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Abstract

The study empirically investigates and shows that on average, the implementation of the Comprehensive Economic and Trade Agreement (CETA) may contribute in the fight against global warming. This study finds that on average, a one percent increase of a percentage point in the bilateral volume of trade as a portion of GDP between Canada and a typical EU member could help reduce annual per capita emissions of GHGs in an average CETA member by about .57 percent. The results also show that the presence of CETA may decrease annual per capita emissions of GHGs in almost all CETA members. There is no statistically significant evidence suggesting an increase of GHGs per capita emissions in any CETA member, regardless of the model or statistical method employed in the paper. These results stand because of the combinations of the factor endowment hypothesis (FEH), the pollution haven hypothesis based on population density variations (PHH2), and the pollution haven hypothesis based on national income differences (PHH1) between each EU member and Canada.

JEL Classification: *F18, F53, F64*
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1 Introduction

The Comprehensive Economic and Trade Agreement (CETA) is a trade deal between the EU and Canada. The main goal of CETA is to boost trade by reducing tariff rates and non-tariff trade barriers between the trade partners. CETA consists of 30 chapters, where chapter 24 entitled "Trade and Environment" contains 16 articles that provide previsions of the environmental impacts of the trade agreement. The articles also set up goals on promoting the use of environmental friendly technologies and encourage policies that lowers tariffs and other trade barriers even further for exporting firms (originating from any CETA member) that use greener technologies. CETA became a reality on September 21, 2017.[1]

This study empirically evaluates the role of trade openness between the EU and Canada on air pollution. The empirical models used in this study are based on simple theories of international trade and environment. They take advantage of three main arguments related to trade openness and pollution. In particular, 1) the pollution haven hypothesis based on national income variations (*PHH1*), 2) another pollution haven hypothesis based on national population density differentials (*PHH2*), and 3) the factor endowment hypothesis based on the Heckscher-Ohlin theory (*FEH*).[2] The combination of the latter three effects may lead to a race to the bottom (where trade openness weakens environmental policies) or race to the top argument (where free trade strengthen environmental policies). The results of this study favor the gains from trade hypothesis implying that the presence of CETA, may help reduce air pollution for a typical CETA member.

The paper uses a panel dataset of 28 EU members and Canada during the 1990-2016 time period. The empirical analysis in addition to the usual fixed and random effects with heteroskedastic robust standard errors, it employs fixed effects with robust to cross-sectional dependence and serial correlation (Driscoll-Kraay) standard errors, respectively.

[1]During the first year of CETA's life (September 2017-October 2108), there has been a 7.7% increase on bilateral trade volume between the EU and Canada relative to the pre-CETA period (there was a 3.9% increase on Canadian exports into the EU and a 10.8% increase of the EU exports into Canada). During this year, the total bilateral volume of trade between the trade partners reached $ 155.2 billion Canadian Dollars. For more details and news on topics related to CETA see its EU official website at http://ec.europa.eu/trade/policy/in-focus/ceta/ and its Canadian counterpart at https://www.international.gc.ca/gac-amc/campaign-campagne/ceta-aecg/year_one-premiere_annee.aspx?lang=eng.

[2]See Copeland and Taylor (1994), Antweiler et al. (2001) and Copeland and Taylor (2013) for theoretical explorations over the existence of *FEH* and *PHH1*. See also Grossman and Krueger (1993), Antweiler et al. (2001), Cole and Elliott (2003) and Davis and Caldeira (2010) for empirical evidence consistent to *FEH*. See Scott (2005), Levinson and Taylor (2008), Cole and Fredriksson (2009), and López et al. (2013) for empirical evidence in support of *PHH1*. In regards to *PHH2*, Frankel and Rose (2005) was the first study to investigate the existence of a pollution haven motive based on national population density variations when evaluating the effects of trade openness on air pollution. However, they find no empirical evidence in support of *PHH2*.

The results yield robust evidence suggesting a negative relationship between trade openness and per capita emissions of *GHGs* in an average CETA member. They also imply that the presence of CETA may help reduce per capita emissions of almost all CETA members. There is no statistically significant evidence that suggests that trade openness between the EU and Canada would increase per capita emissions of *GHGs* in any CETA member. All these results imply that the presence of CETA may indeed help in the fight against a global externality such as air pollution.[3]

Theoretically, the presence of CETA may increase per capita emissions of *GHGs* in low-income or sparsely populated trade partner due to the possible existence of lax environmental regulations as compared to the rich or densely populated trade partner, respectively. In the sample, there are 17 EU members that are poorer and 11 EU members that are richer than Canada, but every EU member is very densely populated relative to Canada. At the same time with *PHH1* and *PHH2*, trade openness between the EU and Canada, may theoretically also follow *FEH*. The latter motive originates from the classical Heckscher-Ohlin theory, where the capital-abundant trade partner has comparative advantage in the production of capital-intensive goods and the labor-abundant one has compared advantage in the labor-intensive goods. Plenty of empirical studies find that capital-intensive goods pollute the environment more than the labor-intensive ones (e.g., Jaffe et al. (1995), Antweiler et al. (2001), Cole and Elliott (2003), etc...). Therefore, according to *FEH*, trade openness should increase air pollution in capital-abundant trade partner and reduce it in the labor-abundant one. There are 13 capital-abundant and 15 labor-abundant EU members relative to Canada. Overall, a typical EU member is labor abundant, poor and densely populated as compared to Canada. Thus, one cannot predict theoretically the effects of trade openness on pollution following *PHH1*, *PHH2* and *FEH*. However, it could be argued that air pollution should increase in capital-abundant but poor

[3]The study employs a lagged moving average (throughout the whole analysis) when constructing the income per capita variable, not only to avoid the possible double causality problem between the latter and the dependent variable, but also to prevent a possible contemporaneous correlation between income per capita and trade intensity variables. The above results stand despite the use of various robustness checks. It also uses the third lag of the moving average of income per capita, land per capita, and capital to labor ratio, respectively. Moreover, it performs two independent instrumental variable approaches in order to avoid any dual causality issues between the main variable of interest (the ratio between the bilateral volume of trade over GDP) and per capita emissions of *GHGs*. In the first one, it employs the Arrelano-Bond one step difference GMM estimation method. In the second one, it follows Frankel and Rose (2005), and it employs a two stage least squared econometric approach, where trade is instrumented with a set of exogenous variables. The regressions are also tested in a subset of CETA members where the Ex-Communist EU members, or the rich EU members, are evaluated separately when trading with Canada. They are also tested in various subset of years in the sample subject to the years various members became part of the EU, or excluding the UK from the sample due to the possible implementation of BREXIT. Furthermore, it also treats the EU as a single country when constructing the relative values (such the relative income, relative capital to labor ratio, or relative land per capita) as compared to Canada.

EU members, but should decrease in labor-abundant but rich EU members.

The empirical results of the study generally yield statistically significant evidence that proves the existence of *FEH* and *PHH2*, respectively. The latter means that the presence of CETA may force Canada to act as pollution haven. There is robust and statistically significant evidence in support of *FEH* implying that higher trade intensity may push labor-abundant EU members to pollute the environment less than Canada. However, there is no evidence that capital-abundant EU members pollute the environment more than Canada. There is no statistically significance evidence consistent with *PHH1* in a typical CETA member. On the other hand, there is strong statistically significant evidence in support of *PHH1* for a subset of CETA members. In particular, there is robust evidence consistent with *PHH1* that suggests that in the presence of CETA, per capita emissions of *GHGs* tend to fall more in the rich EU members.

In addition, as theoretically expected, per capita emissions of *GHGs* fall in labor-abundant but rich EU members. However, there is no evidence that supports the theory that more trade between Canada and capital-abundant but poor EU members should increase per capita emissions of *GHG*s in the latter EU members. The study reports statistically significant evidence implying that higher trade intensity between Canada and the EU members that are capital-abundant and rich reduces per capita emissions of *GHGs* in each of the latter EU members because *PHH1* and *PHH2* dominate *FEH*. Furthermore, more trade between each of the labor-abundant but poor EU members and Canada would also reduce per capita emissions of *GHGs* in the majority of the latter EU members. This suggests that in labor-abundant and poor EU members, *FEH* and *PHH2* dominate *PHH1*. In regards to Canada that is capital abundant, richer, and extremely sparsely populated than a typical EU member, the study mainly finds a positive relationship between trade openness and air pollution, but it is not statistically significant under any model or empirical method used in the paper. Consequently for Canada, the presence of *PHH2* and *FEH* cancel out *PHH1*.

Overall, holding all other factors constant, the study finds robust and statistically significant evidence suggesting that on average, an increase of .01 percent of the bilateral trade (as a share of GDP) between the EU and Canada may help reduce per capita emission of *GHGs* by about .57 percent. This result stands because *FEH* and *PHH2* dominate *PHH1* in a typical CETA member. It may also stand because it turns out that per capita emissions of *GHGs* fall in labor-abundant EU members, even though the majority of them are poor. At the same time there is no increase of air pollution in Canada, at least in a statistically significant way. Thus, even though per capita emissions fall in almost every EU member, there is no shift of *GHGs* from the EU to Canada due to the presence of CETA. One can argue that the latter result is true because most labor-abundant EU members are the Ex-Communist countries. The results show that more trade between them and Canada reduces per capita emissions of *GHGs* in each of them. This is mainly due to *FEH* since *PHH1* and *PHH2* do not appear to be statistically significant. Therefore, trade openness may force these EU members to produce more labor-abundant (clean-intensive) goods and simultaneously force Canada to produce more capital-abundant (pollution-intensive) goods. In this way, per capita emissions of *GHGs* originating from capital-intensive goods are shipped from the labor-abundant members of EU into Canada. However, Canada uses more environmental friendly technologies in the production of the capital-intensive goods as compared to the latter EU members (maybe because it is much richer and at a further stage of economic development as compared to the Ex-Communist members). In this sense, per capita emissions of *GHGs* go down in a typical labor-abundant EU member and at the same time do not increase significantly in Canada.

The key result of the study may also rely on the finding that air pollution appears to fall in rich EU members despite the fact that the majority of them are also capital-abundant. It appears that in rich and capital-abundant EU members, there is no evidence of the presence of *FEH*, but there is evidence consistent with *PHH2* and *PHH1*. The latter suggests that trade openness between Canada and capital-abundant and rich EU members may force Canada to act as pollution haven. Consequently, the presence of CETA may end up pushing Canada to increase air pollution, and simultaneously force the rich EU members to possibly adopt stringent environmental policies, and therefore, produce less pollution-intensive goods. Following this argument, the presence of CETA may shift per capita emissions of *GHGs* from an average rich EU member to Canada. However, the results imply that trade openness between Canada and rich EU members reduce air pollution in a typical rich EU member, but it does not increase it in a statistically significant way in Canada. This could be related to the fact that the rich EU members may adopt stringent environmental regulations and in the meantime Canada does not drop its environmental standards.

Consequently, being a poor EU member does not weaken air pollution policy there due to trading more with Canada. It could be because poor EU members are also labor-abundant and densely populated countries. At the same time, for rich and densely populated EU members, trade openness with Canada may strengthen the air pollution policies in the latter EU members despite the fact that they are mainly capital-abundant countries. This does not mean that air pollution shifts from the EU into Canada. Thus, trade openness between the latter and the former trade partner may neither strengthen nor weaken Canada's air pollution policies despite the fact that Canada is extremely sparsely populated compared to any EU member. However, it does strengthen the environmental policies in rich EU members and this is probably why the overall air pollution may go down in the presence of CETA.

The collapse of the Soviet Union, the opening up of China in the world markets, and the creation and extensions of regional political, or/and free trade regional unions, has generated a lot of debates on the benefits and costs of trade on growth, productivity, innovation, etc... Along these lines, from the 90s and on, there has been a theoretical and empirical burgeoning literature on the interaction between trade and environmental policy, especially on issues related to trade and air pollution.[4] There is a large empirical literature that highlights the positive impacts of trade on reducing air pollution (e.g., Antweiler et al. (2001), Cole and Elliott (2003), Frankel and Rose (2005), Levinson (2009), Martin (2012), McAusland and Millimet (2013), Levinson (2015), Cui et al. (2016), Holladay (2016), Cherniwchan (2017), Forslid et al. (2018), and Qirjo and Pascalau (2019)). However, there is also empirical evidence suggesting that trade may help increase air pollution (e.g., Cristea et al. (2013), Aichele and Felbermayr (2015), and Shapiro (2016))

This study adds in the empirical literature that suggest that trade agreements could help in the fight against global warming. It is the first empirical study, to the best of our knowledge, which analyzes the impacts of trade openness between Canada and the EU on air pollution by using the channels of *PHH1*, *PHH2*, and *FEH*. In this context, the paper follows the work of Antweiler et al. (2001). However, as in Frankel and Rose (2005), it applies a relative measurement of land per capita in order to capture *PHH2*. This hypothesis is absent in the former study. Moreover, it is different from Frankel and Rose (2005) because they use a cross-sectional dataset and find no evidence of the presence of *PHH2*, while this paper employs a panel dataset and finds some evidence consistent with *PHH2*. However, the latter motive is not as strong as to force Canada to act as pollution haven due to the presence of CETA. The study also add in the empirical literature that implies that are no losers, but only winners in reducing air pollution among members of regional trade agreements (e.g. Grossman and Krueger (1993) and Gamper-Rabindran (2006) in the case of NAFTA).

This study is closely related to Qirjo and Pascalau (2019) that uses a panel dataset including the EU members and the U.S. during 1989-2013 time period. They show that the possible implementation of the Transatlantic Trade Investment and Partnership (TTIP)

[4]For theoretical models on trade and environment see Markusen et al. (1993), Copeland (1994),Copeland and Taylor (1995), Antweiler et al. (2001), Copeland and Taylor (2005), Benarroch and Weder (2006), and Shapiro and Walker (2018) among others. See also Copeland and Taylor (2004), Copeland (2011), and Cherniwchan et al. (2017) for a comprehensive review of theory and evidence of the role of trade on pollution. See also Copeland and Taylor (2017) for a review of trade and environment literature in a Canadian retrospective.

may on average help reduce per capita emissions of *GHGs*. However, this is not the case for all TTIP members due to the combinations of *PHH1*, *PHH2*, and *FEH*. They find that trade openness between the EU and the U.S. may help shift air pollution from the former to the latter trade partner.[5] The current study, performing an analogous analysis, finds that the presence of CETA may help on average, reduce per capita emissions of *GHGs*. However, there is no shift of air pollution from one trade partner to the next (at least in a statistically significant way). Note that both Canada and the U.S. are capital-abundant, rich and sparsely populates as compared to a typical EU member, respectively. However, the U.S. is more capital abundant, richer and less sparsely populated than Canada is, as compared to a typical EU member. Consequently, the results of Qirjo and Pascalau (2019) and the current study, may suggest that TTIP and CETA could be allies on combating global warming. However, in the case of TTIP, this is done in the expense of more air pollution in the U.S. In the case of CETA, there are no losers, in terms of higher air pollution due its presence. Further, it appears that being extremely sparsely populated does not necessarily weakens national environmental policy in the trade partner when trading more with the EU. However, being more capital-abundant may weaken environmental policies related to air pollution in the trade partner when opening up trade policies with the EU. Moreover, being richer may not strengthen environmental policies in the trade partner when increasing trade with the EU.

The rest of this paper is organized as follows. Section 2 discusses the dataset and its sources. Section 3 constructs three main regressions. Section 4 describes the empirical methodology. Section 5 analyzes the empirical results. Section 6 reports several robustness checks. Section 7 discusses possible policy implications of the results. Section 8 highlights the main conclusions of the study.

2 Data Description and their Sources

This study uses a panel dataset that includes 29 countries (28 EU members and Canada) over 27 years (1990 - 2016). The data for emissions per capita of *GHGs* are taken from UNFCCC (2019). Their unit of measurement is in *Tg* in CO_2 equivalent per capita emissions *(*note that *GHGs* data are without the LULUCF*)*. *GHGs* consists of four main air pollutants such as 1) Carbon Dioxide *(*CO_2*),* 2) methane (CH_4), 3) nitrous oxide (N_2O), and 4)

[5]This is an interesting result because it contradicts other recent empirical findings that suggest that trade openness has led to lower air pollution in the U.S. See for example Cherniwchan (2017) that provide empirical evidence of this argument in the case of NAFTA. Levinson (2009) and Levinson (2015) also empirically validate the latter claim but for trade intensity between the U.S. and the rest of the world.

Fluorinated gases (*F-gases*) that include mainly the chlorofluorocarbons (*CFCs*), the hydrofluorocarbons (*HFCs*), the per-fluorocarbons (*PFCs*) and the sulfur hexafluoride (SF_6).[6]

The key variable of interest is the trade intensity or simply the trade variable, denoted with *T* and it is calculated as the ratio of the sum of bilateral volume of trade (exports and imports between Canada and each EU member) to GDP. For Canada, when constructing *T,* the numerator is the sum of all EU members' exports to Canada (these are essentially the imports of Canada from all EU members) and all EU members' imports from Canada (these are essentially the exports of Canada from all EU members).[7] The data of the bilateral volume of trade and national real GDP measured in 2011 U.S. Dollars are taken from IMF (2019). The measurement unit of *T* is as a percentage of *GDP*.[8]

Real *GDP* per capita is calculated by dividing a country's real *GDP* to its population. Following the literature on trade and pollution, this study employs the three-year moving average of lagged real *GDP* per capita instead of a contemporaneous measure to avoid the possible dual causality problem between pollution and income, $I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * I_{it-3}$. This measure, simply is labeled as income per capita and it is denoted with *I*. The data for *I*, again are taken from IMF (2019) and bilateral nominal exchange rates are used to measure *GDP* in real 2011 U.S. Dollars. *I* is used to build the Relative real *GDP* per capita, denoted as *RI*. This variable is constructed by dividing each country's real *GDP* per capita to the corresponding Canada's real *GDP* per capita. Table 2 provides more detailed information about this measure, while the trade elasticity graphs (located at the end of the paper) provide a visual description. Table 2 and the trade elasticity graphs show that there are 11 EU members richer and 17 EU members poorer than Canada. In

[6] We analyze the impacts of CETA in each of the above main four groups of GHGs, respectively, in a follow-up project. We find that the implementation of CETA may help reduce per capita emissions of CO_2, CH_4, N_2O, and *F-gases,* respectively. For more details see, Qirjo et al. (2019).

[7] Hence, in each EU member i, $T_i = \left(\frac{X_i+M_i}{GDP_i}\right)$, where X_i and M_i denote each EU member's exports and imports with Canada, respectively. For Canada, $X_{Canada.} = \sum_i M_i$ and $M_{Canada.} = \sum_i X_i$, respectively.

[8] In the dataset, most of the volume of trade data are complete. However, there are missing observations for some of the Ex-Communist EU members in the early 90s (1990-1993) because these countries gained their independence during these years. For example, Croatia and Slovenia gained their independence from Yugoslavia in early 90, but we have complete data for these two countries from 1994-2016. Analogously, there are missing observations from 1990-1992 for the Baltic countries (Estonia, Latvia, and Lithuania), but we have complete data for these Baltic EU members from 1993-2016. The latter countries were part of the Soviet Union and gained their Independence in early 90s. However, since the missing data are in the very beginning of the sample and the series exhibits a clear monotonic trend, we use a simple trend regression to fill in the missing observations. Furthermore, for the countries like the Czech Republic and Slovakia that did not become independent until 1993, we impute the data (1990-1993) by using the information for Czechoslovakia and using a "proportional" approach based on a counterfactual analysis. The same strategy is used for Luxembourg during 1990-1996 time period, using the available data for Luxembourg and Belgium (reported as one country in this time period) and Belgium (that has also complete observations as a single country during this time period).

the paper, the former are referred as rich EU members, while the latter are referred as poor EU members. The product of *T* and *RI* is used to measure *PHH1*.[9] The measurement unit of *T(RI)* is in percentage.

The capital to labor ratio data are taken from PWT (2019). It is denoted by *KL* and it is in current PPPs 2011 billion U.S. Dollars. The *KL* variable is built by dividing the physical capital stock to the labor force, where the latter is measured in thousands. *KL* is employed to construct the relative capital to labor ratio, denoted by *RKL*. This variable is created by dividing each country's capital to labor ratio to Canada's capital-labor ratio. Table 2 and the trade elasticity graphs confirm that there are 15 EU members that have a *KL* ratio lower than Canada's *KL* ratio. In the study, the latter EU members are referred as labor-abundant EU members. There are 13 EU members that have a *KL* ratio higher than Canada's *KL* ratio. The latter EU members are referred as capital-abundant EU members or simply capital-abundant countries. The product of *T* and *RKL* is used to capture *FEH*. The measurement unit of *T(RKL)* is in percentage.

The annual ratio of the stock of inward Foreign Direct Investment to GDP in each country provides the *FDI* measure. IMF (2019) again supplies the data for national GDP, measured in real 2011 U.S. Dollars and PWT (2019) supplies the data for the physical stock of capital, also based in 2011 U.S. Dollars.[10] The measurement unit of *FDI* is as a percentage of *GDP*.

Land per capita is denoted by *LPC*. The land data measured in square kilometers are taken from CIA (2019). Population data measured in millions are taken from IMF (2019). *LPC* is measured as the annual log-ratio of the land area of each country to its population. *LPC* is used to build the relative land per capita variable, denoted by *RLPC*. This is calculated as the ratio of each EU member's land per capita to Canada's *LPC*. Table 2 and the trade elasticity graphs show that Canada is the most sparsely populated country as compared to each EU member (i.e. each EU members has a *RLPC* <1). Thus, in the paper Canada is referred as sparsely populated CETA member, while each EU member is referred as densely populated country. The product of *T* and *RLPC* is employed to account for *PHH2*. The measurement unit of *T(RLPC)* is in percentage.

[9] For the GDP variable, there are also some missing observations for the same years and countries as those of the volume of trade. In the case of Czech Republic, Slovakia, and Luxembourg we employ the same strategy as in the volume of trade. For the other countries (Croatia, Slovenia, Estonia, Latvia, and Lithuania) we use a square polynomial trend (since GDP follows an exponential trend) in order to fill in the missing observations for 1990-1993 time period.

[10] There are also some missing observations for the FDI variable. Here, we employ a simple trend or square polynomial trend regression to fill in the missing observations. In particular, we fill out the data for Belgium and Luxembourg during 1990-2000, Croatia during 1990-1993, and Estonia, Latvia and Lithuania during 1990-1992 time periods.

Sea dummy denotes a dummy variable that is 0 for landlocked countries and 1 for CETA members that have access to the sea or the ocean. *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-French* refers to a dummy variable that is 1 for the countries that use English or/and French as their official languages. Only seven countries in the dataset score a 1 for this variable (i.e., Canada, the UK, Ireland, Malta France, Belgium, and Luxembourg). The information to construct the latter two dummy variables is taken from CIA (2019). *Euro* denotes a dummy variable that switches to 1 beginning with the year in which a country has officially adopted the Euro.[11] *T(Euro)* refers to the interaction between *Trade* and this dummy variable. The information to build the *Euro* dummy variable is taken from Eurostat (2019).

The summary statistics are reported in Table 1 and shows a low degree of skewness for all variables since the means are relatively close to their median.

3 Three Estimating Equations

This section presents the theoretical intuition of the three econometric models (*M1*, *M2*, and *M3*) employed in this study. In all models, 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, where subscripts t and i indicate the year (1990 to 2016) and country, respectively. $GHGs_{it}$ denotes per capita emissions of *GHGs*.

The construction of the econometric model 1 (*M1*) is based on the work of Antweiler et al. (2001). *M1* investigates the relationship between per capita emissions of *GHGs* and the trade effect, which is separated into *FEH* and *PHH1*. The main variable of interest is the trade intensity variable denoted by T_{it} (bilateral volume of trade/GDP between each EU member and Canada). There are also various control variables such as: 1) the levels and 2) the squares of income per capita, 3) the direct composition effect of growth, and 4) the composition effect of growth.

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

[11] Note that Euro came to life as a common currency in 1999 and it was an official currency only for 11 EU members (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain). Greece joined in 2001, Slovenia in 2007, Cyprus and Malta in 2008, Slovakia in 2009, Estonia in 2011, Latvia in 2014, Lithuania in 2015. In 2016, there were 19 EU members that have adopted Euro as their official currency.

The latter equation (1) is denoted by *M1*. It employs a set of four trade-based interactions explanatory variables in order to capture *FEH* and *PHH1*. In particular, *M1* uses 1) the interaction of trade intensity with the relative capital to labor ratio, denoted by *T(RKL),* in order to detect *FEH*, and 2) the interaction of trade intensity with relative per capita income, denoted by *T(RI)*, in order to investigate *PHH1*. In addition, the interaction of trade intensity with the squared relative capital to labor ratio denoted by $T(RKL)^2$ and the interaction of trade intensity with squared relative per capita income, denoted by $T(RI)^2$ are included in order to account for the diminishing returns of each variable, respectively.

The coefficients α_2 and α_3 capture *FEH* and the coefficients α_4 and α_5 measure *PHH1*. Note that, on average, Canada acts as a capital-abundant country since a typical EU country is labor-abundant. However, not all EU countries are labor abundant. There are 13 capital abundant and 15 labor abundant EU members. Luxembourg, Italy and Belgium are the most capital-abundant countries. Thus, following *FEH*, Canada should import capital-intensive goods from these three EU countries implying that CETA should reduce per capita emissions of *GHGs* in Canada while increase them in Luxembourg, Italy and Belgium. At the same time, Bulgaria, Romania, and Poland are the most relatively-labor-abundant countries. Hence, Canada should export capital-intensive goods into these three EU members. Consequently, per capita emissions of *GHGs* should decrease in Bulgaria, Romania, and Poland, but increase in Canada. Note that these theoretical results are based on the large empirical literature that suggests that capital-intensive goods pollute the environment significantly more than the labor-intensive goods.

Simultaneous with *FEH*, there is *PHH1*. On average, the empirical validity of *PHH1* is tested by the statistically significance of the slopes α_4 and α_5. In the dataset, Bulgaria, Romania, and Latvia are the poorest countries, and therefore, according to *PHH1*, they should act as pollution havens because relatively poorer countries design and implement lax environmental regulations as compared to their trading partner, Canada. Thus, along the lines of *PHH1*, per capita emissions of *GHGs* should increase in these three EU members, but they should decrease in Canada. Analogously, Luxembourg, Denmark, and Sweden are the three richest countries in the dataset. Thus, according to *PHH1*, further trade between Canada and each of these three EU members may force Canada to act as pollution haven because relatively richer countries design and implement stringent environmental regulations as compared to their trading partners. Hence, per capita emissions of *GHGs* should decrease in these EU members, but should increase in Canada. In the sample, most EU members are poorer than Canada, and therefore, potential pollution havens as compared to Canada. Table 2 reports that there are 17 EU members that are poorer and 11 EU members that are richer than Canada.

The trade variable T_{it} along with its interactions with the other variables in *M1* (i.e., the slopes of α_1 to α_5) measures the overall impact of trade on pollution. Theoretically, according to Antweiler et al. (2001), one could expect that the implementation of CETA via the combination of both *FEH* and *PHH1* would unambiguously increase per capita emissions of *GHGs* in a capital-abundant and poor country (such as Cyprus, Czech Republic, Greece, Italy, or Spain). Analogously, along the lines of *PHH1* and *FEH*, CETA should unambiguously decrease per capita emissions of *GHGs* in a relatively labor-abundant and rich country (such as Ireland, the Netherlands, or the UK). However, for the rest of the countries, that are either labor-abundant and poor, or capital abundant and rich, the implementation of CETA should theoretically lead to an ambiguous effect of trade on per capita emissions of *GHGs*. Put it differently, the implementation of CETA should reduce (increase) per capita emissions of *GHGs* in labor-abundant (capital-abundant) countries following *FEH,* and simultaneously increase (decrease) pollution in poor countries because of *PHH1*. Whether *FEH* dominates or is dominated by *PHH1* or these two hypothesis cancel each other out, remains an empirical question. See Qirjo and Christopherson (2016), or Pascalau and Qirjo (2017a) for a similar reasoning in the possible implementation of TTIP.

In regards to the control variables, the national income per capita *I* captures the effect of economic growth on the environment.[12] The squared per capita income denoted by I^2 allows for the investigation of the existence of the EKC. The importance of national capital-abundance is measured by the level and the square of the capital to labor ratio *(i.e., KL* and $(KL)^2$*)*, where the square accounts for its diminishing returns. The cross-product of income per capita and capital to labor ratio (i.e., *I(KL)*) captures the general composition of growth.

Model 2 (*M2*) incorporates the works of Antweiler et al. (2001) and Frankel and Rose (2005). 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). Analogously to the argument used for richer countries under *PHH1*, densely populated countries may design stringent environmental regulations as compared to the sparsely populated ones. *M2* uses the coefficients associated with these terms (α_6 and α_7) to empirically test the validity of *PHH2*. In addition to these two variables, *M2* adds the inward stock of *FDI* as a percentage of GDP. An increase in *FDI/GDP* may increase per capita emissions of *GHGs* if multinational corporations choose to move their production in a country with relatively lax environmental standards due to *PHH1* or/and *PHH2*. This is

[12]Since our data of the *GHGs* are in per capita emission levels, we cannot separate the scale from the technique effects of growth. Therefore, the income per capita variable measures both the scale and technique effects. In the specialized literature, this is known as the scale-technique effect.

consistent with the classical pollution haven hypothesis (*PHH*). It argues that some of the firms in richer (more densely populated) countries choose to move up entire plants (or just the dirtiest ones) to the relatively poor (sparsely populated) countries to take advantage of their relatively lax environmental standards. At the same time, an increase in *FDI* could lead to lower per capita emissions of *GHGs* because multinational cooperation may bring cleaner technologies that may spillover to the domestic firms. Thus, the impact of *FDI/GDP* on pollution is theoretically ambiguous. *M2* then writes in the following way

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

Table 2 underlines that all countries in the dataset are more densely populated than Canada. Thus, *PPH2* implies that Canada can adopt lax environmental standards, and therefore, more trade between the EU and Canada may force Canada to act as pollution haven. Hence, holding everything else constant, further trade due to the implementation of CETA should increase per capita emissions of *GHGs* in Canada and decrease them in any other country in the dataset. Comparing *M1* to *M2*, the inclusion of *PHH2* in *M2* changes the unambiguity of the rise of emissions per capita of *GHGs* in capital-abundant and poor countries as described in *M1*. The intuition here is that per capita emissions of *GHGs* in capital-abundant and poor countries should theoretically go down if *PHH2* dominates *FEH* and *PHH1*. Thus, the inclusion of *PHH2* in *M2*, in theory, produces an ambiguous effect of trade on per capita emissions of *GHGs* in capital-abundant but poor EU members.

Moreover, CETA may affect per capita emissions of *GHGs* more in certain treaty members that could be more involved in bilateral trading with Canada due to their geographical location, culture/language/network differences, or the usage of the same currency. These effects are included in model 3 (*M3*) as follows

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

In particular, the international trade literature argues that a free trade agreement, such as CETA, will intensify the bilateral trade relatively more for the EU members that use English or/and French as their official languages, since Canada uses English and French as its official languages. The reasoning here is that trading partners that share the same official languages tend to have stronger network effects, similar cultural values, similar quality of institutions (especially in regards to contract design, property rights and enforcement mechanisms in the rule of law sector), and also relatively low advertisement and labeling costs for their exports. Thus, *M3* proposes an English/French dummy denoted by *English-French dummy* and interacts it with *T*. Theoretically, holding everything else constant, one would expect more trade between Canada and each of the six EU countries where English or French is an official language (these countries are the UK, Ireland, and Malta that use English, at least as one of their official languages, and France, Belgium and Luxembourg that use French, at least as one of their official languages). Furthermore, *M3* also includes a dummy for sea access denoted *Sea dummy* and interacts it with *T*. Since a lot of trade between Canada and the EU is still done by ships, one would expect, as suggested by the international trade literature of the gravity models, more trade between Canada and the EU members that have sea access. However, according to the burgeoning literature in transportation economics, since the transportation costs among EU members have gone down significantly in the last two decades mainly due to improvements in infrastructure, one may suggest that, *Ceteris Paribus*, there shouldn't be any significance differences in trade costs between Canada and Sea Access EU Members as compared to Canada and Landlocked EU members. However, more trade between Canada and Austria could help reduce per capita emissions in Austria (a landlocked country) because in the latter country *PHH1* and *PHH2* could dominate *FEH*. If Austria uses Germany ports to ship (pick) most of its goods into (arriving from) Canada, one can expect an increase in per capita emissions of *GHGs* in Germany due to transportation from ships when theoretically eliminating all trade between Canada and Germany. However, In addition, in *M3*, whether some countries adhere to a currency union such as the euro may matter. Theoretically, holding everything else constant, one would expect more trade between Canada and EU members that are also part of the Eurozone due to lower trading costs associate with currency exchange costs. Therefore, in order to capture the Euro effect, *M3* adds the euro dummy, simply denoted with *Euro dummy* and interacts it with *T*.

4 Empirical Methodology

The results of this study are accomplished by using the usual random and fixed effects approaches that employ heteroskedastic robust standard errors. Furthermore, the paper employs other specifications that are robust to contemporaneous cross-sectional dependence and serial correlation effects, respectively. In particular, the study uses a fixed effects regression with Driscoll-Kraay serial correlation robust standard errors that employ a MA(2) component. Following the environmental literature, the serial correlation effects should be considered because the pollution and macroeconomic variables usually display monotonic trends. Further, the study corrects for the possibility of cross-sectional dependence by using such robust standard errors in a standard fixed effects framework. The paper also employs the simple pooled OLS approach, but the Breusch-Pagan Lagrange Multiplier (BP/LM) test rejects it. Therefore, it is not shown for space purposes.

As tables of the next sections report, the evidence suggests that in general, the estimators across the random and fixed effects specifications, respectively are very similar, especially in terms of sign, significance.

Moreover, the study investigates the existence of unit roots. Table 1 reports the results from applying the Im-Pesharan-Shin panel unit root test for all series after controlling for a deterministic time trend only, tend and its squared trend term, and trend and its squared and cubic trend terms, respectively. All variables are stationary after controlling for the deterministic time trends, with the exception of relative land per capita that is stationary around a constant. For the latter, the Harris-Tzavalis unit root test is performed, where relative land per capital is also found to be stationary around a deterministic time trend. The latter result is not shown in Table 1, but it is available upon request to the authors.

5 Empirical Results

Tables 3 and 4 report the main results of the study. In particular, Table 3 reports the "base" results for *GHGs* emissions per capita. The results using fixed effects for *M1*, *M2* and *M3* are shown in the first, second and third columns, respectively. The results of the same models, using random effects are presented in the fourth, fifth, and sixth columns, respectively. The seventh, eighth and ninth columns report the results of *M1*, *M2* and *M3* using cross-sectional fixed effects. The tenth, eleventh and twelfth columns, respectively, show the results using serial correlation fixed effects (i.e., with Driscoll-Kraay standard errors) for the same models.

The key variable of interest is the trade intensity T (the bilateral volume of trade over

GDP) that along with all of its interactions with the other variables captures the overall effects of further trade between each EU member and Canada on per capita emissions of *GHGs*. Table 3 reports a negative coefficient of trade irrespective of the model and the statistical specifications used in the study (except under *M3* when employing the fixed effects with cross-sectional dependent robust standard errors, where it is still negative, but not statistically significant). This evidence suggests that a higher trade intensity between each EU member and Canada may help reduce per capita emissions of *GHGs*. Consequently, it highlights another channel of the gains from trade. However, this result doesn't imply that per capita emissions of *GHGs* would be reduced in every single CETA member. It simply suggests that, on average, per capita emissions of *GHGs* would fall as a result of trade openness between each EU member and Canada.

In order to see the impacts of the implementation of CETA in each of its members' *GHGs* per capita emissions, Table 4 reports the elasticities of *GHGs* per capita with respect to trade (i.e., the percentage response of *GHGs* per capita emissions due to a .01 percentage point increase in Trade). These elasticities are calculated at sample means using the delta method. Trade elasticity coefficients based on the fixed effects using serial correlation fixed effects (i.e., with Driscoll-Kraay standard errors) are not reported because they appear to be identical to the ones originating from cross-sectional fixed effects. The first three columns present the trade elasticity coefficients using *M1* under fixed, random, and cross-sectional random effects, respectively. The three columns in the middle report trade elasticity slopes that correspond to *M2* under each of the three estimation specifications. The last three columns present trade elasticity coefficients based on *M3* under fixed, random, and cross-sectional random effects, respectively. The last row of Table 4 shows the average total trade elasticities of all CETA members. These results imply a robust and strongly statistically significant evidence suggesting that on average, .01% increase in the share of trade to *GDP* reduces per capita emissions of *GHGs* by about .57% in *M1,* .42% in *M2,* and .63% in *M3*. This constitutes the most important result of this study, since it shows that the presence of CETA may indeed contribute in the fight against global warming. The study uses such a small scale when reporting the results because, in the sample, the average ratio of the bilateral trade to GDP between a typical EU member and Canada is .057%.

The effects of CETA on pollution in each of its members depends on a country's comparative advantage in pollution-intensive versus clean-intensive goods. In the sample, each EU member is more densely populated than Canada and the majority of EU members are labor-abundant and poorer than Canada. However, there are some EU members that are capital-abundant and richer than Canada. Therefore, it is quite possible theoretically to find that some countries in the dataset have negative trade elasticities while others have positive ones. The results reported in Table 4, show that CETA members' trade elasticity estimates are negative and statistically significant for most of the countries in the sample. The rest of the CETA members, which have trade elasticity coefficients that are mainly positive, are not statistically different from zero. These countries are Canada, Estonia, and Finland (bur for both latter EU members, under *M1*, trade elasticities are negative and statistically significant). There is not a single trade elasticity coefficient regardless of the model or estimation method used in this study that is positive and statistically significant. Consequently, this is the most surprising result of the paper since it shows that the presence of CETA may reduce per capita emissions of *GHGs* not only on average, but also in almost any CETA member. For a visual comparison, the trade elasticity graphs (presented in the last page of the paper) plot the country-specific elasticities from Table 4 as a function of income relative to Canada (located on the top). Or, with respect to the capital to labor ratios relative to Canada (located in the middle). And finally, as a function of land per capita relative to Canada (located at the bottom). The trade elasticities graphs that are based on *M1* are presented in the left column, the ones in the middle column originate from *M2*, and the ones in the right column are based on *M3*. All trade elasticity coefficients used in building these graphs are calculated using the fixed effects. The shape of each graph remains the same irrespective of the estimation method used. Note that, for completeness, in each of these graphs, the values of the trade elasticities are used regardless of their statistical significance. Again, the shape of each graph does not change when only statistically significant coefficients of trade elasticity are employed.

An interesting case is Canada, which is capital abundant, richer, and extremely sparsely populated than a typical EU member. Under *M1*, for any estimation method, the trade elasticities for Canada are negative implying that at best, *PHH1* dominates *FEH*, or at least they cancel each other out, since the trade elasticities for Canada are not statistically significant. However, under *M2* and *M3* for all estimation approaches, the trade elasticities for Canada appear to be positive but not statistically significant suggesting that *PHH2* along with *FEH* slightly dominates (or at least cancels out) *PHH1*. Other interesting cases are Austria, Belgium and Luxembourg. Each of these EU members is capital abundant, richer and more densely populated as compared to Canada. The trade elasticities for these three EU members are negative and statistically significant, regardless of the estimation specification and model used in the paper, implying that *PHH1* along with *PHH2* dominate *FEH*. In other words, Canada act as pollution haven (because of the existence of possibly lax government regulation following *PHH1* and *PHH2*) when trading with these three EU members despite the fact that imports capital-intensive goods from these countries and exports labor-intensive goods into these three EU members.

Note that the implementation of CETA could also help to bring down per capita emissions of *GHGs* in other EU members such as Bulgaria, Czech Republic, Denmark, France, Greece, Hungary, Ireland, Italy, Latvia, Malta, Romania, and the UK, where the trade elasticities are negative under each model and empirical method employed in the study but they are not always statistically significant. For more details see Table 4. A more careful examination of the effects of a higher trade intensity (between each EU member and Canada) on per capita emissions of *GHGs* is performed in the following paragraphs, where *PHH1*, *FEH*, and *PHH2* are examined separately.

The cross-product of trade intensity and relative income per capita along with its squared measurement capture *PHH1*. The 4th row in Table 3 reports the coefficients of *T(RI)*, while the 5th row reports the slopes of $T\,(RI)^2$. *PHH1* argues that the implementation of CETA increases exports of dirty goods from poor countries and increase exports of clean goods from rich countries. In other words, poor countries act as pollution havens. Table 3 reports that the slope of *T(RI)* is not statistically significant under each model and/or estimation method employed in the paper. This suggests that, on average, there is no support of *PHH1*. However, when observing the trade elasticity graphs associated with relative income that are located at the top of the last page, there is evidence of the presence of *PHH1* only for countries located to the right of Canada on the horizontal axis. Therefore, on average, per capita emissions of *GHGs* go down as countries get richer only for EU members that are richer than Canada.[13] This suggests that Canada may act as pollution haven if there is more trade between rich EU members and Canada. It is worth noting that in the sample, the volume of trade between rich EU members and Canada consists of about 82% of the overall volume of trade between EU and Canada.

The cross-product of trade intensity and relative capital to labor ratio along with its squared value measure *FEH*. The 2nd row of Table 3 reports the *T(RKL)* coefficients, while the 3rd row shows the coefficients of $T\,(RKL)^2$ to account for the corresponding diminishing returns. The signs of these two coefficients support *FEH* for *GHGs* per capita emissions. However, the slope of *T(RKL*) is always positive, but it is only statistically significant under *M1* for any empirical methods used in the study (with the exception of cross-sectional dependence fixed effects, but it is also statistically significant under *M2* when employing

[13] Therefore, there is no empirical evidence that suggest that poor EU members act as pollution havens due to more trade with Canada. Note that all Ex-Communist EU members are poorer than Canada, and there is no statistically significant evidence that suggest that they act as pollution havens. This could be an important result since it is contradictory to earlier empirical evidence that suggests that trade openness between Central and Eastern European countries and the rest of the world may force these countries to act as pollution havens (e.g., Kheder and Zugravu (2008)).

the fixed effects with Driscoll-Kraay serial correlation robust standard errors). This suggests that, at least under *M1*, the implementation of CETA, on average, would increase per capita emissions of *GHGs* in capital-abundant EU members, but would decrease them in labor-abundant EU members. The set of the elasticity graphs, presented in the middle of the last page, illustrate the validity of *FEH*. 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 Canada. Regardless of the model used, these elasticity graphs indicate that, on average, *FEH* is valid only for the set of countries that are located to the left of Canada. In other words, the relatively more labor-abundant EU members pollute the air less. Thus, more trade between labor-abundant EU members and Canada could force the latter countries to produce more labor-intensive goods (clean goods) and less capital-intensive goods (dirty goods). On the other hand, the elasticity graphs show no support of *FEH* for capital-abundant EU members as compared to Canada (these are the ones located to the right of Canada). Note that in the sample, about 40% of the overall volume of trade between Canada and EU comes from the volume of trade between the labor-abundant EU members and Canada.

Remember that *M1* captures only *FEH* and *PHH1* in the absence of *PHH2*. Thus, in order to see the interactions of the former two effects for each country, one can focus on the trade elasticities of *M1* reported in Table 4. Consistent with the theory, Table 4 reports empirical evidence implying that per capita emissions of *GHGs* fall in labor-abundant and rich EU members, due to a higher trade intensity with Canada. In particular, irrespective of the estimation specification used in this study, under *M1*, trade elasticities are always negative for Ireland, the Netherlands, and the UK (these are the only rich and labor-abundant countries in the sample, but their overall trade volume with Canada is about 36% of the total volume of trade between the EU and Canada). However, they're only statistically significant for Ireland but not for the UK and the Netherlands. Trade elasticities of Table 4, provide no empirical evidence consistent with the theory that per capita emissions of *GHGs* should increase in capital-abundant and poor EU members, as a result of more trade with Canada. Under *M1*, in contrast to the theory, trade elasticity of these EU are always negative (they're statistically significant for Greece and Italy, but they are not for Cyprus, Czech Republic, and Spain). Note that in the sample, only about 14% of the overall volume of trade between Canada and the EU comes from the volume of trade between the capital-abundant but poor EU members and Canada.

Using *M1*, for any estimation method used in the paper, trade elasticities are negative and statistically significant for the majority of labor-abundant and poor EU members (e.g., Bulgaria, Estonia, Latvia, Malta, Poland, and Romania). This suggests that in each of these

EU members, *FEH* dominates *PHH1*. In other words, per capita emissions of *GHGs* in each of the latter EU members decrease because they export labor-intensive goods into Canada, despite the fact that they may act as pollution havens because they are poor. For the rest of labor-abundant and poor EU members, *FEH* cancels out *PHH1* (since trade elasticities are not statistically significant despite the fact that they are always negative). Note that in the sample, only about 4% of the overall volume of trade between the EU and Canada originates from the trade volume of labor-abundant but poor EU members and Canada. Under *M1*, regardless of the empirical methodology, trade elasticities are always negative and statistically significant for each of the 8 capital-abundant and rich EU members (e.g., Austria, Belgium, Denmark, Finland, France, Germany, Luxembourg, and Sweden). This implies that per capita emissions of *GHGs* go down in each of the latter EU member since Canada acts as pollution haven, despite the fact that each of these EU members exports capital-intensive goods into Canada. Put it differently, in each of the latter EU members, *PHH1* dominates *FEH*. Note that in the sample, about 46% of the overall volume of trade between Canada and the EU comes from the volume of trade between the capital-abundant but rich EU members and Canada.

The cross-product of trade intensity and relative land per capita along with its squared measurement are used to capture *PHH2*. In particular, the 11^{th} row of Table 3 reports the cross-product of trade intensity and relative land per capita, while the 12^{th} row shows the product of trade and the squared relative land per capita. Under *M2*, the coefficients of *T(RLPC)* and $T\left(RLPC\right)^2$ are consistent with *PHH2*, where the former coefficient is positive and statistical significant, and the latter is negative and statistically significant. However, those coefficients are not statistically significant when using the fixed effects specifications with Driscoll-Kraay serial correlation robust standard errors. Therefore, there is generally statistically significant empirical evidence suggesting that, on average, the implementation of CETA may reallocate the production of dirty goods from the densely populated trade partner (each EU member) towards the sparsely populated one (Canada). However, it is difficult to visually confirm the existence of *PHH2* when using the trade elasticities graphs located at the bottom of the last page. This could be related to the fact that Canada is extremely more sparsely populated as compared to a typical EU member and in this sense, it is an outlier in the sample.

It could be worth investigating the presence of *PHH2* also by focusing on the trade elasticities differences between *M1* and *M2* reported in Table 4. It turns out that in 6 EU members (e.g. Belgium, Denmark, Germany, Italy, Luxembourg, and the Netherlands, where their overall volume of trade with Canada is about 43% of the total volume of trade between the EU and Canada), regardless of the estimation method used, trade elasticities are still negative and statistically significant, but with higher absolute value when employing *M2* as compared to those of *M1*. Note that *PHH2* is present in *M2*, but it is absent in *M1*. Therefore, Canada may also act as pollution haven when trading with these EU members due to *PHH2*.

In addition, Canada's trade elasticities are negative under *M1*, but they appear to be positive under *M2* irrespective of the estimation specification employed. Canada is capital-abundant, richer and very sparsely populated as compared to a typical EU member. Consequently, the alternation of signs of Canada's trade elasticities when using *M2* as compared to *M1* suggests that Canada may act as pollution haven when trading with an average EU member due to *PHH2*. However, Canada's trade elasticities are not statistically significant.

Focusing on *M3*, one can evaluated the relationship between more trade and per capita emissions of *GHGs* in trade partners that use the same languages, or have access to the sea, or belong to a monetary union, respectively. In particular, the paper employs three dummies: 1) the product of trade and a language dummy (English and/or French =1) shown in the 16^{th} row, 2) the product of trade and a Sea dummy (Sea=1) shown in the 17^{th} row, and 3) the product of trade and a Euro dummy (where Euro=1) reported in the 18^{th} row of Table 3.

The results yield statistically significant evidence, implying that on average, the presence of CETA in countries that use English or (and) French as their official language(s) may help reduce per capita emissions of *GHGs,* as compared to countries where English or French is not an official language. Theoretical literature in international trade suggests that there is relatively more trade between trade partners that share similar/same languages and cultural values mainly due to the existence of stronger network effects and lower advertisement and label costs for exports. Indeed, the dataset employed in this study validate the latter claim, where in the sample about 47% of the overall volume of trade between Canada and the EU originates from the volume of trade between Canada and the six EU members where English or French is an official language (UK with 27%, France with 11.2%, Belgium with 5.2%, Ireland with 2.6%, Malta with .2%, and Luxembourg with .3%). The negative relationship between per capita emissions of *GHGs* and further trade between English/French speaking EU members and Canada could be related to the existence of similar institutional qualities (such as contract design, property rights and enforcement mechanisms in the rule of law sector) among these countries. One can suggest that an increase in trade intensity between these trade partners could have encouraged these countries to better ameliorate and coordinate their efforts (especially on the enforcement mechanism of the rule of law) when dealing with sensitive environmental issues associated with the increase of their national productions.

The empirical results of *M3*, indicate that in CETA members that have sea or ocean access, the raise of trade between Canada and the EU is associated, on average, with higher per capita emissions of *GHGs,* as compared to countries that are landlocked. This result could support the theory that further trade between Canada and landlocked EU members could help increase per capita emissions of *GHGs* in EU members with sea access because the former EU members use the ports of the latter EU members when trading with Canada. Therefore, per capita emissions of *GHGs* in the EU members with sea access could go up simply because there are more ships coming from and going into Canada from the latter EU members because of the ongoing trade between Canada and landlocked EU members. Thus, in addition to *FEH*, *PHH1*, and *PHH2*, there is another channel that trade intensity may influence per capita emissions of *GHGs* in a typical CETA member. This channel is associated with the fact that some EU members have access to the sea and some others are landlocked. The results reported in Table 3, suggest that CETA members that have access to the sea or ocean may have higher per capita emissions of *GHGs* relative to landlocked EU members due to the presence of CETA. However, one should note that in the sample, there are only 5 countries that are landlocked and their total volume of trade with Canada is only about 4% of the total volume of trade between the EU and Canada.

The results of table 3 show statistically significant evidence, implying that the implementation of CETA in EU members that use Euro as their common currency would increase per capita emissions of *GHGs* relative to countries where Euro is not an official currency. This result could be associated to the fact that *GHGs,* which are related to energy and transportation needs, may be facilitated by the use of the same currency.

In a nutshell, the key result of this study implies that the presence of CETA may contribute in the fight against global warming because it may help reduce per capita emissions of *GHGs* in a typical CETA member. Moreover, there is no statistically significant evidence that suggests that the implementation of CETA could increase per capita emissions of *GHGs* in any CETA member regardless of the model or empirical methodology employed in this paper. Furthermore, it provides robust and statistically significant evidence that implies that the presence of CETA may help reduce per capita emissions in almost every CETA member. This results stands due to the combinations of *FEH*, *PHH1*, and *PHH2* between each EU member and Canada.

Generally, there is statistically significant evidence in support of *FEH* and *PHH2*. However, there is no statistically significance evidence consistent with *PHH1* in a typical CETA member. On the other hand, there is strong statistically significant evidence in support of *PHH1* for a subset of CETA members. In particular, there is robust evidence consistent with *PHH1* that suggests that in the presence of CETA, per capita emissions of *GHGs* tend to fall more in the richest EU members forcing Canada to act as pollution haven when trading with the rich EU members. There is also robust statistically significant evidence in support of *FEH* implying that labor-abundant EU members pollute the environment less if trade between them and Canada increases due the presence of CETA. In regards to *PHH2*, one should remember that each EU member is more densely populated as compared to Canada. Thus, the latter CETA member should act as pollution haven due to the implementation of CETA. Trade elasticities of Table 4 for Canada confirm this argument because they alter signs from negative to positive when employing *M2* instead of *M1*. However, they are never statistically significant. On the other hand, trade elasticities of 6 EU members remain negative and statistically significant but with higher absolute values when using *M2* instead of *M1*. This could validate the presence of *PHH2* suggesting that Canada may act as pollution haven if it trades more with these 6 EU members.

Moreover, a higher trade intensity between Canada and the EU members that are capital-abundant and rich reduces per capita emissions of *GHGs* in each of the latter EU members because *PHH1* and PHH2 dominate *FEH*. In addition, per capita emissions of *GHGs* fall in labor-abundant but rich EU members due to further trade with Canada because in the latter EU members, *FEH*, *PHH1*, and *PHH2* forces them to produce mainly the cleaner goods and import the dirtier goods from Canada. Furthermore, a higher trade intensity between each of the labor-abundant but poor EU members and Canada would also reduce per capita emissions of *GHGs* in the majority of the latter EU members. This suggests that in labor-abundant and poor EU members, *FEH* and *PHH2* dominate *PHH1*. There is no evidence that confirms the theory that more trade between Canada and capital-abundant but poor EU members should increase per capita emissions of *GHG*s in the latter EU members.

A short summary of the results of the control variables applied in the three models is presented in the rest of this section. The slopes of income per capita are reported in the 6^{th} row of Table 3, while the 7^{th} row reports its squared value to investigate the existence of an EKC. Inconsistent with the EKC argument, it appears that there is a positive and monotonic relationship between per capita income and per capita emissions of *GHGs*.[14]

The 8^{th} row of Table 3 reports the direct composition effect of growth captured by

[14]We investigate further the empirical validity of the EKC in a follow up project, where we control for various political economy variables such as the GINI coefficient, the rule of law index, institutional quality measurement, etc... We confirm the results found here in regards to the inconsistency of the EKC even when we add the cubic per capita income and break down *GHGs* into 4 main *GHGs*. For more details, see Pascalau et al. (2019). See also Pascalau and Qirjo (2017b)for a similar analysis applied in the case of TTIP. They confirm that empirical validity of the EKC for CO_2, CH_4, HFC/PFC/SF_6, but they find a monotonically positive relationship between income per capita and *GHGs* per capita. They claim that the latter result is associated mainly to the positive relationship between per capita income and N_2O per capita.

the capital-labor ratio, while and 10$^{\text{th}}$ row reports its squared value. The 9$^{\text{th}}$ row shows the general composition effect of growth proxied by the product of income per capita and capital-labor ratio. The results indicate a negative and statistically significant relationship between either the direct, or the general composition of growth and per capita emissions of *GHGs*, respectively.

The 14$^{\text{th}}$ row of Table 3 reports the relationship between land per capita and per capita emissions of *GHGs*, while the slopes of squared land per capita are shown in the 15$^{\text{th}}$row. On average, there is no statistically significant evidence confirming a relationship between the inverse measurement of population density and per capita emissions of *GHGs*.

The effect of inward *FDI* (as a share of GDP) on per capita emissions of *GHGs* is shown in the 13$^{\text{th}}$ row of Table 3, under *M2* and *M3*. The results imply a positive and statistically significant relationship between inward *FDI* and per capita emissions of *GHGs* in a typical CETA member. This is consistent with the theory that multinational corporations may have chosen to move the entire production of dirty goods (or the production of their intermediate dirty goods) in the foreign nations.

6 Robustness Checks

For all tables and trade elasticity graphs of the previews section, to avoid the possible double causation between per capita emissions of *GHGs* and income per capita as identified in the Porter Hypothesis, the study proxies per capita income with its first lag of a weighted three years moving average ($I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * I_{it-3}$).[15] This measurement performs better in the sample in terms of lower root mean squared forecast error as compared to an equally weighted scheme. Note that the use of the lagged per capita income also avoids the possible contemporaneous correlation between income per capita and trade intensity variables (e.g., Chisik et al. (2016) examine theoretically the relationship between trade and population aging via the income channel). In this section, additional robustness checks are performed.

First, the paper employs the third lag of income per capita, capital to labor ratio, and land per capita (e.g., $I_{it} = 0.6 * I_{it-3} + 0.3 * I_{it-4} + 0.1 * I_{it-5}$), respectively. This could be a more cautions way, not only to avoid the possible dual causality between per capita income and per capita emissions of *GHGs*, but also to avoid the possible multicollinearity issues between income per capita, capital to labor ratio, land per capita variables and the trade intensity variable, respectively. The results are shown in Table 5 and they are similar to

[15] See Porter (1991) on details on the latter hypothesis. See also Ambec et al. (2013) and Cohen and Tubb (2018) for recent theoretical and empirical evidence on evaluating the Porter Hypothesis.

the base results of Table 3. The trade slope is still negative regardless of the model or the empirical methodology used, however it loses its statistical significance only for *M1* and *M2* under random, fixed, and serial correlation fixed effects. However, it is always statistically significant irrespective of the model when using the fixed effects setting with Driscoll-Kraay standard errors.[16] The result are also similar to the base results when employing a second or a forth lag of the weighted three years moving average of the above variables, respectively.

Second, the study constructs a dummy variable, where 1 is for Ex-Communist EU members and 0 for the rest of the EU members. This dummy is multiplied by *T*, *T(RKL)*, *T(RI)*, $T\,(RKL)^2$, $T\,(RI)^2$, *T(RLPC)*, and $T\,(RLPC)^2$. In this way, one can isolate the environmental impacts of trade between Ex-Communist EU members and Canada. Table 6 reports the results of this approach, where *EE* stands for the Ex-Communist EU members Dummy. There is statistically significant evidence suggesting that the presence of CETA reduces per capita emissions in a typical EU member. However, regardless of the model or empirical specification used in the paper, there is no statistically significant evidence confirming the latter result for pollution and trade between Canada and Ex-Communist EU members. The slopes of *T(RKL)* when using the *EE* are mainly negative (but only statistically significant under *M2* when employing the fixed effects allowing for cross sectional dependence of the standard errors). These negative coefficients are theoretically expected and suggest the presence of *FEH* when Canada trades with Ex-Communist EU members. This is related to the fact that all the latter EU members are labor-abundant countries with the exception of the Czech Republic. In other words, the presence of CETA may force Ex-Communist EU members to produce more labor-abundant (cleaner) goods and import more capital-abundant (dirty) goods from Canada. The results of Table 6 are mainly consistent with *PHH1*, but exactly as in the base results, they are not statistically significant. Thus, there is no statistically significant evidence that implies that each Ex-Communist EU member would act as pollution haven as a result of CETA. Remember that they are all poor countries relative to Canada. Therefore, one may suggest that in a typical Ex-Communist EU member, there is no statistically significant evidence of a relationship between per capita emissions of *GHGs* and trade intensity because *FEH* cancels out *PHH1* and *PHH2*. Note that the volume of trade between Canada and the Ex-Communist EU members consist of only about 4% of the total trade volume of Canada and the EU.

Third, the study constructs a dummy variable, where 0 is for the poor EU members and 1 for the rich EU members. This is labeled as *Rich* which stands for the Rich EU-Members

[16] The Driscoll-Kraay Fixed Effects approach controls both for cross-section dependence and serial correlation in standard errors up to the second lag.

dummy. Analogously to the *EE*, the *Rich* dummy is interacted with the trade intensity variable and all trade covariates. Consequently, one can test the environmental impacts of trade between Rich EU members and Canada. Table 7 reports the results of this approach. There is statistically significant evidence suggesting that the presence of CETA reduces per capita emissions in a typical EU member. Moreover, there is also statistically significant evidence confirming the latter result for air pollution and trade between Canada and the rich EU members. However, it is statistically significant only under *M2* when employing fixed effects with Driscoll-Kraay robust standard errors. Note that in this case, the magnitude of the trade intensity coefficients are much higher for a typical rich EU member relative to an average EU member. The slopes of *T(RKL)* are negative and statistically significant (while the slopes of $T(RKL)^2$ are positive). Note that the majority of Rich EU members are capital-abundant (only 3 out of 11 are labor-abundant). Also, the latter slopes were expected to be negative after observing the trade elasticity graphs located in the middle row of the last page. The results of Table 7 consistently with *PHH1*, report positive and statistically significant coefficients of *T(RI)*, and negative and statistically significant coefficients of $T(RI)^2$. Hence, there is statistically significant evidence that implies that Canada could act as pollution haven as a result of CETA. The presence of CETA would encourage a typical Rich EU member to produce cleaner goods due to the existence of stringent environmental regulations and also import dirtier goods from Canada that theoretically would have lax environmental regulations. This is because these EU members are richer and more densely populated than Canada. Note that the volume of trade between Canada and the rich EU members consist of about 82% of the total trade volume of Canada and the EU. The results reported in Tables 6 and 7 stand in terms of the sign and statistical significance for the variables of interest, even when the trade covariates (in addition to the trade and dummy covariates) are included in the regressions.

Fourth, the study instruments the potential endogeneity between trade and per capita emissions of *GHGs*, by using the Arrelano-Bond one step difference GMM estimation method.[17] This approach allows for 1 lag of *GHGs* per capita (the dependent variable) and instruments it with 3 and 4 lags, respectively. The results are statistically significant and negative for the trade intensity variable.

Fifth, the study follows Frankel and Rose (2005) two stage least squared econometric technique in order to correct for potential double causality problem between per capita

[17]We also use the Arrelano-Bond two step difference GMM estimator and a system GMM specification. When using both instrumental variable approaches, we run into an instrumental proliferation issue, where we get a perfect Hansen statistics of 1. This is also the case when we instrument both trade and income with lags using the Arrelano-Bond one step difference GMM estimator. Under all these scenarios, instruments either fit the endogenous variables or (and) they outnumber the individual countries.

emissions of *GHGs* and trade intensity. In particular, it instruments trade with a set of exogenous variables including exchange rate, capital to labor ratio, price of exports and imports, land per capita, and four dummies for whether a country has adopted euro, or it is not landlocked, or uses English or French as its official language, or was part of the first 11 countries that joined the EU, respectively. The instruments are created using the predicted values and *RKL*, *RI*, and *RLPC*, respectively. The structural equation includes the trade instrument along with its covariates in addition to all exogenous variables. The results confirm the negative relationship between per capita emissions of *GHGs* and the trade intensity instrumental variable, albeit they are statistically significant only when applying the fixed effects specification with Driscoll-Kraay standard errors.[18]

Sixth, Table 3 reports a positive and statistically significant slopes of FDI, confirming the classical *PHH*. Theoretical literature in trade and environment (e.g. Copeland and Taylor (2004)) suggests that horizontal FDI is highly associated with *PHH*, but this is not the case for the vertical FDI. This is because rich countries could move their entire production plants of their dirty goods toward poor countries taking advantage of lax environmental regulations there. This could be the case here since the presence of CETA decreases tariffs dramatically and some Canadian firms may choose to relocate their production in the Ex-Communist EU members. Thus, the study employs a dummy variable with a value of 1 if the country is an Ex-Communist EU member and zero otherwise. The results indicate no significant evidence of a relationship between inward *FDI* in a typical Ex-Communist member (horizontal FDI) and per capita emissions of *GHGs*. However, there is statistically significant evidence that suggests one percentage point increase in inward *FDI* in a typical Western EU member (vertical FDI) is associated with an increase of per capita emissions of *GHGs* of about .03 percentage points, on average.

Seventh, the study employs a subset of the data under different time period in order to account for the time when each country joined the EU. In this context, the three regressions are tested on: 1) the 6 original EU countries (of the 1958 agreement) and Canada over 1990-2016; 2) the 9 EU countries (of the 1973 agreement) and Canada during 1990-2016; 3) the 10 EU countries (of the 1981 agreement) and Canada on 1990-2016; 4) the 12 EU countries (of the 1986 agreement) and Canada over 1990-2016; 5) the 15 EU members (of the 1995 agreement) and Canada during 1995-2016; 6) the 25 EU members (of the 2004 enlargement) and Canada on 2004-2016; 7) the 27 EU members (of the 2007 enlargement) and Canada during 2007-2016; 8) the 28 EU members (of the 2013 enlargement) and Canada on 2016; and finally, 9) the 27 EU members, where the UK

[18]The Driscoll-Kraay Fixed Effects regression should be theoretically superior to the rest, since it controls both for cross-section dependence and serial correlation in the standard errors.

is excluded due to BREXIT. These key result of the paper concerning the trade intensity variable is still the same in terms of the sign but is it is generally more strongly statistically significant as compared to the result reported in Table 3.

Eighth, in regards to the capital labor ratio, instead of proxing the labor force by *emp* (numbers of persons engaged) as defined in PWT (2019), one can use the product of *emp* and average hours of labor, or the product of *emp* and average hours of labor and human capital. The results are very similar to all results in the study in terms of sign and statistically significance.

Ninth, the study also evaluates the relative income, the relative capital to labor ratio, and the relative land per capita of the overall EU as compared to Canada, respectively. Under this scenario, the EU is capital-abundant, poor and densely populated as compared to Canada. All three regressions are tested again using the same 4 empirical specifications. The key result of the paper still stands and it is statistically significant under any model or empirical method used in the paper. Note that for realistic reasons, the results highlighted in the previews section are to be trusted more than the latter result. This is because there are still trade barriers within EU members (such as different languages, culture, etc...) as compared to different provinces within Canada (or within the different states of the US). However, the key result still stands regardless of how one measures the relative variables of the EU members as compared to Canada.

Finally, the regressions are run using unbalanced panel (without filling the missing observations in the data as described in the footnotes of section 2). All the results are extremely similar to all results in the paper. Note that for space purposes, the results of this section that are not included in the tables of the paper are available upon request from the authors.

7 Discussion of the Results and Policy Implications

A lot of studies and reports summarized in various climate change conventions (i.e. the Kyoto Protocol meetings, the Paris Climate Change Agreement, etc...) have concluded that the fight against global warming requires stringent global regulations in order to achieve visible goals such as a reduction of global *GHGs* emissions. These goals are impossible to be achieved simply by enforcing regulations only at a national level, but they require global coordination. In this sense, air pollution is considered a pure global externality. Therefore, an existence of a global organization (similar to WTO) that sets up rules and regulations and imposes enforcement mechanisms with explicit legal and economic penalties could be a necessary tool for fighting this international negative externality. The implementation and efficiency of this organization requires at least the participation as official members of most of the world economies.

However, there are no guarantees that policies set by such global organization could force large developing economies such as China, India, or Russia to adopt similar policies on *GHGs* emissions reductions as compared to developed countries. This is because of the existence of significant differences on standard of living between developed and developing countries, forcing the latter ones to act as pollution havens. Consequently, a possible short term solution could be the encouragement of international trade agreements, especially the ones among developed and developing countries, where environmental standards are part of trade negotiations. The economic benefits from trading with developed countries may force the developing countries (that would be potential members of the free trade area) to adopt similar environmental policies with the former countries. These international free trade areas may impose carbon tariffs on imported goods from non-member countries.[19] The adoption of a carbon tariff on imported goods could increase the bargaining power of the international free trade areas when dealing with pollution-intensive goods originating from non-members developing countries. It may also reduce the presence of pollution havens in non-members developing countries because international corporations from developed countries may not find it beneficial to relocate their production in these developing countries to take advantage of their lax regulations. Therefore, it could increase the efficiency of such policy in global terms. This could be an example of future benefits in the fight against global warming that the existence of international free trade agreements could achieve, at least in the short-term. In this light, the presence of an international trade agreement, such as CETA could be a step in stone in the right direction.

CETA is one of the few ratified regional trade agreement that has included a trade and pollution chapter in the deal. This is the Chapter 24 of CETA and it includes 16 articles.[20]

[19]Copeland (1996) is the first theoretical study to introduce a pollution content tax on imports. Abrego et al. (2001) derive implications on linking global trade and environmental policy. Carbone et al. (2009) use a game-theoretical structure to analyze potential benefits of global trade in emissions permits.

[20]For more details, see http://ec.europa.eu/trade/policy/in-focus/ceta/ceta-chapter-by-chapter/. In addition to chapter 24 on Trade and Environment, see also chapter 22 entitled "Trade and Sustainable Development (TSD)". Note that the largest international free trade agreement that has included a chapter of environment and trade in its negotiations is TTIP. For more details on this chapter see http://trade.ec.europa.eu/doclib/docs/2016/august/tradoc_154837.pdf. However, despite the earlier progress on trade negotiations between the EU and the US, the trade talks have been put into a halt from August of 2016. On the other hand, Canada and the EU not only have reached an agreement, but also 98% of it is ratified by each member and their respective regional governments. On September, 13 2018, EU and Canadian committee members of TSD, have met to discuss progress on the procedure and institutional structures for the effective implementation of TSD chapters and exchange views on priority areas of trade and environment. For more details see http://trade.ec.europa.eu/doclib/docs/2018/september/tradoc_157409.pdf.

One of the main goals is to prevent either trade partner from relaxing their laws in order to boost trade, and therefore, creating possible pollution havens. Another important goal is in Article 9 and favors the reduction of various non-tariff barriers for environmentally friendly goods. Article 16 discusses the cooperation on environmental issues, where trade in environmental friendly goods and the adoption and progress of green technology is promoted. It encourages changes in environmental laws and regulation of each member that promote the use of efficient energy in export goods. It promotes the positive spillover effects of environmental friendly technologies used by trade partners. These are also important measures that may prevent any future race to the bottom motive and rather encourage race to the top hypothesis in the presence of CETA.

This paper analyzes the impact of trade between the EU and Canada on per capita emissions of *GHGs* during 1990 to 2016 time period. The main finding of the paper is the existence of a robust and statistically significant evidence of a negative relationship between trade intensity and per capita emissions of *GHGs* in a typical CETA member. It reports robust and statistically significant evidence implying that higher trade intensity between Canada and the EU is associated with lower per capita emissions of *GHGs* in almost all CETA members. There is no statistically significant evidence that trade between Canada and the EU raises per capita emissions of *GHG*s in any CETA members.

CETA entered into force provisionally on September, 21, 2017. The study did not included data for 2017 and 2018 years due to missing observations of the main variables of interest for the majority of the CETA members. The presence of CETA, on average, is expected to decrease per capita emissions of *GHGs*, at least theoretically, even further from the empirical results of this study, due to the environmentally friendly procedures laid out in various articles of chapter 24. There is empirical evidence that suggests that trade agreements with environmental provisions tend to reduce air pollution (e.g., Baghdadi et al. (2013) in the case of CO_2). However, for CETA, this a subject for empirical validation in future studies that will make use of 2017 and later data.

Despite the empirical evidence implying the positive impacts of free-trade agreements on reducing air pollution, there is still much public support over the race to the bottom hypothesis on free trade and pollution. In the case of CETA, not even a single politician from the EU or Canada has advertised the potential environmental gains from the presence of CETA. There are plenty of interviews from various politicians from both trade partners highlighting the benefits of CETA on small, medium and large firms.[21]

[21] See for example a short report, http://trade.ec.europa.eu/doclib/docs/2016/july/tradoc_154775.pdf. See also various interviews from the EU and Canadian politicians emphasizing the positive economic impacts of CETA in both trade partners. They have summarized the positive effects of CETA on innovation, productivity, employment, quality of products, etc... There is not even an interview in support on the

This study suggests that, in a typical CETA member, per capita emissions of *GHGs* would be reduced due to the implementation of CETA because of simple economics related to the volume and patterns of trade between trade partners. In particular, this study provides evidence implying that an increase on trade intensity between Canada and labor-abundant members of the EU seems to decrease the production of capital-intensive (dirty) goods and increase the production of labor-intensive (clean) goods in the latter EU countries. In this way, per capita emissions of *GHGs* originating from capital-intensive goods are shipped from the labor-abundant members of the EU into Canada. However, the latter country uses more environmental friendly technologies in the production of latter goods as compared to the latter EU members. In this sense, overall per capita emissions of *GHGs* go down.

This study reports robust and statistically significant evidence supporting the idea that rich countries pollute the environment less because they support the design and implementation of stringent environmental regulation. The paper implies that the latter result is empirically valid only for rich CETA members. Consequently, an increase in trade intensity between Canada and the rich members of the EU would reduce per capita emissions of *GHGs* in the latter countries (e.g., 01% increase in bilateral trade between Canada and Luxembourg that is the riches EU member, with about twice higher GDP per capita relative to Canada, could reduce annual per capita emissions of *GHGs* in Luxembourg by about 3%).

Theoretically Canada may act as pollution haven due to the implementation of CETA because it is extremely sparsely populated as compared to each EU member. Following Frankel and Rose (2005), countries that are sparsely populated tend to have lax environmental standards, and therefore, a reduction of tariffs could lead to higher production of pollution-intensive goods due to lower costs in these countries as compared to densely populated trade partners. Consequently, the Canadian officials may want to keep an eye on this type of pollution haven. However, the study does not find a statistically significant evidence of this argument for Canada. Moreover, the officials of Finland, Sweden, and Latvia, (the three EU members with the highest land per capita in the EU) may also want to keep an eye on this phenomenon despite the fact that the paper does not report any statistical significant evidence consistent with this hypothesis. For more details, compare the signs, magnitude and statistically significance of trade elasticity coefficients of *M1* to

environmental gains of CETA from the economics point of view. For more information, see the official EU website on the CETA related issues, http://ec.europa.eu/trade/policy/in-focus/ceta/index_en.htm, or the official Canadian website on CETA, https://www.international.gc.ca/gac-amc/campaign-campagne/ceta-aecg/index.aspx?lang=eng. There are news on the possible implementation and inclusion of Paris Climate Change Agreement in CETA, but there are no reports or news in the economics behind the reduction of *GHGs* per capita that the presence of CETA may bring on average. See for example, https://ec.europa.eu/clima/events/ceta-taking-action-trade-and-climate_en.

those of *M2* for Canada and the latter three EU members, respectively.

The paper shows that per capita emissions of *GHGs* in Canada would increase due to the presence of CETA. However, this result is never statistically significant regardless of the empirical specification or model used in the study. Therefore, this study suggest that the presence of CETA may help reduce per capita emissions in almost all EU member and at the same time does not increase them (at least in a statistically different way from zero) in Canada. Consequently, even though per capita emissions fall in almost every EU country, there is no shipment of *GHGs* from the EU to Canada or vice versa due to the presence of CETA.[22]

It is worth mentioning that all above results are based on the assumption that the trade intensity variable would increase in the presence of CETA. This is a reasonable assumption based on the classical trade theory that suggests that trade between trade partners boosts when tariff rates and other trade barriers are removed or reduced significantly. It turns out that in the first year of the presence of CETA (September 2017-October 2018), the volume of trade between the EU and Canada has increased by about 7.7%.[23] This is an equivalent of about .03% increase of the bilateral volume of trade between Canada and the EU as a share of GDP. In the absence of *GHGs* per capita emissions data for this time period, one can use the prediction of this study to evaluate the role of CETA on air pollution. Thus, .03% increase of the trade intensity variable due to the realistic presence of CETA could be associated with the reduction of annual per capita emissions of *GHGs* by about 1.71% in a typical EU member during the September 2017-October 2018 time period. One can use the trade elasticity values, reported in Table 4, to predict the changes of per capita *GHGs* emissions in each CETA members.

In conclusion, we hope that the results of this study may help raise public awareness on the positive impact of CETA on air pollution and possible encourage politicians on both sides of the Atlantic to talk more about the environmental gains of CETA along the other trade benefits they often advertise in CETA official websites. We also hope that other

[22]However, CETA environmental previsions along with the empirical results of this study may help increase air pollution in the world even though the presence of CETA decrease air pollution in its members. This is known as the carbon leakage phenomenon. Under this scenario, the presence of CETA may force its members to concentrate production to their core and cleaner products and import pollution-intensive goods from pollution havens located in the rest of the world. And therefore, the overall air pollution may go up. i.e., see Bohringer et al. (2016) for theoretical scenarios that study the effect of boarder taxes on carbon leakage. Or, see Barrows and Ollivier (2014) who show that reduced air pollution from exporters as a result of lower tariffs is solely associated to their production mix and not to applications of more environmentally friendly technologies.

[23]For more information in regards to the increase of the volume of trade between each EU member and Canada, or and to see the top 5 imports and exports categories for each EU member and Canada under the September 2017- October 2018 time period, see https://www.international.gc.ca/gac-amc/campaign-campagne/ceta-aecg/year_one-premiere_annee.aspx?lang=eng

studies related to the potential impact of CETA on air pollution or/and other environmental variables will follow the present one, making use of more recent data or break down pollution data by sector, or analyze firm level data and so on.

8 Conclusion

This study uses a panel dataset of all EU members and Canada over the 1990-2016 time period. The key results of the paper reports empirical evidence highlighting a negative relationship between trade intensity and per capita emissions of *GHGs* in a typical CETA member. More specifically, it indicates robust and statistically significant evidence suggesting that one percent increase on a percentage point of the bilateral trade, as a share of GDP, between Canada and an average EU member may help reduce annual per capita emissions of *GHGs* by about .57 percent. This results implies that in a typical CETA member, the presence of CETA (which came to life, in the real world, on September 2018) may indeed be a realistic example of positive impacts of international trade agreements on air pollution. It provides robust and statistically significant evidence implying that the implementation of CETA reduces per capita emissions of *GHGs* in almost any CETA member regardless of the model or empirical method employed in the paper. Furthermore, there is no statistically significant evidence that suggest a positive relationship between trade intensity and per capita emissions of *GHGs* in any CETA member.

The above result holds due to the combinations of *FEH*, *PHH1* and *PHH2* between trade partners. The study yields robust and statistically significant evidence consistent with *PHH1*, only for rich CETA members as compared to Canada. *PHH1* claims a negative relationship between *GHGs* per capita and income per capita, due to possible existence of lax environmental regulations in poorer countries. In this light, Canada may act as pollution haven when trading with rich EU members. The results also highlight robust evidence consistent with *FEH* only for labor-abundant EU members. *FEH* claims that air pollution is reduced (increased) in labor-abundant (capital-abundant) countries. Following this argument, *FEH* is empirically validated when Canada trades with labor-abundant EU members, but it disappears when Canada trades with capital-abundant EU members. Canada is very sparsely populated as compared to any EU member. Following this fact means that Canada could act as pollution haven, at least theoretically, according to *PHH2* as a result of the presence of CETA. The study finds empirical evidence that supports the latter argument for Canada, but they are not statistically significant under any empirical specification used in the paper (e.g. see Table 4 and compare the trade elasticities for Canada between *M1* and

M2).

An average EU member is labor-abundant, poor and densely populated as compared to Canada. Thus, if *FEH* and *PHH2* dominate *PHH1*, the presence of CETA may help reduce per capita emissions of *GHGs* in a typical EU member. This study provides robust and consistently statistically significant evidence in support of the latter claim. Canada is capital-abundant, rich and sparsely populated as compared to an average EU member. Therefore, if *FEH* and *PHH2* dominate *PHH1*, per capita emissions of *GHGs* may increase in Canada due to the implementation of CETA. The empirical results reported in the study, validate the latter argument when *M2* and *M3* is employed, but they are not statistically significant under any empirical method used in the paper. Hence, in Canada *FEH* and *PHH2* eliminate *PHH1* in the presence of CETA.

Furthermore, it is shown that a higher trade intensity between Canada and EU members that are capital-abundant and rich reduces per capita emissions of *GHGs* in each of the latter EU members. This result stand because *PHH1* and *PHH2* dominate *FEH*. In addition, per capita emissions of *GHGs* could fall in all labor-abundant but rich EU members as a consequence of the implementation of CETA. This implies that *FEH*, *PHH1*, and *PHH2* may force the latter EU members to mainly produce relatively cleaner goods and import the relatively dirtier goods from Canada. Further, the presence of CETA would also reduce per capita emissions of *GHGs* in the majority of labor-abundant but poor EU members. This suggests that in latter EU members, *FEH* and *PHH2* dominate *PHH1*. There is no evidence that confirms the argument that more trade between Canada and capital-abundant but poor EU members should increase per capita emissions of *GHG*s in the latter EU members.

In addition, the results of the study imply that per capita emissions of *GHGs* may be reduce more in CETA members that are landlocked, or are not using Euro as their official currency, or use English or French, as one of their official languages.

In a nutshell, the empirical results reported in this paper suggest that the presence of CETA may truly help in the global fight against the negative and international externality of air pollution. It is shown that the implementation of CETA, may reduce (albeit in a very marginal way) per capita emissions of *GHGs* in a typical CETA member. This result is based on the empirical validity of simple economics theories on the impacts of trade openness on air pollution, where *FEH* and *PHH2* dominate *PHH1*. Surprisingly, the robust and statistically significant results suggest that the presence of CETA may help reduce per capita emissions of *GHGs* in almost all EU members. Moreover, there is no statistically significant evidence which implies that the presence of CETA could shift some *GHGs* emissions from most of the EU members towards Canada, or vice versa.

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Tables and Figures

Table 1: Summary Statistics and Unit Root Tests

Variable	Dimension	N	Mean	SD	Min	Max	Unit Root Tests
GHGs	tons/capita	783	16.79	31.08	4.19	219.74	-3.658*** †
Trade	(X+M)/GDP	783	0.056%	0.095%	0.003%	0.74%	-6.857*** ∗
Rel. K/L	CAN = 1	783	0.856	0.365	0.041	1.655	-5.774*** ‡
Rel. I	CAN = 1	696	0.725	0.502	0.029	2.519	-2.745*** †
Rel. LPC	CAN = 1	783	0.077	0.179	0.002	1	N.A.
I	2011 USD	696	27,894.18	19,931.42	949.97	117,633.5	-2.313** ‡
K/L	2011 USD	783	248,425.3	133,666	88,99.91	690,601.9	-1.400* ‡
FDI/GDP	%	783	12.53	47.86	-75.31	731.93	-6.909*** †
LPC	Sq.Km/capita	783	0.024	0.056	0.001	0.359	-2.478*** †

***, **, and * denote significance at the 1%, 5%, and 10% significance level, respectively. For all series, we use the *Z-t-tilde-bar* statistic of the Im-Pesaran-Shin unit-root test where the AR parameter is panel specific. The null states that all panels contain unit roots, while the alternative states that some panels are stationary. ∗, †, ‡ means that the unit root test controls for (i) a trend only, (ii) trend and a squared trend term and (iii) trend, a squared trend, and a cubic trend term, respectively. Relative Land per Capita is stationary around a constant.

Table 2: Relative (to Canada) Measures of Income, Capital/Labor and Land per Capita ratios

Country	Relative Income	Relative K/L ratio	Relative LPC ratio
Austria	1.117367	1.127084	0.032709
Belgium	1.045962	1.285901	0.009241
Bulgaria	0.101232	0.146827	0.045332
Canada	1	1	1
Croatia	0.247387	0.585975	0.04072
Cyprus	0.640459	1.136682	0.030083
Czechia	0.337635	1.002536	0.024289
Denmark	1.362923	1.046758	0.0254
Estonia	0.240707	0.483427	0.104469
Finland	1.086206	1.090806	0.205616
France	1.03528	1.032433	0.032846
Germany	1.081756	1.021696	0.013947
Greece	0.560493	1.186642	0.038921
Hungary	0.250218	0.570419	0.029318
Ireland	1.106298	0.987077	0.055093
Italy	0.884257	1.326103	0.016532
Latvia	0.188636	0.628461	0.091297
Lithuania	0.199943	0.388242	0.062963
Luxembourg	2.193493	1.377379	0.017903
Malta	0.441521	0.562086	0.002523
Netherlands	1.159178	0.967618	0.008222
Poland	0.211064	0.321403	0.026071
Portugal	0.496686	0.944284	0.02846
Romania	0.123457	0.285539	0.035586
Slovakia	0.255806	0.586686	0.029074
Slovenia	0.493314	0.846416	0.032077
Spain	0.682424	1.013103	0.037631
Sweden	1.259957	1.053778	0.157782
UK	1.062318	0.843649	0.01283

Table 3: Dependent Variable 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	–168.479***	–133.304**	–191.191*	–170.370***	–147.230**	–185.461*	–168.479**	–133.304*	–191.191	–256.901***	–215.037***	–323.143*
Trade × RKL	331.796*	211.898	100.818	326.933*	227.637	112.016	331.796	211.898	100.818	631.923**	476.144*	447.526
Trade × $(RKL)^2$	–221.677***	–178.730**	–156.899**	–219.237***	–187.110**	–163.245**	–221.677***	–178.730**	–156.899**	–240.379**	–182.839*	–182.790*
Trade × RI	118.628	183.009	143.120	128.975	199.619	171.983	118.628	183.009	143.120	–155.354	–72.604	–98.318
Trade × $(RI)^2$	–84.363	–123.907**	–84.009	–87.609	–129.682**	–95.922	–84.363	–123.907*	–84.009	37.143	–2.100	28.223
I	1.276***	.519**	.545**	1.263***	.669***	.683***	1.276***	.519	.545	1.602***	.936***	.935***
I^2	.108***	.119***	.101***	.108***	.116***	.100***	.108***	.119***	.101***	.104***	.113***	.103***
KL	–1.579***	–1.308***	–1.302***	–1.582***	–1.375***	–1.359***	–1.579***	–1.308***	–1.302***	–.850**	–.582	–.596
$(KL)^2$	.172***	.143***	.135***	.172***	.149***	.141***	.172***	.143***	.135***	.139***	.113***	.108***
KL × I	–.266***	–.221***	–.197***	–.265***	–.228***	–.206***	–.266***	–.221***	–.197***	–.285***	–.244***	–.230***
Trade × RLPC		695.409*	283.598		819.560**	358.554		695.409*	283.598		644.042	–164.054
Trade × $(RLPC)^2$		–611.383	–109.550		–748.929**	–196.804		–611.383*	–109.550		–573.117	276.253
FDI/GDP		.016**	.014**		.015**	.013**		.016*	.014*		.020*	.019*
LPC		.260	.029		.107	–.072		.260	.029		.493	.287
$(LPC)^2$		–.021	–.055*		–.024	–.052**		–.021	–.055*		.007	–.024
EnglishFrench × Trade			–89.952*			–93.763*			–89.952*			–104.693**
Sea × Trade			141.442*			125.369*			141.442*			190.695
Euro × Trade			79.450***			76.592***			79.450***			48.724**
Constant	5.121***	8.564***	8.082***	5.178***	7.602***	7.226***	4.927***	8.372***	7.890***	.476	4.059**	3.832**
N	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000
R2	.590	.615	.628				.988	.989	.989			
R2 adj.	.551	.575	.587									
BIC	–1496.610	–1507.614	–1512.487	.	.	.	.	.	.	.	.	.

***, **, 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 dependent robust standard errors among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay robust 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, $I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * I_{it-3}$. All the other variables are in their contemporaneous values. Trade is the ratio of the sum of bilateral exports and imports (between Canada and each EU member) over GDP. All relative variables denoted by R in front of them are constructed relative to Canada. KL denotes the capital to labor ratio that also measures the direct composition of growth. FDI/GDP is the ratio of the stock of inward FDI to GDP. 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. EnglishFrench × Trade is a dummy variable. If a country uses English or French 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. In the years that a country uses Euro as its official currency, we put the value of our Trade variable, otherwise we put zero.

Table 4: GHGs Elasticity Results

Estimation Method	M1 (FE) (1)	M1 (RE) (2)	M1 (CSD) (3)	M2 (FE) (4)	M2 (RE) (5)	M2 (CSD) (6)	M3 (FE) (7)	M3 (RE) (8)	M3 (CSD) (9)
Trade									
Austria	–57.648**	–54.385**	–57.648**	–59.097*	–50.865*	–59.097*	–156.768**	–129.855*	–156.768**
Belgium	–98.019***	–94.689***	–98.019***	–114.528***	–110.520***	–114.528***	–173.171***	–168.211***	–173.171***
Bulgaria	–111.900***	–113.502***	–111.900**	–57.590	–62.230	–57.590	–12.587	–15.337	–12.587
Canada	–24.094	–21.307	–24.094	42.992	33.864	42.992	37.378	32.727	37.378
Croatia	–33.096	–34.568*	–33.096	–12.600	–11.628	–12.600	–12.302	–8.964	–12.302
Cyprus	–41.265	–40.119	–41.265	–41.463	–36.522	–41.463	–47.103	–38.208	–47.103
Czechia	–33.669	–34.811	–33.669	–41.937	–40.675	–41.937	–209.293***	–188.609**	–209.293***
Denmark	–71.423**	–67.633**	–71.423**	–84.100**	–76.090**	–84.100**	–82.840	–69.841	–82.840
Estonia	–40.897**	–42.278**	–40.897*	26.036	33.032	26.036	34.091	40.080	34.091
Finland	–45.035*	–41.941*	–45.035*	51.391	75.555	51.391	38.434	59.506	38.434
France	–42.785**	–39.798*	–42.785*	–39.017	–31.071	–39.017	–88.385***	–80.848***	–88.385***
Germany	–38.457*	–35.426	–38.457	–49.879*	–43.748*	–49.879*	.929	11.162	.929
Greece	–56.324*	–55.623*	–56.324	–52.642	–47.679	–52.642	–43.308	–36.025	–43.308
Hungary	–31.243	–32.695*	–31.243	–17.338	–17.684	–17.338	–152.564**	–133.908*	–152.564**
Ireland	–60.458**	–57.191**	–60.458**	–42.033	–31.992	–42.033	–92.144**	–83.619**	–92.144**
Italy	–96.177***	–93.514***	–96.177***	–106.693***	–102.789***	–106.693***	–83.987	–75.856	–83.987
Latvia	–54.336***	–55.866***	–54.336**	–6.889	–5.487	–6.889	11.509	13.955	11.509
Lithuania	–40.846	–42.904	–40.846	7.266	12.882	7.266	–1.283	3.467	–1.283
Luxemburg	–288.486***	–285.538***	–288.486**	–377.517***	–375.301***	–377.517***	–475.301***	–465.834***	–475.301***
Malta	–16.695**	–16.646**	–16.695	–14.097	–15.267*	–14.097	–58.725***	–59.061***	–58.725***
Nederlands	–40.516	–37.128	–40.516	–54.424**	–48.692*	–54.424*	6.141	16.317	6.141
Poland	–62.272***	–63.441***	–62.272**	–32.095	–35.295	–32.095	.063	.232	.063
Portugal	–30.755	–30.541	–30.755	–27.889	–24.532	–27.889	6.776	12.424	6.776
Romania	–80.364***	–82.266***	–80.364**	–45.434	–49.286*	–45.434	–12.011	–13.783	–12.011
Slovakia	–16.222	–16.141	–16.222	–8.267	–4.393	–8.267	–1.396	5.726	–1.396
Slovenia	–34.877*	–33.481	–34.877	–25.120	–19.036	–25.120	10.052	18.638	10.052
Spain	–26.755	–28.297	–26.755	–14.174	–14.447	–14.174	–122.713*	–105.016	–122.713*
Sweden	–54.412**	–50.872*	–54.412*	14.714	35.916	14.714	–35.354	–14.022	–35.354
UK	–22.882	–19.823	–22.882	–27.256	–21.335	–27.256	–114.679***	–106.046***	–114.679***
Average	-56.962***	-55.945***	-56.962***	-41.713**	-37.424**	-41.713**	-63.122**	-54.441**	-63.122***

Note: The entries in this table are Trade elasticities. All values are in percentage. The average Trade to GDP ratio in the sample is around 0.057%. Thus, in response to a 0.01% percentage point increase in Trade, GHGs per capita in Bulgaria should decrease by approximately 1.11% (i.e., $exp(0.0001*\epsilon)$-1; $where \epsilon$ is one of the elasticity coefficients in the table). Columns (1), (2), and (3) show coefficients of Trade elasticities using Model 1 (M1) under Fixed Effects (FE), Random Effects (RE), and Fixed Effects with cross-sectional dependence robust standard errors (CSD), respectively. Columns (4), (5), and (6) indicate Trade elasticities for GHGs using Model 2 (M2) under FE, RE, and CSD, respectively. Columns (7), (8), and (9) indicate Trade elasticities for GHGs using Model 3 (M3) under FE, RE, and CSD, 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 CETA members.

Table 5: Dependent Variable - GHGs Robustness Check

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	–89.201	–71.069	–166.398*	–91.719	–83.784	–161.424*	–89.201	–71.069	–166.398	–182.902**	–134.069*	–255.088*
Trade × RKL	236.768	186.191	98.968	230.008	187.363	92.799	236.768	186.191	98.968	600.473***	470.006**	409.278*
Trade × $(RKL)^2$	–221.885***	–198.006**	–175.764**	–218.644***	–200.983***	–175.708**	–221.885***	–198.006**	–175.764**	–294.509***	–241.233***	–221.062**
Trade × RI	28.716	37.548	–51.044	42.946	69.502	–11.718	28.716	37.548	–51.044	–275.395	–254.285	–344.448
Trade × $(RI)^2$	–3.986	–23.067	38.760	–8.566	–33.997	24.082	–3.986	–23.067	38.760	135.603	119.315	177.396*
I	1.070***	.470*	.562**	1.054***	.605**	.682***	1.070***	.470	.562	1.601***	.967***	.972***
I^2	.069***	.084***	.067***	.069***	.080***	.064***	.069***	.084***	.067***	.052***	.067***	.058***
KL	–1.289***	–1.054***	–1.071***	–1.292***	–1.116***	–1.121***	–1.289***	–1.054***	–1.071***	–.496	–.252	–.266
$(KL)^2$	.132***	.112***	.106***	.132***	.117***	.111***	.132***	.112***	.106***	.097***	.075***	.071***
KL × I	–.190***	–.164***	–.147***	–.189***	–.168***	–.152***	–.190***	–.164***	–.147***	–.210***	–.182***	–.168***
Trade × RLPC		568.073	185.293		697.543*	285.864		568.073	185.293		472.778	–70.096
Trade × $(RLPC)^2$		–464.414	10.318		–615.577*	–105.571		–464.414	10.318		–357.350	261.779
FDI/GDP		.012*	.010		.011	.009		.012	.010		.016	.015*
LPC		.472*	.166		.289	.054		.472*	.166		.891**	.595
$(LPC)^2$		.003	–.039		–.002	–.037		.003	–.039		.046	.004
EnglishFrench × Trade			–90.135*			–91.706*			–90.135*			–93.433*
Sea × Trade			173.741**			159.618**			173.741**			202.046*
Euro × Trade			86.465***			84.599***			86.465***			74.152***
Constant	4.153***	7.675***	6.934***	4.218***	6.647***	6.065***	3.963***	7.529***	6.790***	–1.436	3.159**	2.763*
N	667.000	667.000	667.000	667.000	667.000	667.000	667.000	667.000	667.000	667.000	667.000	667.000
R2	.607	.627	.644				.989	.989	.990			
R2 adj.	.568	.587	.604									
BIC	–1472.127	–1474.790	–1486.726	.	.	.	.	.	.	.	.	.

***, **, 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 dependent robust standard errors among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay robust 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, $I_{it} = 0.6 * I_{it-3} + 0.3 * I_{it-4} + 0.1 * I_{it-5}$. All the other variables are in their contemporaneous values. Trade is the ratio of the sum of bilateral exports and imports (between Canada and each EU member) over GDP. All relative variables denoted by R in front of them are constructed relative to Canada. KL denotes the capital to labor ratio that also measures the direct composition of growth. FDI/GDP is the ratio of the stock of inward FDI to GDP. 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. EnglishFrench × Trade is a dummy variable. If a country uses English or French 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. In the years that a country uses Euro as its official currency, we put the value of our Trade variable, otherwise we put zero.

Table 6: Dependent Variable (GHGs) - Eastern Europe Results

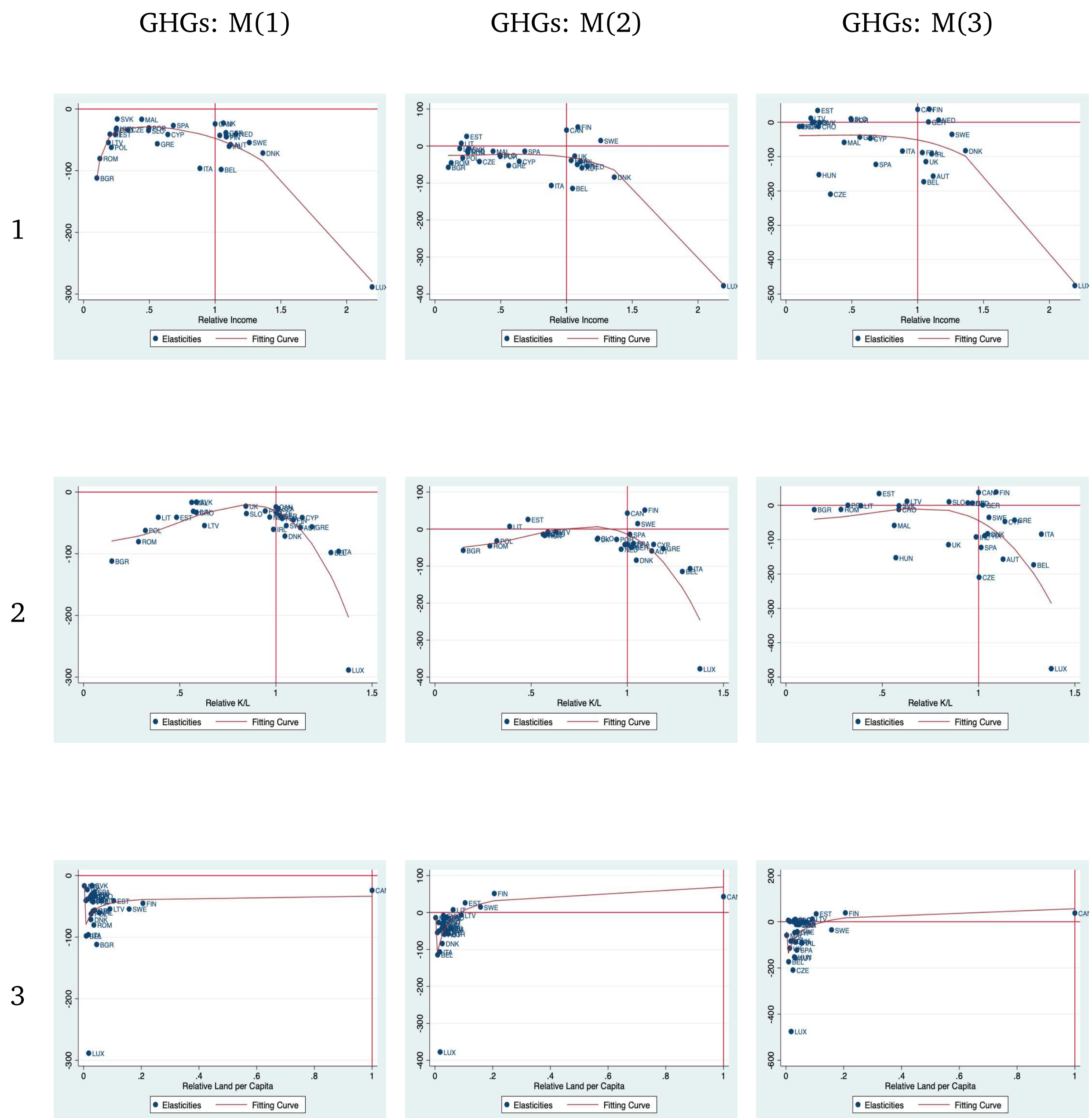
Estimation Method	Fixed Effects			Random Effects			Cross Section Dependence			Serial Correlation Effects		
Specification	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Trade	–18.151**	–10.264	–314.099***	–17.708**	–10.753	–281.555***	–18.151*	–10.264	–314.099***	–28.336*	–20.398	–168.413**
Trade $\times$ EE	–2.383	–17.526	212.459	.211	–31.953	173.190	–2.383	–17.526	212.459	119.213	37.482	138.507
Trade $\times$ RKL $\times$ EE	–895.473	–977.465	–587.640	–902.147	–988.681	–614.926	–895.473	–977.465*	–587.640	82.972	–5.535	297.394
Trade $\times$ RI $\times$ EE	1144.668	448.977	338.729	1143.725	443.166	308.970	1144.668	448.977	338.729	–1519.647	–2087.030	–2250.317
Trade $\times$ $(RKL)^2$ $\times$ EE	712.468*	644.884	439.133	713.298*	664.140	467.302	712.468*	644.884*	439.133	328.453	288.773	141.437
Trade $\times$ $(RI)^2$ $\times$ EE	280.872	1311.325	1095.946	263.348	1388.687	1224.846	280.872	1311.325	1095.946	2614.369	3499.670	3443.367
I	1.253***	.870***	.876***	1.236***	.968***	.970***	1.253***	.870**	.876**	1.180***	.804**	.854***
I^2	.106***	.120***	.108***	.107***	.118***	.108***	.106***	.120***	.108***	.088***	.100***	.093***
KL	–.981***	–.878***	–.895***	–.988***	–.909***	–.922***	–.981***	–.878**	–.895**	–.211	–.133	–.174
$(KL)^2$	.145***	.136***	.131***	.145***	.140***	.135***	.145***	.136***	.131***	.091***	.083**	.082**
KL $\times$ I	–.266***	–.255***	–.238***	–.265***	–.260***	–.245***	–.266***	–.255***	–.238***	–.227***	–.215***	–.207***
Trade $\times$ RLPC $\times$ EE		825.671	–5004.741		1196.508	–4309.414		825.671	–5004.741		2670.554	–1712.808
Trade $\times$ $(RLPC)^2$ $\times$ EE		16845.514	42447.448		14634.529	38798.614		16845.514	42447.448		325.297	18196.782
FDI/GDP		.018**	.018***		.017**	.018***		.018**	.018**		.023**	.023**
LPC		.135	–.114		.064	–.137		.135	–.114		.308	.040
$(LPC)^2$		–.027	–.063**		–.024	–.055**		–.027	–.063**		–.007	–.040
EnglishFrench $\times$ Trade			2.387			–11.387			2.387			–91.941
Sea $\times$ Trade			269.658***			253.374***			269.658***			209.720**
Euro $\times$ Trade			37.037**			33.313**			37.037***			33.492*
Constant	2.092*	4.449***	4.255***	2.174**	3.791***	3.673***	1.959*	4.295***	4.157***	–1.387	1.473	.947
N	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000
R2	.592	.612	.622				.988	.989	.989			
R2 adj	.552	.571	.579									
BIC	–1492.926	–1495.393	–1493.633	.	.	.	.	.	.	.	.	.

***, **, 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 dependent robust standard errors among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay robust 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, $I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * I_{it-3}$. All the other variables are in their contemporaneous values. Trade is the ratio of the sum of exports and imports (between Canada and each EU member) over GDP. All relative variables denoted by R in front of them are constructed relative to Canada. KL denotes the capital to labor ratio that also measures the direct composition of growth. FDI/GDP is the ratio of the stock of inward FDI to GDP. LPC denotes the land area per capita. KL $\times$ I denotes the general composition of growth. Trade $\times$ RKL and Trade $\times$ $(RKL)^2$ measure FEH. Trade $\times$ RI and Trade $\times$ $(RI)^2$ measure PHH1. Trade $\times$ RLPC and Trade $\times$ $(RLPC)^2$ measure PHH2. English $\times$ Trade is a dummy variable. If a country uses English or French as one of their official languages, we put the value of our Trade variable, otherwise we put zero. Sea $\times$ 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 $\times$ Trade is a dummy variable. In the years that a country uses Euro as its official currency, we put the value of our Trade variable, otherwise we put zero. EE denotes a dummy variable that is one if a country is an Ex-Communist EU member and zero otherwise.

Table 7: Dependent Variable (GHGs) - Rich 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	–18.004**	–10.162	–160.202**	–18.129**	–10.439	–136.587*	–18.004*	–10.162	–160.202**	–30.588**	–25.430**	–140.348
Trade × Rich	324.584	133.502	453.880**	350.353	251.414	542.008**	324.584*	133.502	453.880**	–291.193	–537.527*	–285.448
Trade × RKL × Rich	–847.682**	–635.592*	–837.403**	–851.687**	–726.260**	–916.483***	–847.682***	–635.592**	–837.403***	–283.733	–46.918	–220.207
Trade × RI × Rich	616.363***	617.827***	390.611*	591.037***	579.544***	373.121*	616.363**	617.827***	390.611	907.193**	920.678**	738.978
Trade × $(RKL)^2$ × Rich	230.918	163.309	217.485	231.933	193.186	244.140*	230.918**	163.309	217.485*	84.314	11.031	64.152
Trade × $(RI)^2$ × Rich	–265.253***	–266.073***	–169.334**	–257.156***	–255.886***	–166.268**	–265.253**	–266.073***	–169.334*	–334.851*	–336.193**	–256.674
I	.701***	.294	.289	.677***	.417*	.388	.701**	.294	.289	1.267***	.715***	.679***
I^2	.095***	.104***	.091***	.096***	.103***	.091***	.095***	.104***	.091***	.082***	.095***	.086***
KL	–1.204***	–1.042***	–1.034***	–1.206***	–1.118***	–1.079***	–1.204***	–1.042***	–1.034***	–.617**	–.419	–.384
$(KL)^2$	.132***	.117***	.109***	.132***	.123***	.114***	.132***	.117***	.109***	.109***	.090***	.083***
KL × I	–.197***	–.179***	–.159***	–.197***	–.187***	–.166***	–.197***	–.179***	–.159***	–.224***	–.200***	–.184***
Trade × RLPC × Rich		–327.501	–1111.500		–371.810	–1120.097*		–327.501	–1111.500*		–162.884	–742.292
Trade × $(RLPC)^2$ × Rich		368.538	1181.680*		374.126	1173.874*		368.538	1181.680**		268.374	868.803
FDI/GDP		.016**	.013*		.015**	.012*		.016*	.013		.021**	.019**
LPC		.272	–.212		.059	–.289		.272	–.212		.866**	.526
$(LPC)^2$		–.018	–.073**		–.025	–.065**		–.018	–.073***		.038	.001
EnglishFrench × Trade			–110.681***			–116.593***			–110.681***			–91.696*
Sea × Trade			175.040**			155.890***			175.040**			147.573
Euro × Trade			85.628***			84.818***			85.628***			57.247**
Constant	5.163***	7.961***	6.823***	5.251***	6.879***	6.005***	4.941***	7.766***	6.587***	.328	5.038***	4.185**
N	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000	696.000
R2	.605	.620	.636				.989	.989	.989			
R2 adj.	.567	.579	.596									
BIC	–1516.300	–1509.334	–1521.148	.	.	.	.	.	.	.	.	.

***, **, 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 dependent robust standard errors among countries. Serial correlation effects denote a fixed effects regression setting with Driscoll-Kraay robust 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, $I_{it} = 0.6 * I_{it-1} + 0.3 * I_{it-2} + 0.1 * I_{it-3}$. All the other variables are in their contemporaneous values. Trade is the ratio of the sum of bilateral exports and imports (between Canada and each EU member) over GDP. All relative variables denoted by R in front of them are constructed relative to Canada. KL denotes the capital to labor ratio that also measures the direct composition of growth. FDI/GDP is the ratio of the stock of inward FDI to GDP. 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. EnglishFrench × Trade is a dummy variable. If a country uses English or French 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. In the years that a country uses Euro as its official currency, we put the value of our Trade variable, otherwise we put zero. Rich is a dummy that is 1 for countries that have Income per Capita higher than the EU average. Hence, the Rich group excludes Cyprus, Greece, and Malta in addition to the Ex-Communist EU members.



Note: Each vertical axis corresponds to the Trade Elasticities of GHGs produced by the Fixed Effects (FE) 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 Canada, 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.