International Environmental Agreement and Trade in Environmental Goods: The Case of Kyoto Protocol

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Abstract

The Kyoto Protocol has received much criticism for its effectiveness as well as the spillover effect (i.e. carbon leakage and competitiveness loss). This paper provides the first evidence for the effect of the Kyoto Protocol on the bilateral trade in environmental goods, which can mitigate and prevent environmental damage. Using the generalized synthetic control method, I construct the counterfactual of trading pairs with Kyoto commitment and show that the export of environment goods by Kyoto countries increases by 31%–32% after the Protocol enters into force. The results suggest that the ratification of the Protocol could be a source of comparative advantage on environmental good production.

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1 Introduction

The Kyoto Protocol (KP, henceforth) was adopted in 1997 in the hope of mitigating the issue of climate change and global warming. Despite an ambitious international treaty aiming to reduce the greenhouse gas (GHG) emission to a safe level, it has received lots of criticism about its design and skepticism about its effectiveness. **?** suggest that re-examination of the KP is needed when the trade theory is neglected in the design. In addition, **?** find that the Clean Development Mechanism, which allows industrialized countries with KP commitments to reach their targets by using carbon offsets from developing countries, does not lead to a decrease in sulfur dioxide emissions. In contrast, several empirical studies have shown that the Protocol has been successful in reducing carbon emission in legally bound countries (Aichele and Felbermayr, 2013a; Grunewald and Martinez-Zarzoso, 2016; Maamoun, 2019). However, some research indicates that the decrease in greenhouse gas emission is not necessarily a success due to evidence of carbon leakage (via trade of high carbon content goods) (Aichele and Felbermayr, 2012, 2015). Furthermore, Aichele and Felbermayr (2013b) show that the Kyoto commitments lead to a comparative disadvantage in manufacturing sectors, especially pollution-intensive ones. As a result, the overall picture on the impact of the Kyoto Protocol is not clear.

This paper investigates the impact of Kyoto commitments on trade in EGs. Studies about the trade flow of environmentally friendly products is relatively scant in the literature. Even though studies look at these products, they mainly focus on one part of EGs (e.g., energy technology, solar and wind technology) and do not find causal evidence for the effect of the KP (Costantini and Crespi, 2008; Miyamoto and Takeuchi, 2018). In contrast to previous works, this paper expands the analysis to products relevant to the purpose of dealing with greenhouse gas emission: the Air Pollution Control, the Environmental Monitoring, Cleaner Technology and the Renewable Energy sub-groups..[1] A look at the statistics of trade of these products (in Figure 1) suggests this market has a fast-paced growth, especially after 2000. The world trade of these products increases significantly in early 2000s, which coincides with the ratification of the KP. Therefore, this trend motivates the research question: Does the Kyoto commitment increase the bilateral export of EGs?[2]

[Figure 1 here]

In this study, I follow Aichele and Felbermayr (2013b) and choose the unit of analysis

[1]Air Pollution Control and Environmental Monitoring belong to the Pollution Management group while Renewable Energy is in the Resource Management group. Together they comprise approximately 25% of EG trade value in 2011, as shown in Figure 1. Details of 6-digit Harmonized System (HS) product code in the analysis can be found in Appedix Table 2 in Sugathan (2013).

[2]From now on, EGs are used to imply only products in the analysis, unless otherwise indicated.

as an exporter–importer pair. Using the bilateral trade of EGs, I apply the generalized synthetic control (GSC) method of Xu (2017) to evaluate the causal effect of the KP on the bilateral export of EGs. In particular, I construct the counterfactual of trading pairs with Kyoto commitments and estimate the average treatment effect on the treated (ATT) on export. My findings show that the Protocol commitment leads to an average 31%–32% increase in exports of committed countries. The results are robust and consistent in a number of robustness check.

This paper contributes to the literature in two important ways. First, it is the first study to provide evidence for the EG trade effect of the Kyoto Protocol. Export performance in EGs has been shown to improve after the ratification of the KP. This result is in line with the finding in Costantini and Crespi (2008). Moreover, it also supports the previous findings about the effect of the Kyoto Protocol on innovation and further the Porter hypothesis.[3]

Second, the paper applies the newly developed methodology, the GSC, in the gravity model context to estimate the treatment effect on trade. As previously discussed, the well-known approach in investigating the trade effect in the international trade literature is to use either the gravity model with fixed-effects or matching-DID (as in Aichele and Felbermayr (2013b)). Compared to the DID and the synthetic control approach, the GSC has two major advantages. First, based on the concept of the original synthetic control method (Abadie et al., 2010, 2015), the GSC also constructs the counterfactual of the treated countries from the untreated ones so that the treated and synthetic countries have similar outcomes in the pre-treatment periods. In this way, the synthetic control approach can overcome the difficulty in ensuring the validity of the "parallel assumption". Second, the GSC integrates the synthetic control method and the interactive fixed effect model by Bai (2009) to synthesize the counterfactual of the treated trading pairs. This allows the method to analyze multiple treated units simultaneously instead of one-by-one unit analysis and provides classical standard errors for statistical significance inference.[4]

My results have important policy implications. Ever since its adoption, the KP has been a controversial topic. My results indicate that the KP could have a pro-green trade effect by improving the export performance of the committed countries on EG production. Therefore, along with findings of the effectiveness of the KP Grunewald and Martinez-Zarzoso (2016); Maamoun (2019), they have implications regarding consideration for the participation

[3]The stringency of environmental policy could encourage innovation and even increased competitiveness, according to Porter and van der Linde (1995). The "weak" version of the Porter hypothesis emphasizes on the impact of the regulatory stringency on innovation while the "strong" version states that it can eventually lead to more competitiveness (Ambec et al., 2013)

[4]The synthetic method relies on the placebo tests to gauge the uncertainty of the estimated treatment effect. Detailed comparison of the two approaches can be found in Section 4.

of more countries such as China and India as well as potentially stronger commitments. Furthermore, this provides hope to the future of international cooperation regarding the environmental issues, such as the 2015 Paris Agreement.

The rest of this paper is laid out as follows. Section 2 gives a brief review of the literature. Section 3 provides background information on the Kyoto Protocol. Section 4 presents the framework and methodology, followed by the data description in Section 5. Section 6 discusses the results, along with robustness checks; and Section ?? concludes.

2 Literature review

In the debate about the relationship between environmental regulation and competitiveness, findings from Aichele and Felbermayr (2012, 2013b, 2015) suggest that the case of KP appears to support the pollution haven hypothesis, which posits that high environmental standards drive the re-allocation of pollution-intensive industries to countries with less stringent regulations. Conversely, little evidence from the KP has been found for the Porter hypothesis so far. The Porter hypothesis, which is an opposing view to the pollution haven hypothesis, states that tightening the environmental regulation could lead to innovation, and even increased competitiveness (Porter and van der Linde, 1995). In terms of trade, it could imply the improvement of export performance of environmental-friendly products.

However, there are a few studies on the environmentally friendly products in the existing literature. Costantini and Crespi (2008); Miyamoto and Takeuchi (2018) are the two closely related research to this paper. Focusing on the energy technology sector and 20 OECD members, Costantini and Crespi (2008) use gravity model and show that environmental regulation is a significant source of comparative advantages.[5] Specifically, they provide evidence that the stringency of environmental regulation drives the export of renewable energy technology using a number of proxies for the environmental regulation.[6] While the effect of the Kyoto Protocol is not directly considered in the research, the authors argue that they make implicit considerations regarding the role of the KP when studying the energy sectors as the Protocol provides an institutional framework favorable to technology diffusion.[7]

[5]The products in the analysis are from the two sub-categories of the Resources Management group of EGs: (1) Renewable energy plant and (2) Heat energy savings and management.

[6]The proxies are carbon dioxide emission, current environmental protection expenditures by both of the public and private sectors, the percentage of revenues from environmental taxes on total revenues, and the public investments on environmental protection.

[7]Costantini and Crespi (2008) argue that the carbon dioxide emission is a proxy variable that partially represents countries' efforts to respect Kyoto abatement targets. Yet the coefficient estimation shows no

Although Miyamoto and Takeuchi (2018) investigate the impact of technological development (proxied by the patent application counts) on the trade flow of solar and wind technology, they also control for environmental policies, which are the KP and feed-in-tariff and renewable portfolio standard variables. The results report a strong positive correlation between the Protocol and the trade in solar and wind technology. Unfortunately, since the KP serves as a control variable in this study, the estimation of this variable coefficient cannot be interpreted as causal.

My research also relates to the literature on the relationship between international environmental agreements (IEAs) and trade in manufacturing sectors. Aichele and Felbermayr (2013b); Kim (2016) are probably the two only studies that explore the impact of the Protocol on bilateral exports of manufacturing industries. Using the combination of the propensity score matching technique and a difference-in-difference design to control for the self-selection into the Protocol, Aichele and Felbermayr (2013b) estimate a negative effect of the Kyoto Protocol on the bilateral trade of manufacturing sectors.[8] Specifically, they find a 15 to 20 per cent reduction in bilateral export due to the Kyoto commitments. Similarly, by employing the gravity model and fixed-effects, Kim (2016) also reports supporting evidence for the negative effect of the Kyoto Protocol to G20 countries.

In addition, this negative impact is also documented in studies about other IEAs (Ederington et al., 2018; Besedeš et al., 2017). These two studies investigate all available IEAs and report that there is a decrease in the trade of manufacturing sectors due to the ratification of IEAs. However, Ederington et al. (2018) further shows that this effect is small and disappears in the long run. In fact, the decline in dirty-good exports has been compensated by an increase in exports of cleaner industries within the member countries. These studies suggest consistency in the competitiveness loss effect of the IEAs in the manufacturing sectors. Yet the ambiguity of the impact persistence indicates that the IEAs in general and the Kyoto Protocol in particular might not necessarily lead to an overall negative effect on competitiveness.

3 Background

3.1 The Kyoto Protocol

The Kyoto Protocol was adopted in 1997 as a commitment to reduce GHG emissions and an attempt to slow down global warming as well as climate change. With the ratification of

statistical significance.

[8] In this study, they choose the unit of the analysis as an exporter–importer pair, which makes it easier and more credible to find matched unit.

Russia and Canada in 2004, the KP entered into force in 2005. Although there are currently 192 parties to the Protocol, only a group of countries listed in the Annex B of the Protocol is set to legally binding targets.[9] According to Article 3, these countries agreed to reduce their GHG emission to at least 5% below their 1990 levels in the first commitment period (2008–2012).[10] [11] On 21 December 2012, the Doha Amendment to the KP was adopted. The Amendment requires at least 144 instruments of acceptance for the entry into force, yet currently only 132 Parties have accepted it.[12] This results in the ambiguity of the validity of the KP beyond 2012 as well as the Doha Amendment.

Like other IEAs, the KP has received lots of criticism from experts due to the free-rider issues since its adoption. Specifically, the legally binding targets are applied to a limited number of nations while other major polluting countries such as China and India are excluded. Besides, the term "legally binding" is also ambiguous. Article 18 of the KP briefly mentions that consequences for any case of non-compliance shall be discussed and determined by the Parties, and "shall be adopted by means of an amendment to this Protocol" (United Nations, 1998). Thus, no punishment is clearly stated. In terms of competitiveness, the Kyoto commitments mean increased environmental policy stringency, which is expected to lead to a comparative disadvantage of pollution-intensive industries in these Annex B countries.

3.2 Industry of Environmental Goods

Facing the deteriorating environmental issues, the Organization for Economic and Co-operation Development (OECD)/Eurostat Informal Working Group, in its meeting in 1995, identified a group of products and services that can provide promising solutions. They are named "environmental goods", which consist of "activities which produce goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste noise and eco-systems" (OECD, 1999).

The Working Group divides EGs into three categories: Pollution Management, Cleaner Technologies and Products, and Resource Management (OECD, 1999). Of all three groups, the Pollution Management group accounts for the majority of EGs. Products in Pollution Management group are categorized into six sub-groups with a target to a pollution type: air pollution control, wastewater management, solid waste management, remediation and

[9] Details of the emission limitation or reduction commitment can be found at https://unfccc.int/kyoto_protocol

[10] See https://unfccc.int/kyoto-protocol-html-version.

[11] From now, the terms "Annex B countries" and "Kyoto countries" are used interchangeably to indicate countries that have commitments in the KP.

[12] See https://unfccc.int/process/the-kyoto-protocol/the-doha-amendment

cleanup of soil and water, noise and vibration abatement, and monitoring, analysis & assessment. While the products in the Pollution Management group aim to solve current pollution issues and damage in many environmental dimensions (e.g., water, air, noise), products in the two remaining groups focus on limiting and preventing emission via clean technology and energy as well as ensure natural resource sustainability.

Although the definition given by OECD is well-known, there are also other definitions and lists of EGs proposed by other organizations (Sugathan, 2013). In fact, classification and definition of EGs is not universally agreed. In this analysis, I use a combination of the OECD and APEC Early Voluntary Sector Liberalization (EVSL) initiative lists. However, I restrict my attention to only products in the Air Pollution Control (sub-category of the Pollution Management group) and the Renewable Energy Plant (sub-category of the Resource Management group) as they provide direct solution to the air pollution and global warming issue.

4 Empirical strategy

4.1 Framework

To evaluate the effect of the KP on trade in environmental goods, I follow Aichele and Felbermayr (2013b) and choose the unit of analysis as an exporter-importer pair (denoted p, henceforth).[13] By considering the country pair unit, I can generate the model to similar frameworks in causal inference as noted in Xu (2017). The functional form is written as

$$Y_{pt} = \alpha_0 + \alpha_{pt} Kyoto_{pt} + \beta x'_{pt} + \lambda'_p f_t + \varepsilon_{pt} \tag{1}$$

where Y_{pt} denotes the bilateral trade value of an exporter-importer pair p in year t; $Kyoto_{pt}$ is a dummy variable taking a value of one if the exporter of a country pair p has a Kyoto commitment in year t and zero otherwise; x_{pt} is a (k x 1) vector of observed covariates, including exporter's and importer's GDP and other bilateral gravity variables (i.e., regional trade agreement membership, common currency membership), β is a (k x 1) vector of parameters; α_{pt} is the heterogeneous treatment effect on country pair p in year t;f_t is a (r x 1) vector of unobserved common factors, λ_p is a (r x 1) vector of unknown factor

[13]As argued by Aichele and Felbermayr (2013b), finding a control for a country pair is more feasible and credible than for a country (e.g., it is hard to find a comparable unit with US). Even though in this case, I construct the counterfactual for the treated unit, the construction relies on the control group, which contains mostly less-developed countries. Therefore, using the country pair as the analysis unit is also more appropriate.

loadings[14], and ε_{pt} represents unobserved idiosyncratic shocks for pair p in year t.

As argued by Almer and Winkler (2017), the treatment period of the KP is not very clear. Most countries ratified the Procotol during 2002–2003, but it did not enter in force until 2005.[15] However, according to the literature of the IEA, the ratification year can be considered as the treatment period as once countries ratify, they start making changes in their policies and implementation.[16] Therefore, I select the ratification years as treatment period.

According to the functional form, α_{pt} is the coefficient of interest, representing the treatment effect. Let $Y_{pt}(1)$ and $Y_{pt}(0)$ be the outcome for a country pair p in year t when $Kyoto_{pt} = 1$ or $Kyoto_{pt} = 0$, respectively. Therefore, the treatment effect on treated pair p in year t is expressed as[17]

$$\alpha_{pt} = Y_{pt}(1) - Y_{pt}(0), t > T_0 \qquad (2)$$

4.2 Generalized Synthetic Control

4.2.1 Description

To assess the impact of the Kyoto commitment on the bilateral trade in environmental good, I employ the generalized synthetic control method proposed by Xu (2017). This method is based on the idea of the synthetic control method, developed by Abadie et al. (2010, 2015) such that the treated counterfactuals are synthesized by using the pretreatment treated outcomes as benchmarks to select weights for control units and utilizing cross-sectional correlations between treated and control units. In addition, it also integrates the interactive fixed effects (IFE) model proposed by Bai (2009).

The generalized synthetic control method has a number of advantages over the popular DID and the synthetic control approach. First, similar to the synthetic control method, it overcomes the issue with "parallel trend" assumption of the DID identification, which could not be valid in many cases. By minimizing the difference between the treated and the synthetic counterfactutal in the pretreatment period, it makes the comparison between the treated and synthetic control units transparent. Second, this method allows the analysis on multiple treated units and multiple treatment time periods while the synthetic control method is applicable to only one by one treated unit. This is particularly useful when

[14] It is assumed that the factor component $\lambda'_p f_t = \lambda_{p1} f_{1t} + \lambda_{p2} f_{2t} + ... + \lambda_{pr} f_{rt}$ takes a linear and additive form

[15] Australia and Croatia ratified in 2007, so the enforcement year for these two countries is also 2007.

[16] Ratification is used as treatment period in the majority of the Kyoto studies, such as Grunewald and Martinez-Zarzoso (2016); Almer and Winkler (2017)

[17] T_0 is the treatment year

there are so many country pairs being analyzed and Australia and Croatia receive treatment later than other countries.[18] Third, it provides classical standard errors to infer statistical significance whereas the SCM relies on comparing the estimates with the placebo treatment effects.[19]

Of course, the GSC method also has three limitations that require researchers to be cautious when applying it. First, since it is a data-driven approach, it is advised that the method should be applied to data with at least ten pre-treatment periods and at least 40 control units. Otherwise, the treatment effect would be biased. In this exercise, this should not be an issue as the analysis period spans from 1990 to 2012 with treatment year of either 2002 or 2005. Furthermore, the number of control country pair is much larger than 40. Second, excessive extrapolation resulting from no common factor loadings between the treated and control units might provide misleading results. A solution to this issue is recommended to check the overlap of the estimated factor loadings of both treated and control units (Xu, 2017). Last but not least, the method cannot accommodate complex data generating processes, such as dynamic relationships between treatment, covariates and outcome, structural breaks and multiple times of treatment and variable treatment intensity. As can be seen in the framework, these issues do not exist. While there are different ratification years (2001 - 2004) among the Annex B countries, 2002 is the year in which majority ratifies the KP. In addition, there is not much difference between 2002 - 2004 or treatment intensity among countries. In conclusion, the GSC is a suitable method in this study.

4.2.2 Estimation strategy

As stated in Equation (2), the main issue of the treatment effect estimation is the counterfactual $Y_{pt}(0)$, which is not observed when the pair receives the treatment. Therefore, the core idea of the GSC is to estimate the counterfactual of the treated pairs. Below is a brief description of the counterfactual estimation.[20]

Assuming the number of country pairs is $N = N_{tr} + N_{co}$, where N_{tr} and N_{co} are the number of treated and control units, respectively. The outcome of a pair from the control group can be written as

$$Y_{pt} = X'_{pt}\beta + \lambda'_p f_t + \varepsilon_{pt}$$

[18] Aichele and Felbermayr (2013b) restrict their analysis period to 2007 and consider Australia as a "untreated" country.

[19] The placebo studies are conducted by assigning one unit in the control group as "treated" and analyze its effect with the remaining units in the control group. Theoretically, there should be no treatment effect found in these control units. Therefore, the treatment effect found in the actual "treated" unit are considered to be significant when it is larger than that of all control units

[20] Further details can be referred in Xu (2017)

Thus, the outcome of the counterfactual after the combination of all control pairs is

$$Y_{co} = X_{co}\beta + F\Lambda'_{co} + \varepsilon_{co}$$

where Y_{co} and ε_{co} are (T x N_{co}) matrices; X_{co} is a three dimensional matrix (T x N_{co} x k); Λ_{co} is a (N_{co} x r) matrix. There are two constraints required to identify β, F, Λ_{co}: all factors are normalized and they are orthogonal to each other.

The construction of the counterfactual $\hat{Y_{pt}}(0)$ contains three steps. The first step is the estimation of an IFE model using only the control group data and obtain $\hat{\beta}$, $\hat{F}$, $\hat{\Lambda_{co}}$:

$$(\hat{\beta}, \hat{F}, \hat{\Lambda_{co}}) = \text{argmin}_{\tilde{\beta}\tilde{F}\tilde{\Lambda_{co}}} \sum_{p \in C} (Y_p - X_p\tilde{\beta} - \tilde{F}\tilde{\lambda_p})'(Y_p - X_p\tilde{\beta} - \tilde{F}\tilde{\lambda_p})$$

s.t. $\tilde{F}'\tilde{F}/T = I_r$ and $\tilde{\Lambda_{co}}'\tilde{\Lambda_{co}} = \text{diagonal}$

In the second step, factor loadings for each treated unit are estimated by minimizing the mean squared error of the predicted treated outcome (MSPE) in pretreatment periods:

$$\hat{\lambda_p} = \text{argmin}_{\tilde{\lambda_p}}(Y_p^0 - X_p^0\hat{\beta} - \hat{F^0}\tilde{\lambda_p})'(Y_p^0 - X_p^0\hat{\beta} - \hat{F^0}\tilde{\lambda_p})$$

$$= (\hat{F^{0\prime}}\hat{F^0})^{-1}\hat{F^{0\prime}}(Y_p^0 - X_p^0\hat{\beta}), p \in \mathcal{T}$$

where $\hat{\beta}$ and $\hat{F^0}$ are from the first-step estimation and the superscripts "0"s represent the pretreatment periods; $\mathcal{T}$ denotes the set of units in the treatment group. The third step is to calculate treated counterfactuals based on $\hat{\beta}$, $\hat{F}$, $\hat{\lambda_p}$:

$$\hat{Y_{pt}^0} = x'_{pt}\hat{\beta} + \hat{\lambda_p}'\hat{f_t}$$

$$p \in \mathcal{T}, t > T_0$$

The ATT_t is hence estimated as $A\hat{T}T_t = \frac{1}{N_{tr}} \sum_{i \in \mathcal{T}} [Y_{pt}(1) - \hat{Y_{pt}}(0)]$ for $t > T_0$

5 Data

Bilateral EG trade data at the product level during the period 1990–2015 come from the UN Comtrade (2018) database.[21] However, the analysis period is restricted to 1990–2012. The first commitment period of the KP ended in 2012. After that, there is an Amendment, but it has not been valid yet and no one really knows whether the Kyoto Protocol is still effective. As a result, I choose 2012 as the ending year of the analysis period. As stated in the

[21] Trade value is expressed in current USD, so it is deflated using US Consumer Price Index

introduction, this study includes products in the Air Pollution Control, the Environmental Monitoring, Cleaner Technology, and the Renewable Energy sub-groups. Together they comprise 86 out of 173 6-digit HS EGs listed in both the OECD list and the APEC list. Information on the Annex B countries and their ratification years is available at Table A2.[22] Definition and data source of other variables is provided in Table A1.

Many country pairs have missing values for a number of periods in the original data. As discussed previously, the method works well with a minimum of 10 years in the pre-treatment period. Therefore, I restrict the dataset to country pairs with non-missing value for at least 20 years.[23] The final dataset consists of 136 exporters and 95 importers, representing 3,932 country pairs and a 23-year period from 1990 to 2012. Of all, 1,790 exporter-importer pairs commit to the KP, accounting for 45.5%. As briefly discussed in the Section 3, the Doha Amendment was adopted by the end of 2012. The Parties are then required to ratify this Amendment again. In addition, the number of Parties submitting their instrument of acceptance is below the requirement (at least 144) to date. Therefore these facts might affect the consistency of the treatment (i.e., the Kyoto commitments) due to unobserved factors. Since the methodology cannot accommodate complex DGPs, extending the sample period beyond 2012 might result in biased estimation.[24]

As previously discussed, there is a steady increase in world trade of EGs during early 2000s, which is the period that most countries ratify the Protocol (Figure 1). Therefore it is expected that there is correlation between the Kyoto commitment and trade in EGs. Moreover, there is a difference in the change in bilateral trade level between the exports from Annex B countries and those from non-Annex B ones. Summary statistics of all variables are presented in Table 1.

[Table 1 here]

[22]Source: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-a&chapter=27&clang=_en

[23]This restriction will help speed up the analysis as larger unbalanced panel will significantly slow down the process. In addition, any pairs with fewer than 10 period observations will be automatically dropped during the analysis.

[24]In the robustness check, I extend the analysis to 2015 as some might argue the Doha Amendment has not yet been effective. It is possible that the Doha Amendment has little effect on the original Kyoto commitments. While the data is now available until 2017, I again restrict the analysis till 2015 as the Paris Agreement was adopted in 2015. The Agreement could be regarded as a structural break, so the method cannot accommodate the DGP in this case.

6 Results and Discussion

6.1 Main results

Table 2 presents the baseline results. Column (1) includes basic gravity variables as covariates while column (2) includes additional variables such as per capita GDP of the exporter and importer, the energy intensity of the trading pairs[25], and dummies for EU membership and WTO membership of the trading pair. Additional variables are included to control endogeneity resulting from the voluntary selection into the KP or the non-random treatment. Countries with Kyoto commitments are chosen based on their previous industrialization, and could also strategically choose to ratify to boost the reputation of EGs quality or not ratify at all (e.g. the USA). In theory, endogeneity should influence the counterfactual, so using the synthetic counterfactual should control part of the issue (**?**). In addition, the unobservable confounders, capturing the inherent differences that potentially result from non-random treatment, could also alleviate the endogeneity. Nevertheless, to ensure the robustness of the results, I include additional covariates that could reflect the difference between the treated group and control group. These variables are chosen based on the arguments that could influence the self-selection into the KP as discussed in Aichele and Felbermayr (2013b).

However, the results of the two columns are very similar, so further analysis includes only the basic covariates. The cross validation scheme finds one unobservable factor.[26] According to Xu (2017), the unobservable factors found are usually not interpretable. However as the unobserved factor in this panel data represents the cross-section dependence, it exhibits the correlation among countries. Plot of the factor is displayed in Figure A1. Thus conditioning on the additive fixed-effects and unobservable factor, the results show that the Kyoto commitments result in a 29%–30% increase in the export of EGs compared with the scenario of "no-Kyoto".

[Table 2 here]

Figure 2a–3a present the plot of treated and counterfactual averages and the dynamics of the estimated ATT. For each figure, the x-axis represents the time relative to treatment (i.e., time is scaled to 0 at the time of treatment). The vertical line at time of 0 demonstrates the

[25]Similar to Aichele and Felbermayr (2013b), energy intensity of the pair is the difference between the energy intensity of the exporter and that of the importer

[26]As the exact number of factors to be included in the model is unknown, the cross validation procedure is designed to choose the number of factors before the causal effect estimation. Basically the procedure chooses the number of factors that minimizes the mean square prediction error (MSPE) from a given set of number (i.e., 0 to 5 in this case).

start of the treatment. As can be seen, the treated and counterfactual averages match quite well in the pre-treatment period and diverge once the treatment starts (i.e., countries ratify the KP). The estimated ATT plot exhibits a constant increase in export of EGs following the ratification of the Protocol. However, in the furthest period relative to the treatment, the ATT is estimated to be negative, yet statistically insignificant. The reason lies in the fact that Romania is the first country ratified the KP in 2001 while the ratification year for most of the remaining countries is 2002. As the method scales the ratification year as 0 for all countries, only Romania has the longest post-treatment period. Hence, Romania is the only treated country in the last period, which might result in exaggerating the estimation of the counterfactual average at this period.

[Figure 2–3 here]

To confirm my hypothesis, I exclude Romania from the treated group and find that the estimated average effect is slightly smaller (31%–32%). To better visualize this effect, considering the export of EGs from Germany to Argentina in 2004. The export value was recorded to be 47.2 million USD. In the absence of the Kyoto commitment, this number could only reach to 35.7 million USD. The plot of the treated and counterfactual averages (Figure 2b) and the estimated ATT (Figure 3b) look exactly the same those in Figure 2a–3a with the last period removed.

These results could be explained by the findings in Miyamoto and Takeuchi (2019). In particular, they report increased patent applications for renewable energy technology resulting from the KP. Therefore, the technological diffusion effect of the Protocol is probably the mechanism that leads to the comparative advantage in EG production. Furthermore, this finding provides supporting evidence for the Porter hypothesis. Not only does the increased stringency of environmental policies followed by the KP spur innovation, but also it increases competitiveness.

Besides, it is important to note the coefficient of the exporter's and importer's GDP. It is estimated that there is a larger export elasticity with respect to the exporter's GDP than with respect to the importer's GDP, which is contrary to what is usually observed in most of gravity trade studies. An explanation has been provided by Feenstra et al. (2001) with the case of trading differentiated goods, and this observation is termed as "home-market effect" (Krugman, 1980). As established in Feenstra et al. (2001), high demand of goods produced in the large country leading to more entry of firms as well as more product variety. Eventually, the product supply is greater than the demand in the larger country, so the exports of the differentiated goods exceed imports (i.e., positive net export).

In addition, the coefficient of free trade dummy is not statistically significant although it is positive. This study focuses on a group of products, and trade liberalization of EGs is still under negotiation[27]. Regarding the trade liberalization of EGs, APEC 2012 Vladivostok Declaration has been the most concrete international agreement on EG trade to date. However this agreement also applies to a small number of EGs. Therefore, a strong correlation between free trade agreement and trade of EGs is not observed.

6.2 Robustness check

To ensure the robustnesss of my results, I perform several sensitivity analysis. The results of all robustness checks are presented in Table 3.

[Table 3 here]

Treatment period—Although most countries have ratified the KP by 2003, it did not enter into force until 2005.[28] Several studies have chosen the enforcement year as the treatment period, such as Maamoun (2019). Therefore, in the first robustness check, I change the treatment period to the enforcement year: 2007 for Australia and Croatia and 2005 for all other countries. Despite the statistical significance, the ATT is reported to be 18.8% in column (1), which is smaller than the estimation in the main result.

Figure 4 exhibits the plots of treated and counterfactual average and estimated ATT. As can be seen, there is an increase in export even before the assigned treatment year. Therefore, by choosing the enforcement year as the treatment period, the estimated effect is much smaller than the baseline. This finding indicates that countries have already prepared actions right after their ratification. In fact, it is found in Miyamoto and Takeuchi (2019) that since the adoption of the Protocol (1997), innovation activity, indicated by the number of international patent application, have increased significantly. Therefore, it makes sense that by the time countries ratified they have already gained a comparative advantage in production of EGs and increased competitiveness in the export market.

[Figure 4 here]

Period extension to 2015—Even though after 2012, there is Doha Amendment of the KP, yet to date this amendment has not entered into force yet. Therefore, one can argue that the KP should still be valid. I extend my analysis period to 2015, and the estimated ATT (0.448) is larger than the baseline result. This is expected as it accounts for additional

[27] https://www.wto.org/english/tratop_e/envir_e/ega_e.htm

[28] Details of ratification year can be found in Table A2.

years. This indicates that the effect of the KP could persist after its first commitment period. However, this interpretation needs to be cautious as the confidence interval in the ATT plots, shown in Figure 5, is quite large when years beyond 2012 are considered.

[Figure 5 here]

Removal of trade to Kyoto countries—The analysis so far is conducted on the sample including export to both Kyoto and non-Kyoto countries. However, one can be concerned that the Protocol could affect import of Annex B countries, which bias the main results. Therefore, I restrict the sample to export to countries without Kyoto commitments only (i.e., only export from either Annex B or non-Annex B countries to non-Annex B countries). The estimated ATT is reported to be 0.320, which is slightly higher than the baseline results. This implies that the observed result above is not driven by the effect of Kyoto Protocol on the import of Annex B countries.

[Figure 6 here]

Canada as a treated country—Canada originally ratified the Protocol, but then decided to withdraw at the end of 2012.[29] As the analysis period in this study runs from 1990–2012, Canada can still be regarded as one of the Annex B countries.[30] Therefore, I now consider any trading pairs with Canada as an exporter as "treated" country. The result is reported in column (4) of Table 3. As can be seen, there is almost no difference in the estimated ATT (0.337) relative to the main results. Moreover, the plots, as demonstrated in Figure 7, are very similar to the baseline results. The results suggest the reported effect is not affected by Canada's membership status.

[Figure 7 here]

Sample period of 1992–2012—As it is known that there are a few countries retrospectively reporting the trade data using the 1992 Harmonized System before 1992, column (3) estimates the sample for 1992–2012. In the previous analysis, the trade value in the first pre-treatment period is very low, which affects the synthesis of the counterfactuals. Thus, dropping the years 1990 and 1991 results in larger estimation as shown in column (5) of Table 3. Despite larger value of estimated ATT (roughly 37.5%), it is generally not much different from the baseline finding.

[Figure 8 here]

[29] See https://unfccc.int/files/kyoto_protocol/compliance/enforcement_branch/application/pdf/cc-eb-25-2014-2_canada_withdrawal_from_kp.pdf

[30] Almer and Winkler (2017) use Canada as a treated country in their analysis of KP's effectiveness.

Exclusion of top exporters—The statistics show that USA and Germany are the top two exporters in the market of EGs. While both countries signed the agreement, USA never ratified so it is considered as "untreated". It is possible that both countries could affect the estimated effect. Therefore, I re-conduct the analysis excluding either USA or Germany as the exporter from the sample. The results are reported on column (6) and (7) of Table 3. The graphs of synthetic counterfactuals and ATT over time can be found in Figure A2–A3.

The estimated ATT in both analysis is quite similar to each other and the main result. This finding implies that the reported effect is not driven by the top exporters. Furthermore, this also suggests that the GSC method has performed a good job on developing the suitable counterfactuals with the adjusted control group.

7 Conclusion

With the increasing intensity of the global warming and climate change, a sustainable economic growth has been the main focus of many policy-makers. Hence, the concept of the IEAs or particularly the KP still sounds as a promising solution. However, whether it is worth doing so is again a controversial topic. While many studies have posit pessimistic views about the impact of Kyoto Protocol on the carbon leakage as well as competitiveness loss, this paper is the first one to provide evidence of its pro-green trade effect. Using the generalized synthetic control method, it shows that following the enforcement of the Protocol, countries with commitment increase their export of EGs by 31%–32%. The findings indicate the Kyoto commitment as a source of comparative advantage of these countries over EG production.

The results presented in this paper looks another spillover effect that is often ignored (i.e., innovation effect). Together with the findings about the effectiveness of the Kyoto Protocol, these results indicate that it is possible to be optimistic about the effort that the community has put on in the battle against carbon emission. Indeed, further steps including participation of more countries as well as extra commitment should be considered.

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Table 1: Summary Statistics

VARIABLES	N	mean	sd	min	max
Ln($TradeValue_{pt}$)	90,848	14.20	3.143	0.723	22.96
$Kyoto_{pt}$	90,848	0.214	0.410	0	1
Ln(GDP_{it})	90,848	26.48	1.760	19.18	30.44
Ln(GDP_{jt})	90,848	25.99	2.080	19.83	30.44
Ln($GDPC_{it}$)	90,848	9.542	1.284	5.087	11.43
Ln($GDPC_{jt}$)	90,848	9.246	1.411	5.208	11.43
FTA_{pt}	90,848	0.251	0.433	0	1
$Currency_{pt}$	90,848	0.0273	0.163	0	1
$ENERGY_{pt}$	90,848	-0.000219	4.354	-31.46	46.60
EU_{pt}	90,848	0.0646	0.246	0	1
WTO_{pt}	90,848	0.842	0.365	0	1

Notes. Author's calculation from UN Comtrade (2018)

Table 2: The effect of KP on trade in environmental goods

	Full sample		Romania excluded	
	(1)	(2)	(3)	(4)
ATT	0.297***	0.291***	0.320***	0.314***
	(0.068)	(0.065)	(0.065)	(0.069)
Ln(GDP_{it})	1.629***	1.995***	1.629***	1.995***
	(0.144)	(0.236)	(0.143)	(0.244)
Ln(GDP_{jt})	1.280***	1.135***	1.280***	1.135***
	(0.146)	(0.327)	(0.147)	(0.320)
Ln($GDPC_{it}$)		-0.324		-0.324
		(0.202)		(0.215)
Ln($GDPC_{jt}$)		0.055		0.055
		(0.363)		(0.351)
$Energy_{pt}$		0.027***		0.027***
		(0.012)		(0.012)
FTA_{pt}	0.076	0.064	0.076	0.064
	(0.044)	(0.047)	(0.043)	(0.046)
$Currency_{pt}$	1.034***	0.892***	1.034***	0.892***
	(0.194)	(0.209)	(0.190)	(0.220)
EU_{pt}		0.318*		0.318
		(0.191)		(0.200)
WTO_{pt}		0.173***		0.173***
		(0.056)		(0.054)
MSPE	0.782	0.781	0.761	0.760
No. treated	907	907	895	895
No. control	2,142	2,142	2,142	2,142
Unobserved factors	1	1	1	1

Notes. The period of analysis is 1990–2012. Standard errors, in parentheses, are based on parametric bootstraps of 1000 times. ***, **, * Significance at 1%, 5%, and 10%.

Table 3: Robustness check

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ATT	0.188***	0.448***	0.320***	0.337***	0.375***	0.310***	0.308***
	(0.041)	(0.076)	(0.100)	(0.069)	(0.069)	(0.072)	(0.071)
Ln(GDP_{it})	1.629***	1.747***	1.974***	1.597***	1.646***	1.514***	1.629***
	(0.141)	(0.121)	(0.178)	(0.142)	(0.156)	(0.147)	(0.141)
Ln(GDP_{jt})	1.280***	1.302***	1.258***	1.295***	1.319***	1.313***	1.280***
	(0.145)	(0.132)	(0.202)	(0.156)	(0.154)	(0.159)	(0.149)
FTA_{pt}	0.076	0.063	-0.105	0.071	0.061	0.069	0.076
	(0.047)	(0.042)	(0.064)	(0.048)	(0.049)	(0.046)	(0.048)
$Currency_{pt}$	1.034***	0.803***	-2.253	1.034***	1.023***	1.000***	1.034***
	(0.195)	(0.210)	(6.490)	(0.200)	(0.198)	(0.195)	(0.203)
MSPE	0.818	0.761	0.873	0.751	0.738	0.761	0.786
No. treated	1,619	895	568	937	852	895	853
No. control	2,142	2,142	1,231	2,058	2,142	2,049	2,142
Unobserved factors	1	1	1	1	1	1	1

Notes. Standard errors, in parentheses, are based on parametric bootstraps of 1000 times unless noted. ***, **, * Significance at 1%, 5%, and 10%.
(1) Treatment period: Enforcement year (2007 for Australia and Croatia; 2005 for all other countries)
(2) The sample period is 1990–2015
(3) Only trade to non-Kyoto countries are analyzed
(4) Canada is included in the treated group
(5) The sample period is 1992–2012
(6) The sample excludes USA as exporter
(7) The sample excludes DEU as exporter

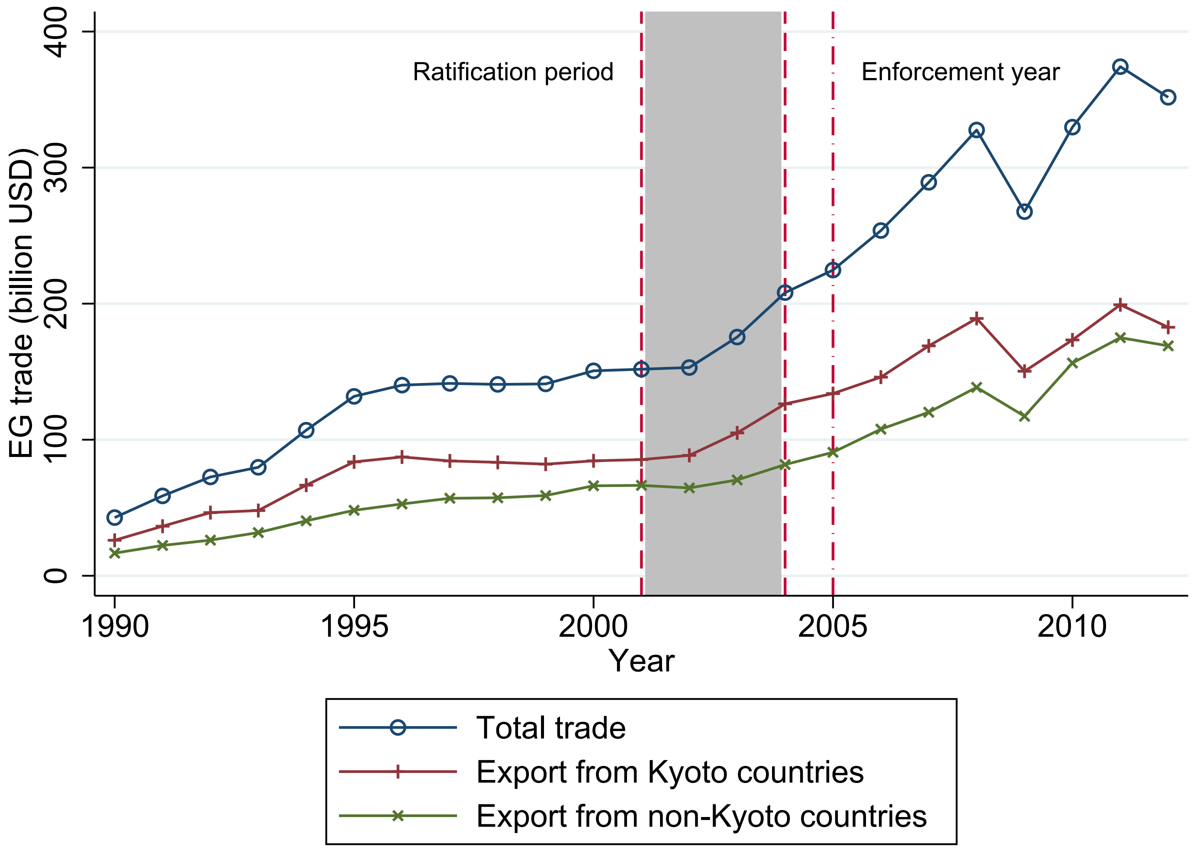
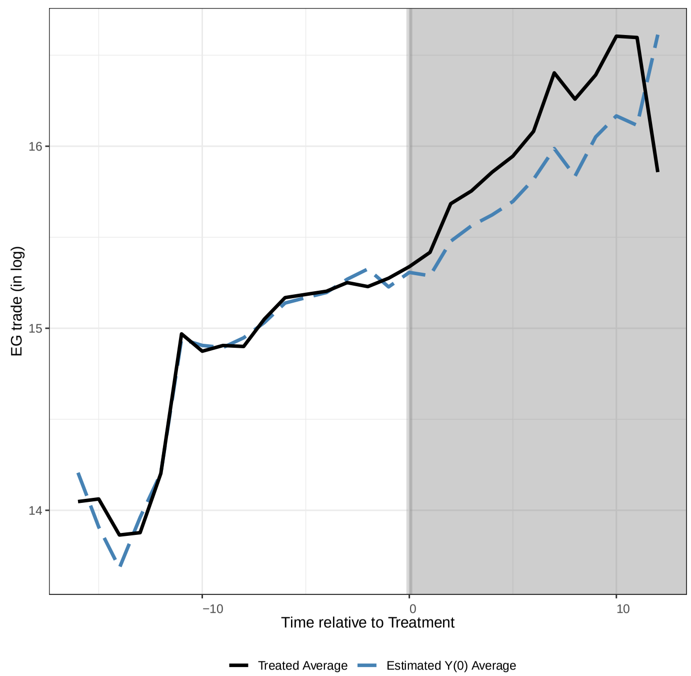
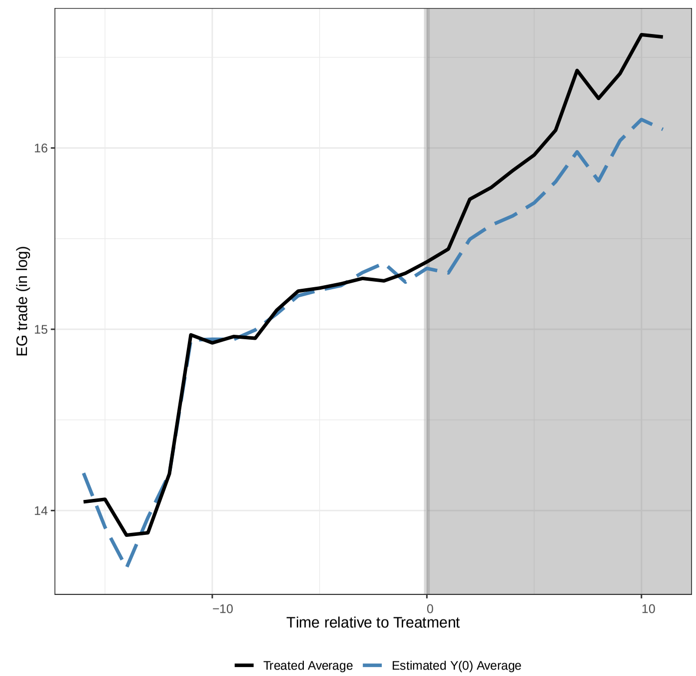


Figure 1: World trade of EGs during 1990–2012

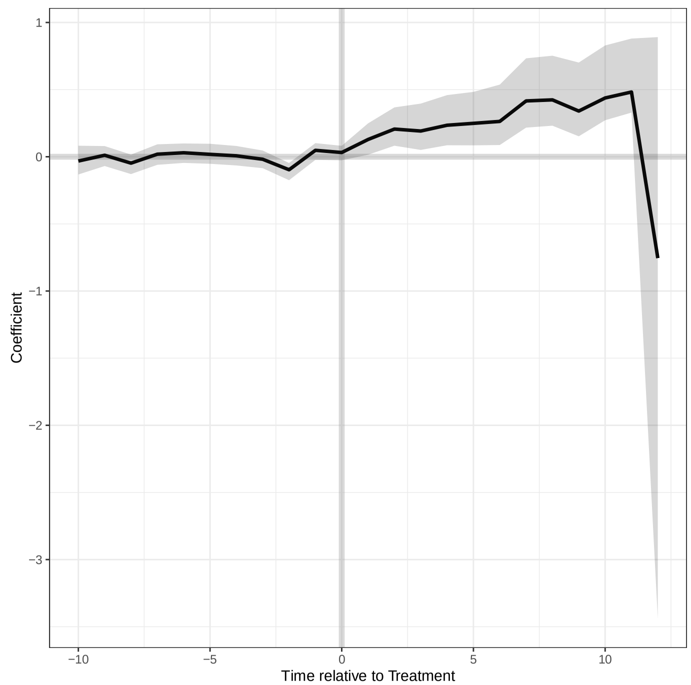


(a) Full sample

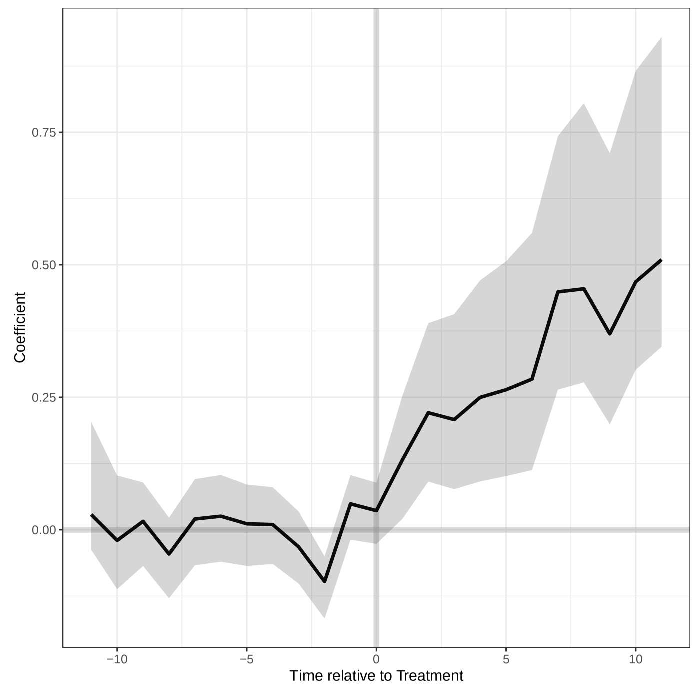


(b) Romania excluded

Figure 2: Main result: Treated and Counterfactual Average

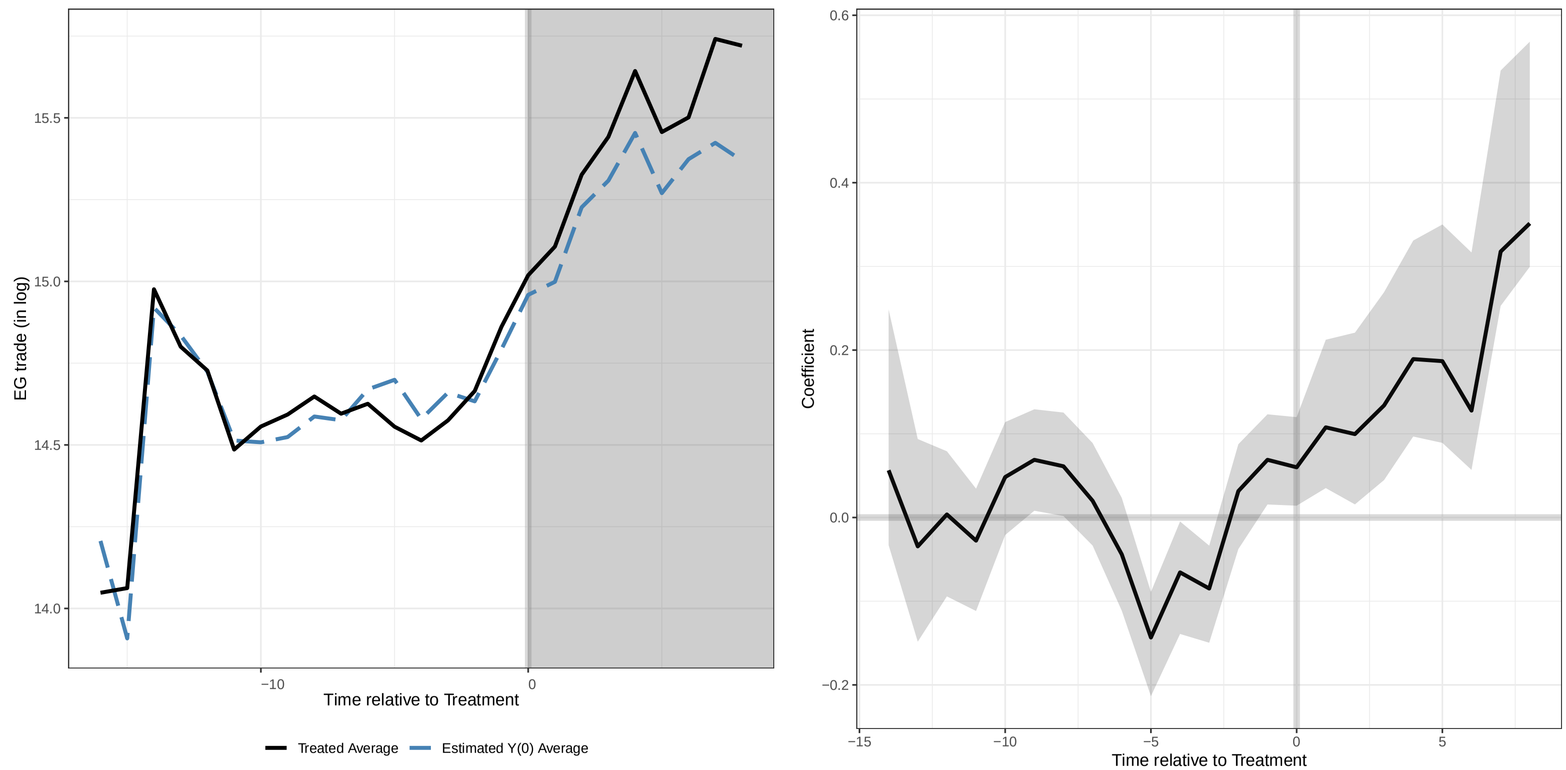


(a) Full sample



(b) Romania excluded

Figure 3: Main result: Estimated ATT

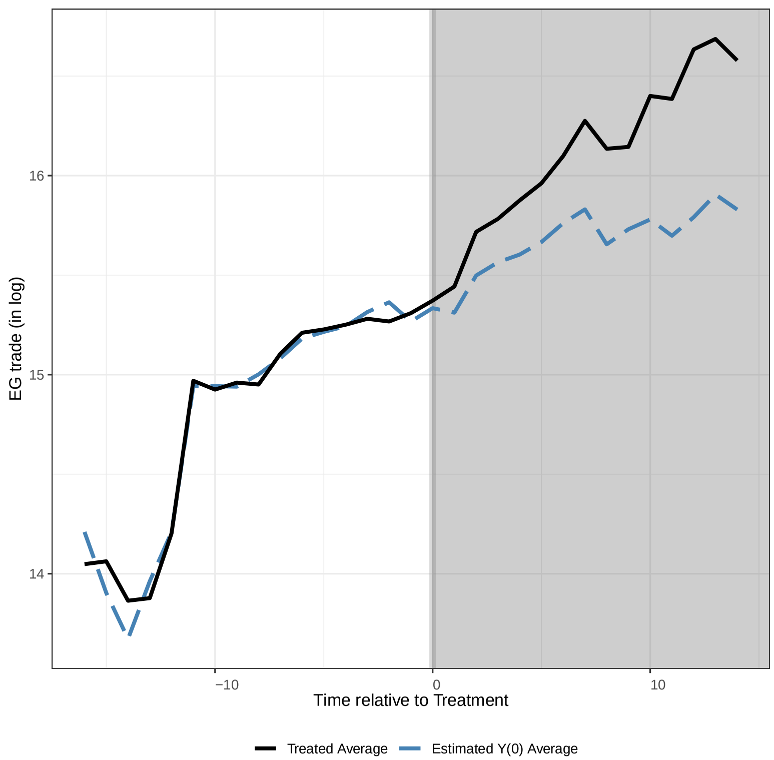


(a) Treated and Counterfactual Average

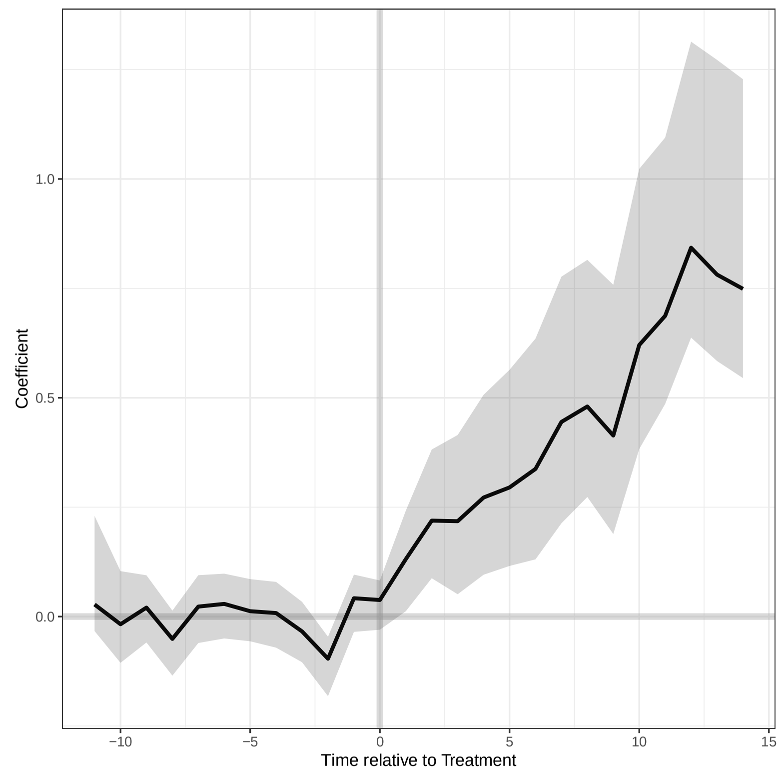
(b) Estimated ATT

Figure 4: Robustness check: Different treatment period

Notes. Treatment period is enforcement year (2005 for all countries except Australia and Croatia (2007))



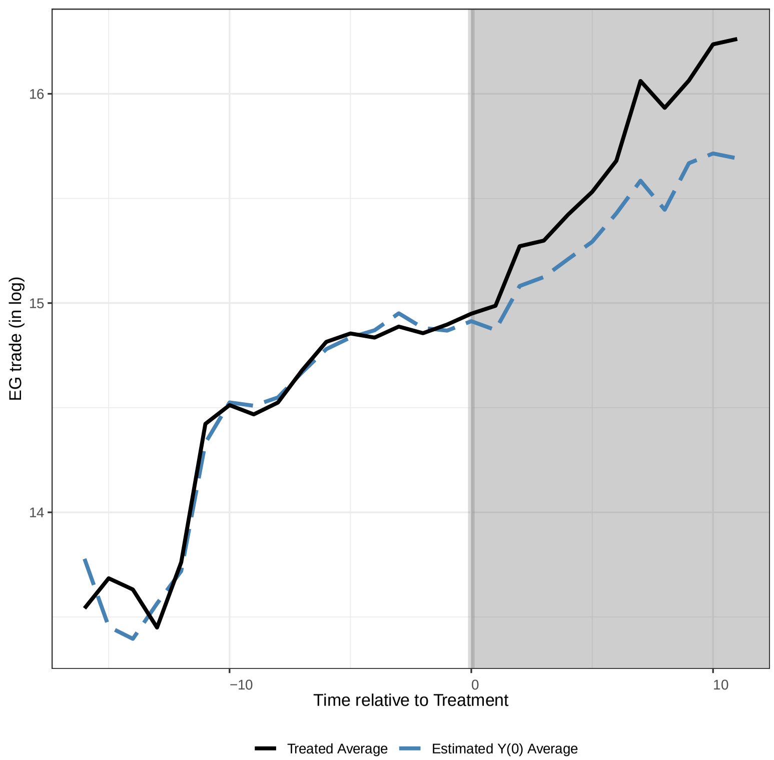
(a) Treated and Counterfactual Average



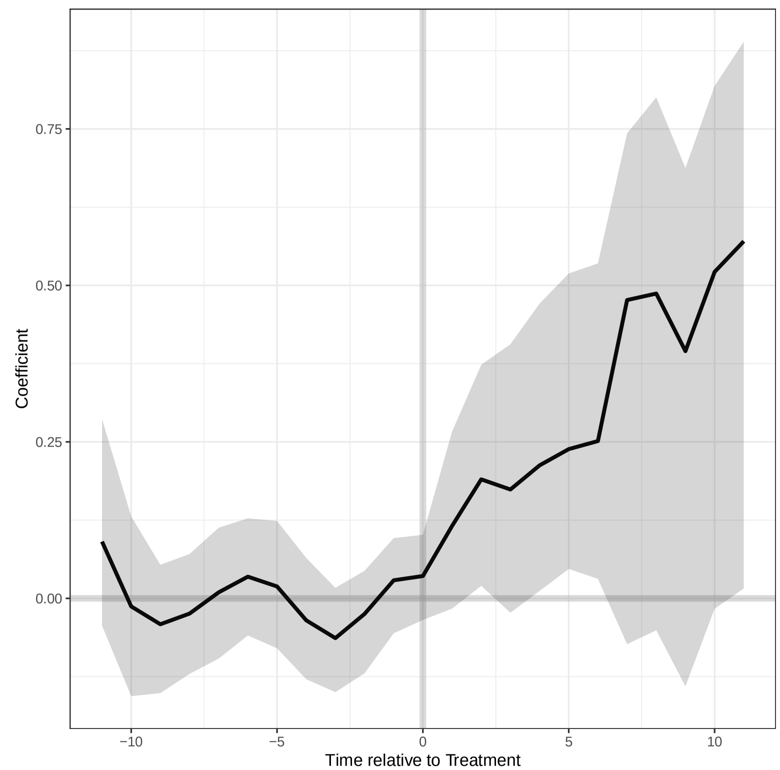
(b) Estimated ATT

Figure 5: Robustness check: Analysis extension to 2015

Notes. The analysis sample period spans 1992–2015. Treatment period is the ratification year.



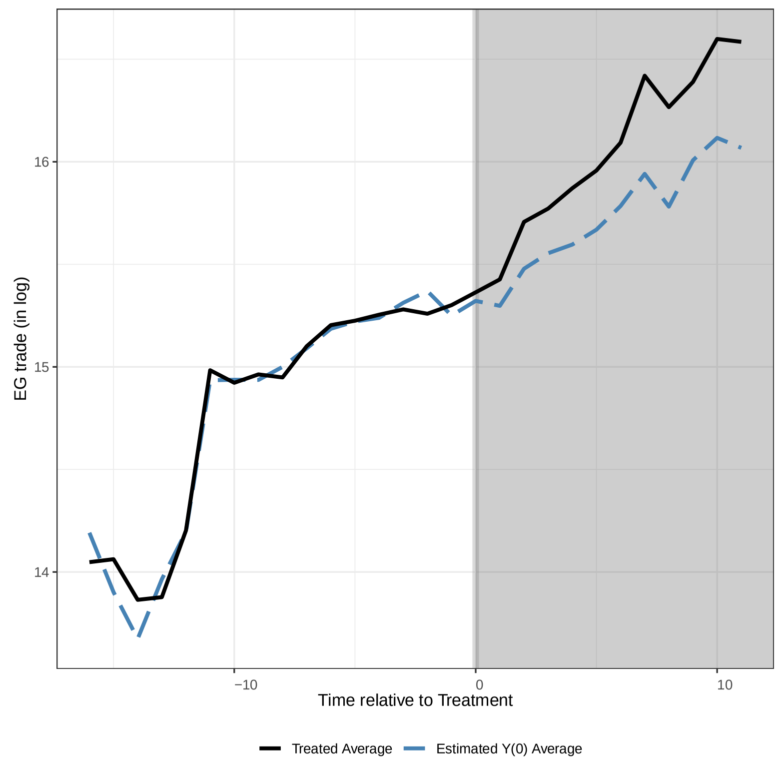
(a) Treated and Counterfactual Average



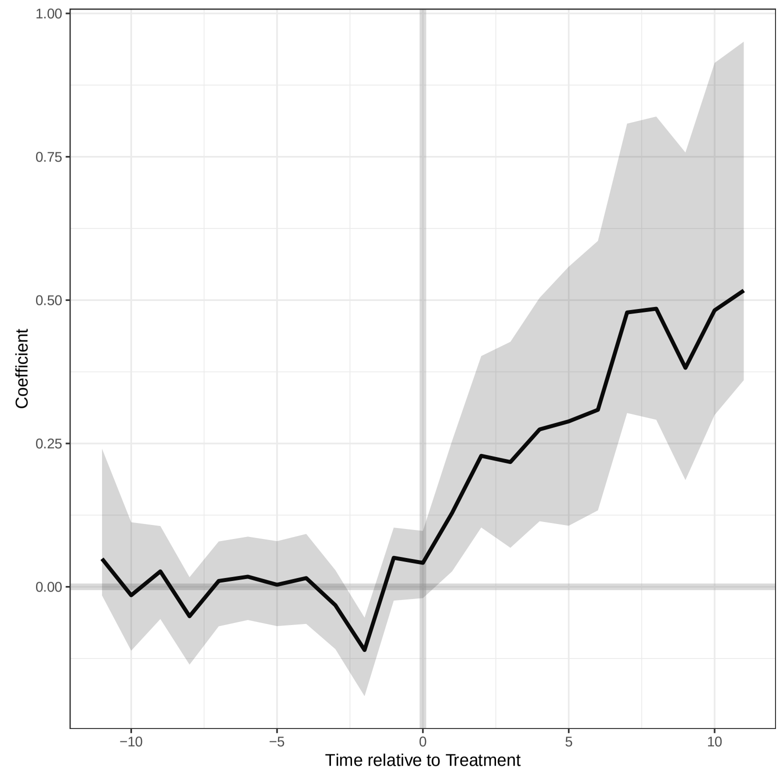
(b) Estimated ATT

Figure 6: Robustness check: Trade to non-Kyoto countries only

Notes. The analysis sample contains only bilateral trade to non-Kyoto countries only. Treatment period is the ratification year.



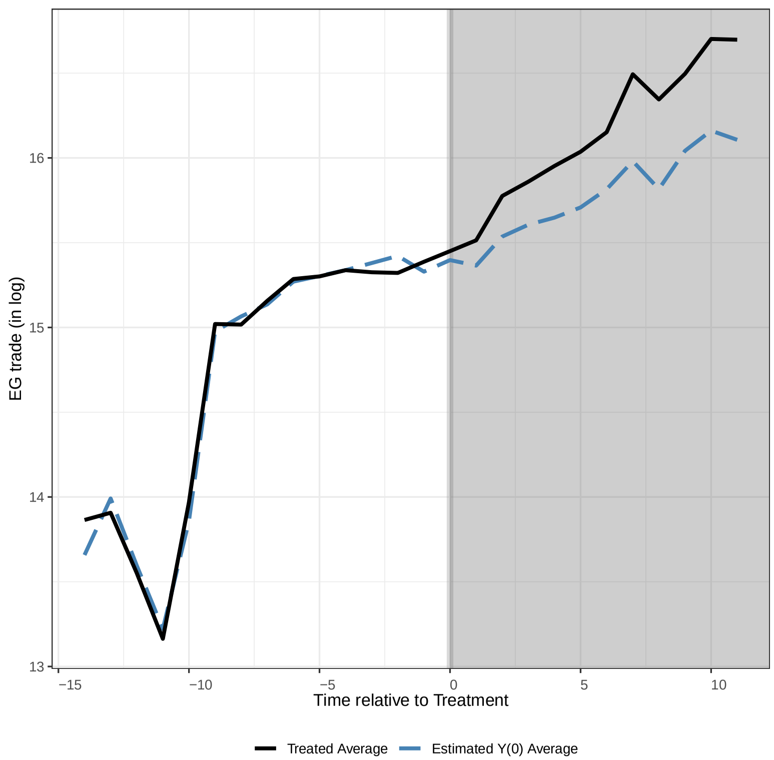
(a) Treated and Counterfactual Average



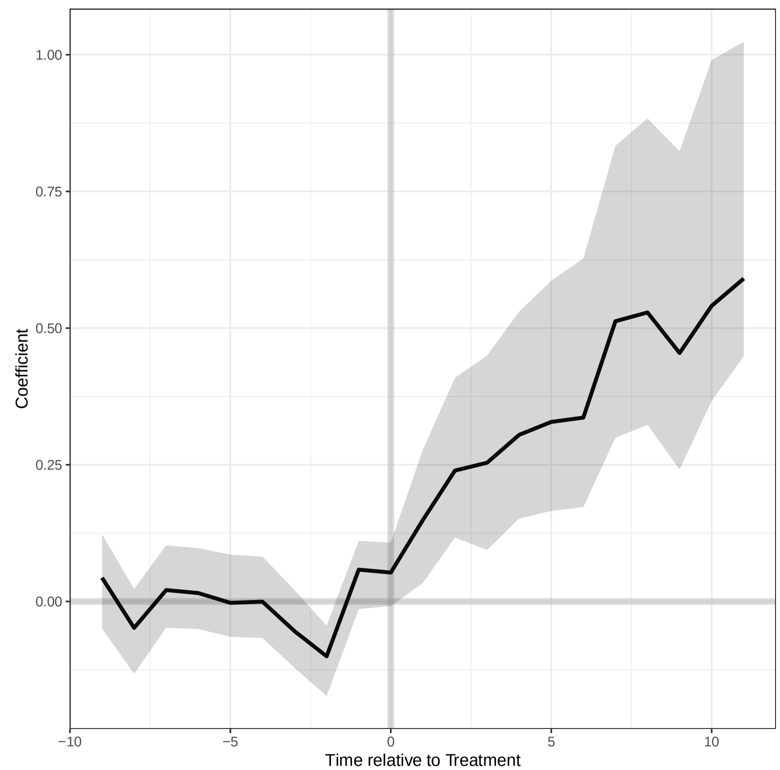
(b) Estimated ATT

Figure 7: Robustness check: Canada is in the treated group

Notes. The analysis sample considers Canada as a “treated” country. Treatment period is the ratification year.



(a) Treated and Counterfactual Average



(b) Estimated ATT

Figure 8: Robustness check: Sample restriction to period 1992–2012

Notes. The analysis sample period spans 1992–2012. Treatment period is the ratification year.

A - Additional Figures

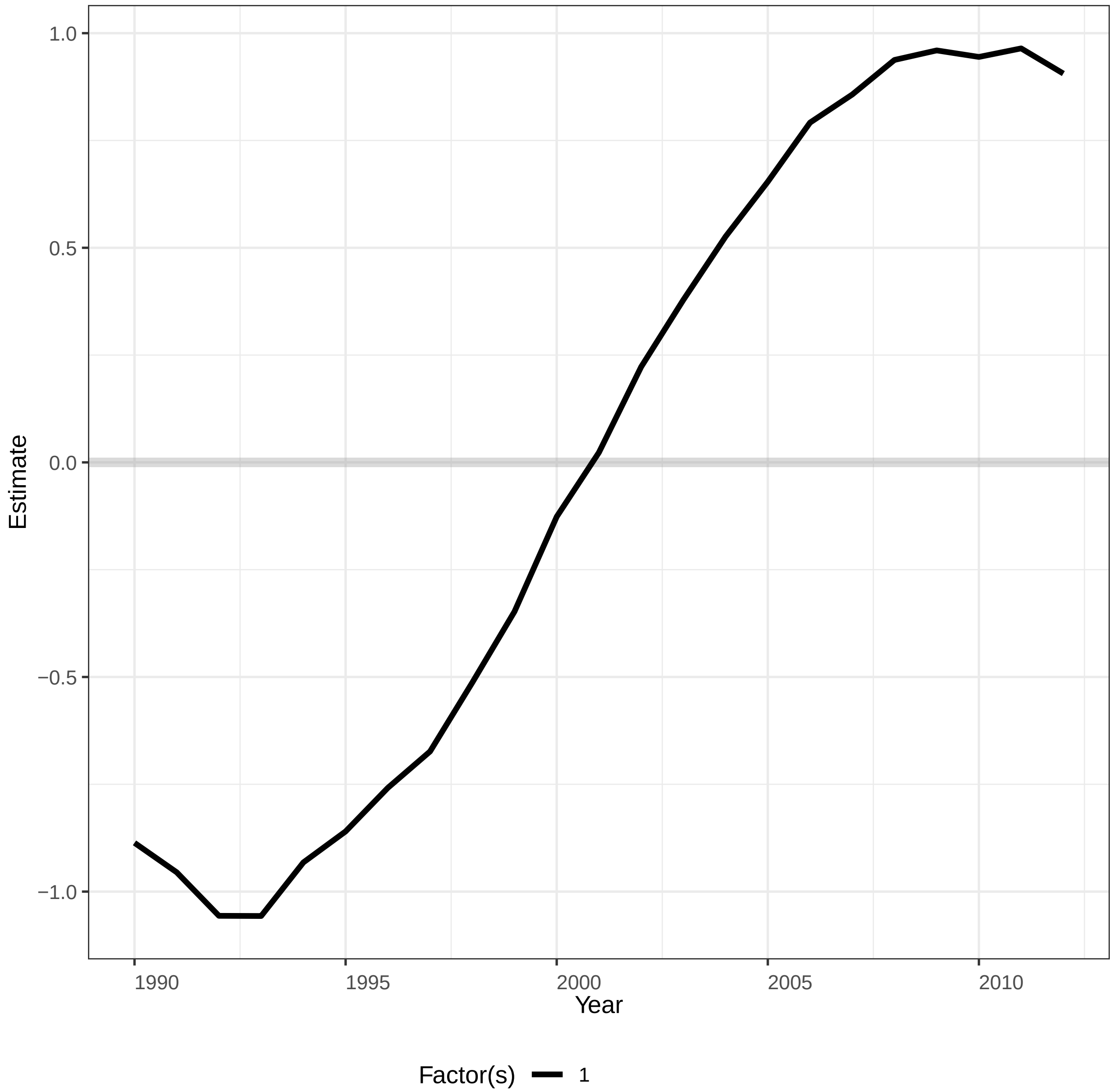
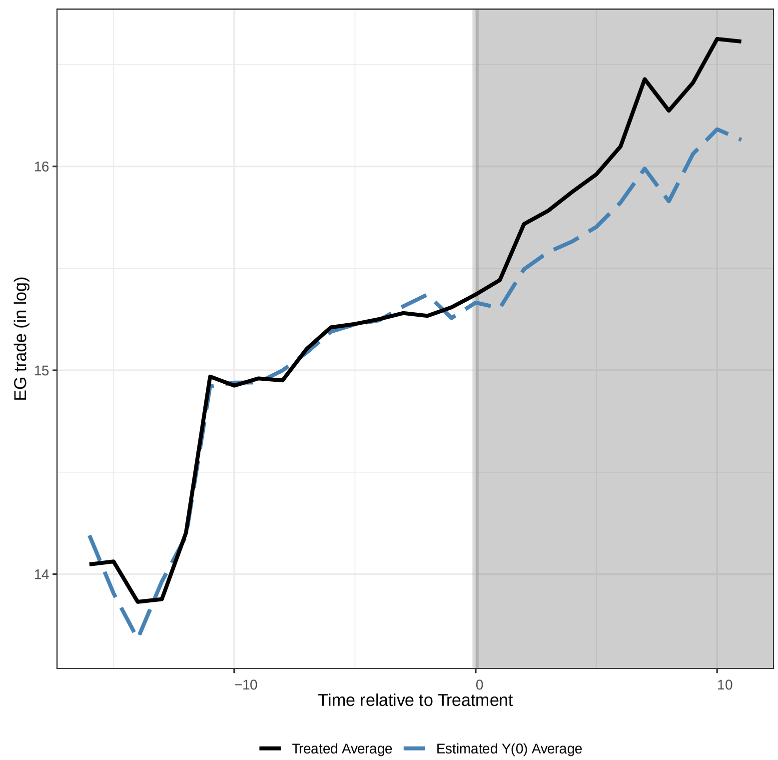
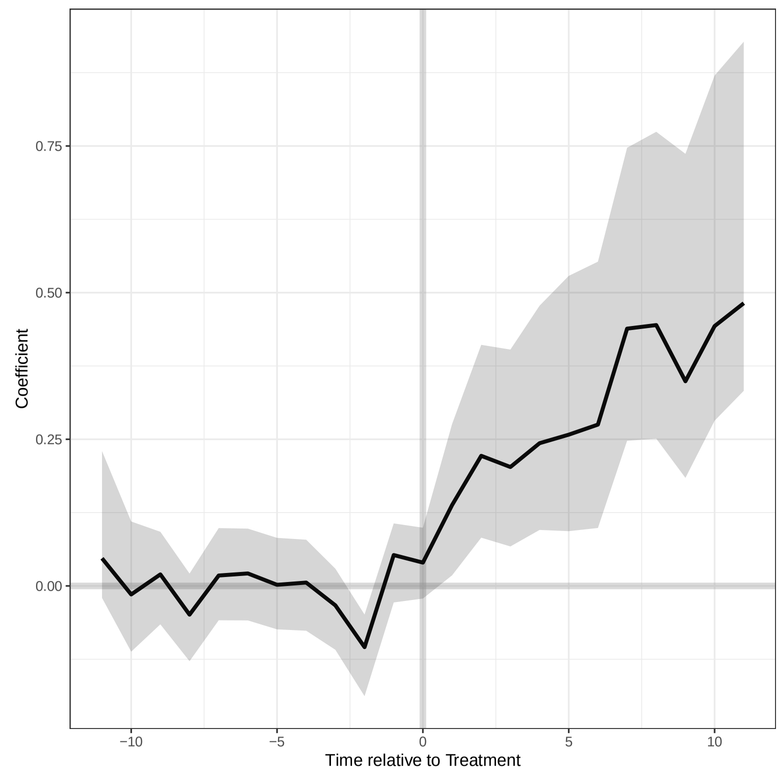


Figure A1: Factor loading



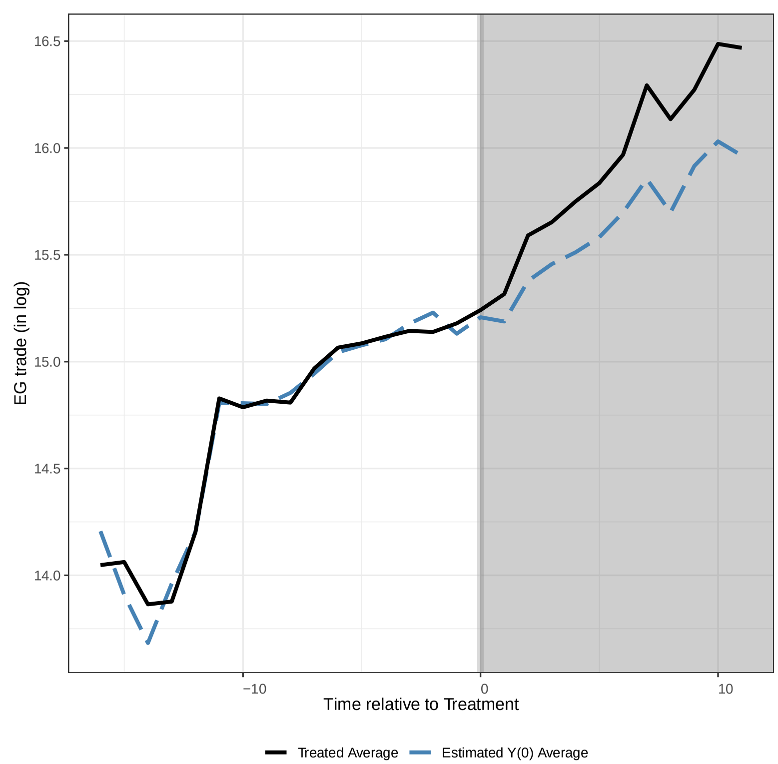
(a) Treated and Counterfactual Average



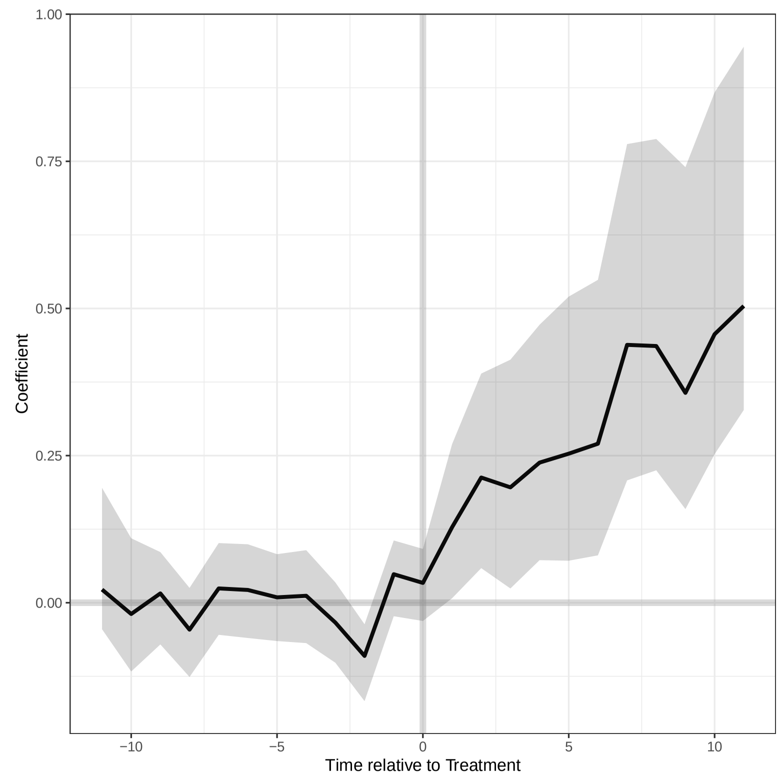
(b) Estimated ATT

Figure A2: Robustness check: Exclusion of USA as an exporter

Notes. USA as an exporter is dropped from the analysis sample. Treatment period is the ratification year.



(a) Treated and Counterfactual Average



(b) Estimated ATT

Figure A3: Robustness check: Exclusion of Germany as an exporter

Notes. Germany as an exporter is dropped from the analysis sample. Treatment period is the ratification year.

B - Additional Tables

Table A1: Definition of variables

Variable	Definition	Data source
$TradeValue_{pt}$	Value of EG trade of the exporter–importer pair p in year t	UN Comtrade (2018)
$Kyoto_{pt}$	A dummy on whether the exporter of the exporter–importer pair p ratified the KP in year t	
GDP_{it}	GDP of exporter i in year t	World Bank
GDP_{jt}	GDP of importer i in year t	World Bank
$GDPC_{it}$	GDP per capita of exporter i in year t	World Bank
$GDPC_{jt}$	GDP per capita of importer j in year t	World Bank
$ENERGY_{pt}$	Energy intensity of the exporter–importer pair p, defined as the difference between exporter i and importer j in year t	World Bank Indicator (2019)
FTA_{pt}	A dummy on whether the exporter–importer pair p is member of a free-trade agreement in year t	De Sousa's database
$Currency_{pt}$	A dummy on whether the exporter–importer pair p is member of a common currency area in year t	De Sousa's database
EU_{pt}	A dummy on whether the exporter–importer pair p is member of European Union (EU) in year t	CEPII database
WTO_{pt}	A dummy on whether the exporter–importer pair p is member of World Trade Organization (WTO) in year t	CEPII database

Notes. Energy intensity data is available at https://data.worldbank.org/indicator/EG.EGY.PRIM.PP.KD. The CEPII dataset can be found at http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=8. De Sousa's gravity data on common currency and FTA can be found at http://jdesousa.univ.free.fr/data.htm

Table A2: Annex B countries and ratification year

Australia - 2007	Austria - 2002	Belgium - 2002	Bulgaria - 2002
Czech Republic - 2001	Croatia - 2007	Denmark - 2002	Estonia - 2002
Finland - 2002	France - 2002	Germany - 2002	Greece - 2002
Hungary - 2002	Iceland - 2002	Ireland - 2002	Italy - 2002
Japan - 2002	Latvia - 2002	Lithuiana - 2003	Luxembourg - 2002
Netherlands - 2002	New Zealand - 2002	Norway - 2002	Poland - 2002
Portugal - 2002	Romania - 2001	Russia - 2004	Slovakia - 2002
Slovenia - 2002	Spain - 2002	Sweden - 2002	Switzerland - 2003
Ukraine - 2002	United Kingdom - 2002		

Notes. (1) Source: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-a&chapter=27&clang=_en. (2) Canada ratified in 2004 but withdrew from the Protocol in 2012, so it is considered as "untreated".

Table A3: List of countries in the analysis

Albania	Algeria	Angola*	Antigua and Barbuda*	Argentina
Armenia*	Australia	Austria	Azerbaijan	Bahamas*
Bahrain*	Bangladesh	Barbados*	Belarus*	Belgium
Belize	Bhutan*	Bolivia	Brazil	Brunei Darussalam*
Bulgaria	Burkina Faso	Burundi**	Cabo Verde*	Cameroon
Canada	Central African Republic**	Chile	China	China, Hong Kong
China, Macao	Colombia	Congo*	Costa Rica	Cuba*
Cyprus	Czechia	Cte d'Ivoire	Democratic Republic of the Congo*	Denmark
Dominica*	Dominican Republic*	Ecuador	Egypt	El Salvador
Equatorial Guinea*	Ethiopia	Fiji*	Finland	France
Gabon*	Gambia**	Georgia	Germany	Ghana*
Greece	Grenada*	Guatemala	Guinea*	Guyana
Honduras	India	Indonesia	Iran*	Ireland
Israel	Italy	Jamaica	Japan	Jordan
Kazakhstan*	Kenya*	Kyrgyzstan*	Lebanon*	Madagascar
Malawi	Malaysia	Mali*	Malta	Mauritania*
Mauritius	Mexico	Mongolia	Morocco	Mozambique*
Myanmar*	Nepal*	Netherlands	New Zealand	Nicaragua
Niger	Nigeria*	Norway	Oman	Pakistan*
Panama	Paraguay	Peru	Philippines	Poland
Portugal	Republic of Korea	Romania	Russian Federation	Saint Kitts and Nevis
Saint Lucia	Saint Vincent and the Grenadines	Saudi Arabia	Senegal	Seychelles
Sierra Leone*	Singapore	South Africa	Spain	Sri Lanka
Sudan*	Suriname*	Sweden	Switzerland	Tajikistan*
Thailand	The former Yugoslav Republic of Macedonia	Trinidad and Tobago	Tunisia	Turkey
Turkmenistan*	Uganda	Ukraine	United Arab Emirates*	United Kingdom
United Republic of Tanzania	United States of America	Uruguay	Uzbekistan*	Vanuatu*
Viet Nam*	Yemen*	Zambia	Zimbabwe*	

Notes. * denotes country appearing as exporter only in the sample. ** denotes country appearing as importer only in the sample