. First, we estimate a reduced form for our trade variable using all the exogenous variables and we get the fitted values for trade. Next, we construct instruments (not regressors) using the interaction between the predicted values and relative income, relative capital to labor ratio and relative land per capita respectively. Finally, we estimate the structural equation using all interacted instruments in addition to all the exogenous variables. As Wooldridge (2010) argues in chapter 20 of the 2nd edition of his textbook entitled âEconometric Analysis of Cross Section and Panel Dataâ: There is no need to adjust the standard errors asymptotically.

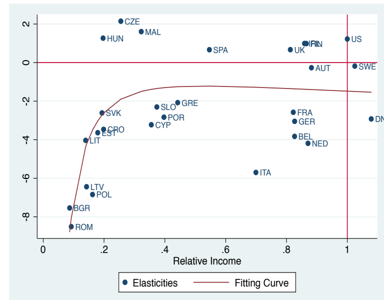
Elasticities Graphs

CO2: M(1) CO2: M(2) CO2: M(3)

1







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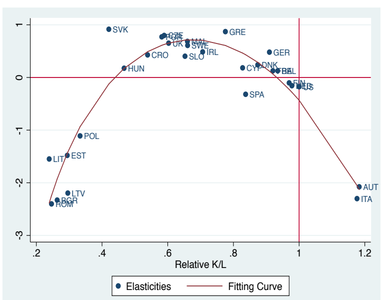

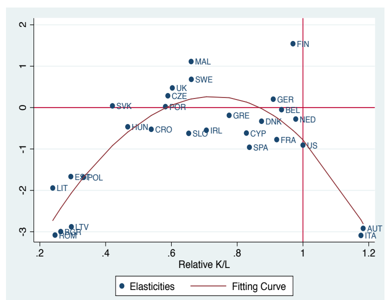

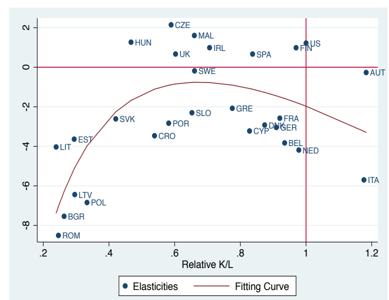

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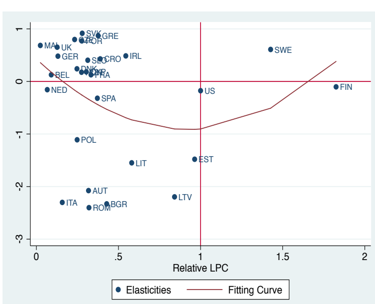
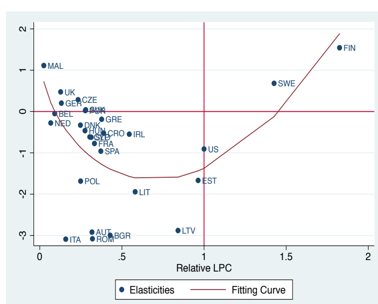
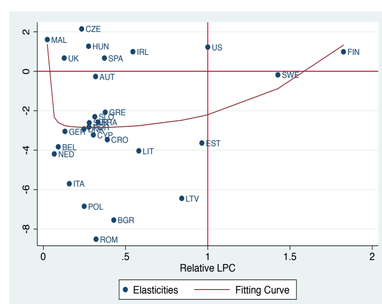






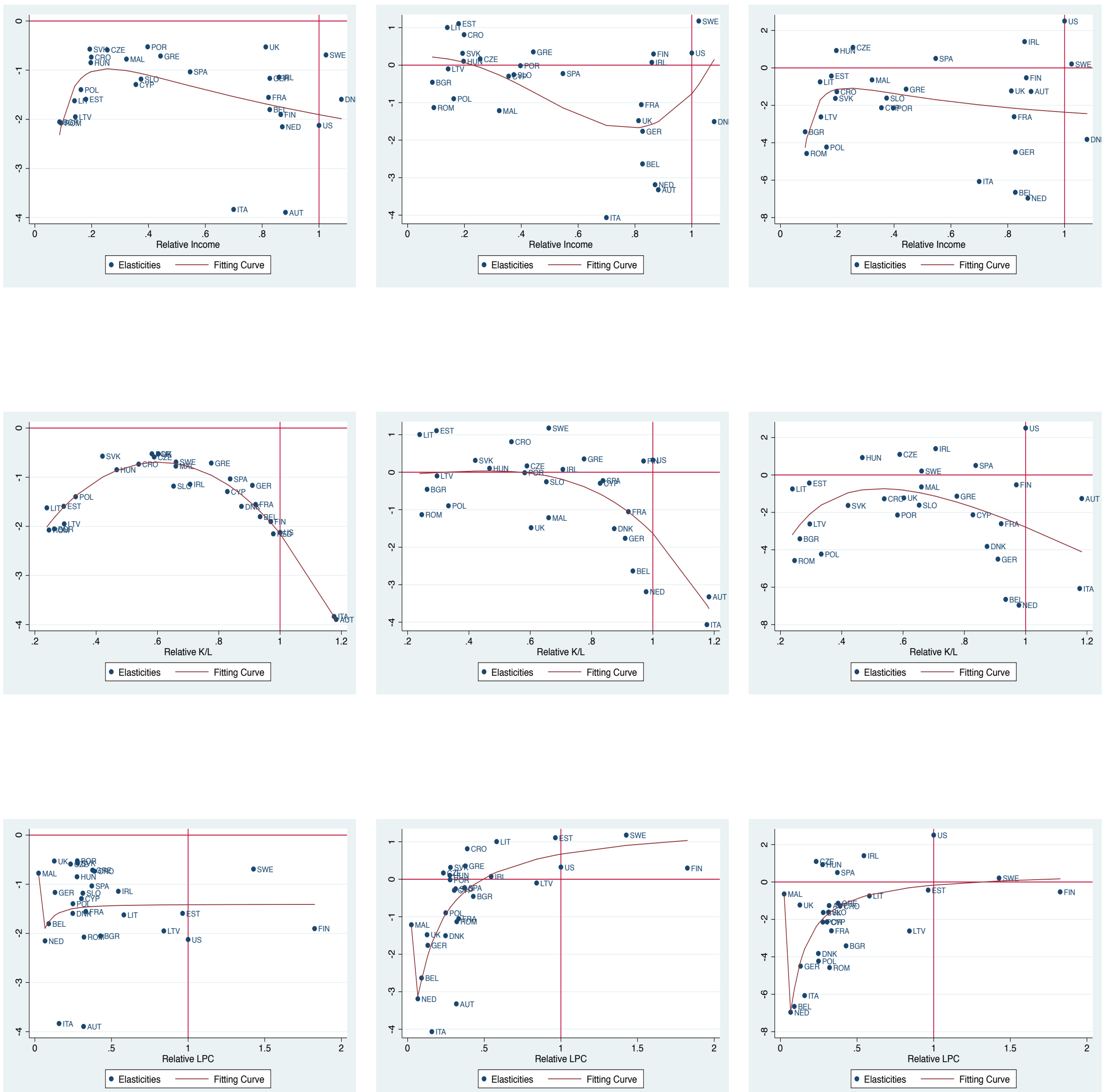
Note: These Figures plot the entries in Table 9. Each vertical axis corresponds to the Trade Elasticities of CO2 produced by the Random Effects (RE) specification of Models M1, M2, and M3, respectively. The first row plots the elasticities with respect to Relative Income, the second with respect to the Relative Capital/Labor (K/L) ratio, and the third with respect to Relative Land Per Capita (LPC), respectively. The vertical line in each case corresponds to the elasticity coefficient of the U.S., which provides the benchmark for the Relative Income, K/L, and LPC variables, respectively. The Fitting Curve provides an ad-hoc polynomial approximation to help the reader visualize the pattern in the elasticities.

GHGs: M(1) GHGs: M(2) GHGs: M(3)

1

2

3



Note: These Figures plot the entries in Table 9. Each vertical axis corresponds to the Trade Elasticities of GHGs produced by the Random Effects (RE) specification of Models M1, M2, and M3, respectively. The first row plots the elasticities with respect to Relative Income, the second with respect to the Relative Capital/Labor (K/L) ratio, and the third with respect to Relative Land Per Capita (LPC), respectively. The vertical line in each case corresponds to the elasticity coefficient of the U.S., which provides the benchmark for the Relative Income, K/L, and LPC variables, respectively. The Fitting Curve provides an ad-hoc polynomial approximation to help the reader visualize the pattern in the elasticities.

Appendix

This appendix shows the data imputation methods for the main variables in the study.

Trade: Most of the missing observations for *Trade* occur during the early part of the sample, specifically from 1989 to approximately 1993. For instance, until 1993 the Czech Republic and Slovakia were part of Czechoslovakia. In this case, we fill the missing gaps for both countries by using the aggregate data for Czechoslovakia and using the would-be weight of *Trade* for the Czech Republic and Slovakia as if they were a single country over the 1993 to 1998 period. Instead, for the Baltic countries, we use the Amelia II program and a set of factors for which complete information exists, e.g., *total population, the unemployment rate, labor force*, and a *time trend*, respectively. We then individually check every imputed value for consistency with the immediately proceeding and following values to make sure that no aberrant observations are produced.

Pollutants: As Table 1 shows, we use several different sources to gather the pollutant data. The results section employs the measure where the fewest missing observations were found. Thus, both the CO_2 and *GHGs* measures do not require any imputations since we had a complete dataset.

Income: As in the case of the *Trade* measure, we proceeded in a similar manner for the Czech Republic and Slovakia, respectively. In rest, since the GDP measure follows an exponential trend, we employ a square polynomial trend to estimate the few missing observations for the 1989 - 1993 period for the Baltic countries, Croatia and Slovenia, respectively.

KL: Both the capital stock as reported by the World Penn Tables and the labor force measure as reported by the IMF are fairly complete series. However, since as in the previous cases some missing observations occur at the start of the sample (usually over the 1989-1993 period) we use a simple trend or square polynomial trend regression.

FDI: We obtain the annual Foreign Direct Investment data from the UNCTAD database. We follow the approach above to fill in the few missing observations for the Czech Republic and Slovakia, respectively. In rest, we use the Amelia program in R with the following covariates: *total population, real, GDP, the Gross*

Fixed Capital Formation and the changes in inventories, respectively to impute the missing observations for the few countries with missing information (i.e., Croatia over the 1989 to 1991 period, Cyprus over the 1989 to 1995 period, Estonia, Lithuania, and Latvia over the 1989 to 1991 period, Hungary for 1989, Luxembourg over the 1989 to 2001 period, and Slovenia over the 1989 to 1991 period, respectively). The *Gross Fixed Capital Formation* and the changes in inventories variables are from the IMF and have no missing information.

LPC: *LPC* is complete and has no missing information. The CIA Factbook (2015) supplies the land area information for each country.