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Do PTAs with Environmental Provisions Reduce GHG Emissions? Distinguishing the Role of Climate-Related Provisions

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Abstract
This paper assesses the effectiveness of the environmental-related commitments contained in preferential trade agreements (PTAs) on climate change mitigation. A novel and detailed database identifying nearly 300 different types of environmental provisions from more than 680 PTAs since 1947 allows us to distinguish the PTAs with climate-related provisions (PTAwCP) from those with provisions related to other environmental issues. Using panel data covering 165 countries over the period 1995 to 2012, controlling for endogeneity issues, our main result shows that PTAwCP statistically reduce the emissions while the effect of PTAs with provisions related to other environmental issues remains negative but does not significantly affect GHG emissions. Our results suggest that it is rather the specific climate-related provisions in PTAwEP that reduce emissions (carbon dioxide, methane and nitrous oxide). Thus, to be effective in terms of mitigating climate change, PTAwEP should contain climate-related commitments.

Keywords Preferential trade agreements · Climate-related provisions · Environmental policy · Greenhouse gases · Global warming · Climate change

JEL Classification F13 · F18 · Q51 · Q54

1 Introduction

The impact of international trade on the environment has been the subject of numerous studies. Since the first analysis of the overall impact of trade on the environment (Grossman and Krueger 1991), the influence of trade on environmental quality has been investigated repeatedly (e.g., Antweiler et al. 2001; Cole and Elliot, 2003; Copeland and Taylor 2005; Frankel and Rose 2005; Grether et al. 2009; Levinson 2009; Managi et al. 2009;

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Lovely and Popp 2011; Brunel and Levinson 2016; Nemati et al. 2016). Another way to study the multiple and complex relationships between trade and the environment is to assess the effect of preferential trade agreements (PTAs) on pollutant emissions. Studies published so far suggest that this effect depends on whether environmental provisions are included in the agreement (e.g. Baghdadi et al. 2013; Zhou et al. 2017; and Martínez-Zarzoso and Oueslati, 2018).

The effects of trade liberalized by PTAs on environmental quality appear to occur through three mechanisms: (1) a scale effect, whereby increased economic activity leads *ceteris paribus* to increased emissions; (2) a composition effect, or changes in specialization and hence emission patterns; (3) a technological effect, leading to cleaner production processes through increased income and technology transfer.[1]

Since the Uruguay Round (concluded in the mid-1990s), the world economy has seen an increase in the number of PTAs. At 124 before 1995, the number of PTAs has increased rapidly, reaching 646 notifications at the end of 2016 (Sorgho 2018). The most common goal of PTAs is to reduce if not eliminate tariffs, quotas and other restrictions on goods and services traded between the partner nations. However, more recent PTAs include, in addition to wide-ranging economic and commercial rules, a full-length chapter devoted entirely to environmental protection with precise and enforceable obligations, in particular commitment to maintaining environmental standards, the right to enact environmental legislation, address climate change issues and implementation of multilateral environmental agreements (Morin et al. 2017).

How effective PTAs are at mitigating climate change continues to be debated. Some critics argue that PTAs ultimately weaken national environmental standards, that environmental provisions (EPs) are mere “fig leafs” included to sanitize the trade agreements in the eyes of the public and legislators (Berger et al. 2017) or even tools of “green protectionism” against cheaper products from developing countries. The proponents of PTAs insist on the potential of EPs for improving environmental protection, making the agreements more compatible with environmental and climate policies (Berger et al. 2017), playing a role in articulating new environmental norms (Morin et al. 2017), exporting environmental policies (Jinnah and Lindsay 2016), dealing with trade-related aspects of climate change mitigation such as border-tax adjustments on pollutant-emitting production processes, fossil fuel subsidies, and trade in carbon credits (Morin and Jinnah 2018). Through EPs, PTAs can help spread cleaner technologies that improve production standards and decrease greenhouse gas (GHG) emissions. The PTA with EPs is thus viewed as potentially contributing to climate-oriented governance (e.g., OECD 2007; Whalley 2011; Leal-Arcas 2013; Gehring et al. 2013; van Asselt 2017). By systematically including climate-related provisions in its PTAs, a government signals its position on climate change issues. Indeed, a positive relationship has been observed between international obligations on specific environmental issue areas and domestic environmental legislation in these same areas (see George and Yamaguchi 2018; Brandi et al. 2019). A government signing a PTA with EPs sends a signal to businesses operating in its jurisdiction that incorporation of international commitments on the environment or climate into domestic law may be imminent and that they should therefore act early to adopt environmentally friendly technologies and practices. This is one way that PTAs with EPs (PTAwEP) can lead to lower emissions of pollutants and hence improvement of the quality of the environment.

[1] For a recent discussion and a literature review on the subject, see Cherniwchan et al. (2017).

Empirical research on the contribution of PTAs to global climate-driven governance remains scant (Morin and Jinnah 2018). Indeed, to the best of our knowledge, few empirical studies have investigated the environmental effects of PTAs as opposed to the effect of trade openness.[2] The first empirical study of the impact of PTAs on the environment (Ghosh and Yamarik 2006) was followed by only three articles on the effects of PTAs with EPs on pollution levels or environmental outcomes (Baghdadi et al. 2013; Zhou et al. 2017; and Martínez-Zarzoso and Oueslati, 2018). We describe their findings in detail in Sect. 2 below.

The expected improvement in environmental quality through the reduction of emissions following the signing of PTAs is based on the presumption that EPs in the agreement will encourage trading partners to apply and enforce more stringent environmental regulations (Martínez-Zarzoso, 2018). However, the effects estimated in previous studies are averages for all types of agreements, which may include very different areas, for example biodiversity, desertification, hazardous waste, forestry, GHG emissions, or ozone depletion, while others only mention the environment in the investment chapters (see OECD 2007). This raises the question of whether all EPs or only those with climate-related provisions (CPs) have an impact on GHG emissions. The intention of CPs is clearly to address climate change by mitigating GHG emissions. Since details on PTA provisions are difficult to obtain, distinguishing the specific role of climate-related provisions from the overall impact of PTAs with EPs in mitigating GHG emissions has not been attempted until now. This is the main contribution of the present article.

A novel and detailed database ("TRade and ENvironment Database" – TREND)[3] identifying nearly 300 different types of environmental provisions from more than 680 PTAs since 1947 allows us to establish per country and per year the number of signed PTAs with EPs containing climate-related provisions. We distinguish two types of agreement: (i) those with climate-related provisions, and (ii) those with provisions related to other environmental issues. Making this distinction allows us to assess whether there is a causal relationship between climate-related commitments included in PTAs and GHG emissions from the signatory countries.

Our main finding is that after controlling for scale, technological and composition effects and considering income, trade and PTA endogeneity, PTAs with climate-related provisions (PTAwCP) are statistically associated with reductions in per capita GHG emissions, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Furthermore, it is specifically the CPs included in the PTA that have a positive impact on environmental quality. This evidence suggests that to be effective in terms of climate change mitigation, the environmental provisions negotiated in PTAs should contain specific climate-related commitments.

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[2] Other articles (e.g., Yu et al. 2011; Stern 2007; Logsdon and Husted 2000; Grossman and Krueger 1991) focus on the environmental effects (e.g., energy consumption) of a specific trade agreement (e.g., the North American Free Trade Agreement—NAFTA) at the national level (e.g., United States or Mexico).

[3] TREND, created and managed within a Canada Research Chair in International Political Economy at Laval University in Canada, is a free access database. Since 2018, the complete dataset has been available here and a dyadic version is now available here. For more information on TREND, see Morin, Dür and Lechner (2018). Moreover, in collaboration with the German Development Institute (DIE), an online analytical tool has been created to allow users to explore the TREND database: www.TRENDanalytics.info. For more information on the DESTA database and access to its database: https://www.designoftradeagreements.org/.

The rest of this article is structured as follows: In Sect. 2, we review the literature on the relationship between PTAs and environmental quality. The heterogeneous nature of environmental provisions contained in PTAs is discussed in Sect. 3. Our analytical framework and data are presented in Sect. 4, followed by the estimation strategy and results in Sect. 5. Our concluding remarks appear in Sect. 6.

2 Literature Review

In this section, we summarize the literature on the effect of PTAs on the environment. The principal findings of these studies along with their data and empirical strategies are summarized in Table 1.

Estimations of environmental degradation that could result from PTAs have been proposed based on an empirical model that considers trade and economic growth and distinguishes direct and indirect effects on the environment (Ghosh and Yamarik 2006). The effect of increasing trade and growth is considered indirect. Based on measurements of atmospheric suspended particulate matter, SO_2, NO_2 and CO_2, deforestation, energy depletion and water pollution associated with resource consumption as proxies of environmental degradation and using OLS in combination with the instrumented variable technique to estimate the endogeneity of GDP and trade for 151 countries in 1995, PTAs appear to have an indirect effect but no direct effect on pollution. However, the cross-sectional data used in this study do not allow consideration of dynamics or controls for unobserved country-specific and time-invariant factors. Nor do they allow a distinction between PTAs with or without EPs. This could explain the ambiguous results obtained.

Later studies (Baghdadi et al. 2013; Zhou et al. 2017; Martínez-Zarzoso and Oueslati, 2018) were built on the modelling strategy described above, first by treating trade, GDP growth and PTA membership as endogenous variables, and secondly by assuming that if a direct positive effect of PTAs on the environment does exist, it should be found empirically only for agreements that include specific environmental provisions in the main text or in environmental appendices. The empirical estimations in these articles also distinguished between PTAs with environmental provisions from those without such provisions. They showed that a direct positive effect on the environment does exist in the latter case.

Baghdadi et al. (2013) analyzed the impact of PTAs with and without EPs on CO_2 emissions. They focus on per capita GDP and trade endogeneity, and the PTA variable. To deal with endogeneity, instrumental variables were used. The sample covered 182 countries over the period of 1980 to 2008. They found that PTAs with EP reduce CO_2 emissions domestically.

In another comparison of PTAs with and without EPs (Zhou et al. 2017), PM2.5 concentrations were examined, which were arguably a better indicator of pollution than gross CO_2 emissions.[4] Covering 136 countries over a period of 10 years, this empirical analysis used the instrumental variables method and DiD with propensity score matching (PSM) in order to control for the potential selection bias of PTAs with EP. It was shown that PM2.5 concentrations increase where PTAs without environmental provisions are signed but decrease when such provisions are included.

[4] PM2.5 is defined as fine inhalable particles with diameters generally 2.5 μm or smaller.

Table 1 Summary of studies of the impact of PTAs on the environment

Authors	Variables studied	Data and source	Environmental indicators	Empirical strategy	Main results
Martínez-Zarzoso and Oueslati (2018)	Summed number of trading partners (*j*) that each country (*i*) has in its PTA PTAs with EPs and PTAs without EPs are distinguished and both are introduced together in the model	Cross section of countries (mainly 23 OECD + 6 BRIICS[a]) from 1999 to 2011 Extending to 173 countries over the period 1990–2011 PTAs from the WTO	Log of population-weighted of the following variables: Particulate matter with a diameter < 2.5 (PM2.5) Sulfur dioxide (SO_2) Nitrogen dioxide (NO_2) Carbon dioxide (CO_2) Nitrogen oxide (NO_x)	FE-GLS Difference GMM	PTAs with EPs significantly lower PM2.5, SO_2, NO_x and CO_2 PTAs without EPs have a negative (but insignificant) effect, or a significant positive effect on emissions In their sample, CO_2 emissions are reduced by 0.3% with PTAs with EPs
Zhou et al. (2017)	As a dummy: equal to 1 if country *i* has a PTA in effect in year t, otherwise 0 PTAs with and without EPs are distinguished	Panel data for 136 countries from 2001 to 2010 Information on PTAs from the WTO database	Particulate matter with a diameter < 2.5 (PM2.5)	PSM approach combined with DiD OLS with Instrumented variables	PTAs have a significant negative effect on PM2.5 PTAs with EPs significantly lower PM2.5
Baghdadi et al. (2013)	Summed number of trading partners (*j*) that each country (*i*) has in its PTA PTAs with EPs and PTAs without EPs are distinguished, but analysed separately	Cross-section of 182 countries over the period 1980 to 2008 PTA data from De Sousa (2012) and WTO website	Carbon dioxide (CO_2)	Propensity score (PS) matching approach is combined with DiD techniques	PTAs with EPs significantly reduce domestically produced CO_2 PTAs without EPs significantly increase CO_2
Ghosh and Yamarik (2006)	The current number of PTA signatories	Cross-sectional data for 162 countries in 1990 Only 17 PTAs are considered	Particulate matter (PM) Sulfur dioxide (SO_2) Nitrogen dioxide (NO_2) Carbon dioxide (CO_2) Deforestation, Energy depletion Water pollution	OLS estimation	No direct significant effect of PTAs on environment PTAs significantly increase environmental quality via trade and income

[a]Martínez-Zarzoso and Oueslati (2018) use the term “BRIICS” to refer to the following 6 countries: Brazil, Russia, India, Indonesia, China and South Africa

The effect of environmental provisions in PTAs on particulate concentrations in 173 countries from 1990 to 2011 has been analyzed using an instrumental approach to deal with the endogeneity of the variables (Martínez-Zarzoso and Oueslati, 2018). Based on a previous model (Baghdadi et al. 2013) with controls for national environmental regulations, it was again found that PTAs with environmental provisions were associated with lowering of PM2.5 concentrations and other emissions (SO_2, NO_x and CO_2), and as was found for CO_2 emissions (Baghdadi et al. 2013), PM2.5 concentrations tended to converge in the pairs of countries that were participating in a PTA with environmental provisions (PTA with EPs).

The summary in Table 1 allows us to compare the approaches adopted in the different studies and to see how the analyses evolved. The first article introduced the idea of the existence of an effect of PTAs on the environment. The next three articles improved the analysis by distinguishing the effects of agreements with and without environmental provisions. However, the types of EPs were not distinguished. In our analysis, we allow for the possibility that climate change provisions have their own specific effects.

3 Heterogeneity of PTAs with environmental provisions

In previous studies of the effect of PTAs on environmental quality, the EPs included in the agreements were very heterogeneous, some being very detailed whereas others described only general objectives. Such detail is provided systematically in the Trade & Environment Database (TREND). This database is based on the Design of Trade Agreements (DESTA) database: a PTA compilation used in numerous previous studies but which only specifies the presence or not of environmental provisions.

Following Morin and Jinnah (2018) who defined the specific PTA-provisions addressing climate change from TREND, we were able to identify PTAs with provisions related to climate change issues, those addressing other environmental issues, and PTAs without any environmental provision. The elements defining the climate-related provisions are described in the online appendices (see Appendix A).[5]

Examination of TREND reveals nearly 300 different types of environmental provisions contained in 730 PTAs from 1947 to 2018. Due to the limited availability of emissions data, we narrowed our study to the period 1995 to 2012.[6] Among the 630 PTAs signed up to 2012, 539 included at least one EP. In terms of emphasis, these EPs were grouped into eight categories: biodiversity, water, waste, fisheries, forest, dessert, ozone, and climate change, as found previously (Morin and Jinnah 2018). Among the 539 agreements, 335 (62%) contained at least one provision addressing the question of climate change.

As Fig. 1 shows, since 1970 the share of bilateral and regional PTAs negotiated with comprehensive environmental elements has increased. In 1970, more than 50 per cent of all PTAs contained EPs. By 2012, this had passed 85 per cent. Some included provisions

[5] The online Appendix A reports the list of terms related to climate change expressed in PTAs' provisions in TREND according to Morin and Jinnah (2018). We define a PTA with climate-related provisions (PTAwCP) from TREND, as a PTA containing at least one of these provisions. Thus, the online Appendix C reports a list of PTAwCP from TREND, entered into force between 1947 and 2012.

[6] For data on GHG emissions, we use the Emissions Database for Global Atmospheric Research (EDGAR), release EDGAR v4.3.2 (1970—2012) of March 2016: http://edgar.jrc.ec.europa.eu. [Accessed June 05, 2018].

addressing climate change. This type of provision was not common prior to 1990, appearing in about 18 per cent of the total number of PTAs then signed. By 2012, this share had reached about 55 per cent.

In this article, we analyze the impact of different types of PTA with EPs on putative climate change mitigation, based on reductions of GHG emissions including CO_2, CH_4 and N_2O, the emissions believed most responsible for global warming, a major element of climate change. This is the first article to focus explicitly on the climate-related provisions included in PTAs and hence to distinguish between these and environmental provisions other than climate-related.

Figure 2 shows the evolution of the average numbers of signed PTAs with environmental and climate-related provisions. The number of countries participating in agreements that include at least one climate change provision is clearly increasing, which presumably reflects increasing awareness of the climate change issue. Conspicuous jumps occurred in 1975 and 1994, the former due likely to the Generalized System of Preferences, adopted in 1968 under the auspices of the UNCTAD, which provided a formal system of exemption from the more general rules and resulted in the USA and other industrialized countries signing PTAs preferentially with developing nations (Sorgho and Tharakan 2019). The second jump may have been by the structural change of the multilateral trading system brought about by the creation of the World Trade Organization in 1995. Since 2008, nations participate on average in at least 15 PTAs with CPs, versus less than 5 in 1995.

Many PTAs address climate change issues explicitly with clauses more specific and restrictive than those found in multilateral environmental agreements. More than 50 agreements include innovative climate provisions more specific and enforceable than those proposed in the Kyoto Protocol or the Paris Agreement. As mentioned above, there is evidence of a positive and significant direct link between signing PTAs with many comprehensive EPs and introducing more environmental legislation nationally (see George and Yamaguchi 2018; Brandi et al. 2019).[7]

4 Analytical Framework and Data

4.1 Analytical framework

To estimate the potential impact of climate change commitments on the environment, we used the following empirical model:

$$\log\left(Em_{it}^{g}\right) = \begin{bmatrix} \alpha_0 + \alpha_1 \log\left(Em_{it-1}^{g}\right) + \alpha_2 \log\left(Open_{it}\right) + \alpha_3 \log\left(Popdens_{it}\right) \\ +\alpha_4 \log\left(GDPcap_{it}\right) + \alpha_5 Reg_{it}^{pta} + FE_t + FE_i + \varepsilon_{it} \end{bmatrix} \quad (1)$$

where Em_{it}^{g} denotes per capita emissions of each pollutant (g = CO_2, CH_4, or N_2O) from country i at period t. A dynamic model of the evolution of environmental quality is obtained using a first-order autoregressive process as given in (1). Since "…changes in explanatory variables, such as trade openness, at a specific point in time would also

[7] In principle, the relationship between environmental or climate-related provisions and national environmental legislation could be bidirectional. A country with stronger environmental protection is more likely to integrate EPs into its trade agreements. However, the empirical methodology adopted here allows us to control for this.

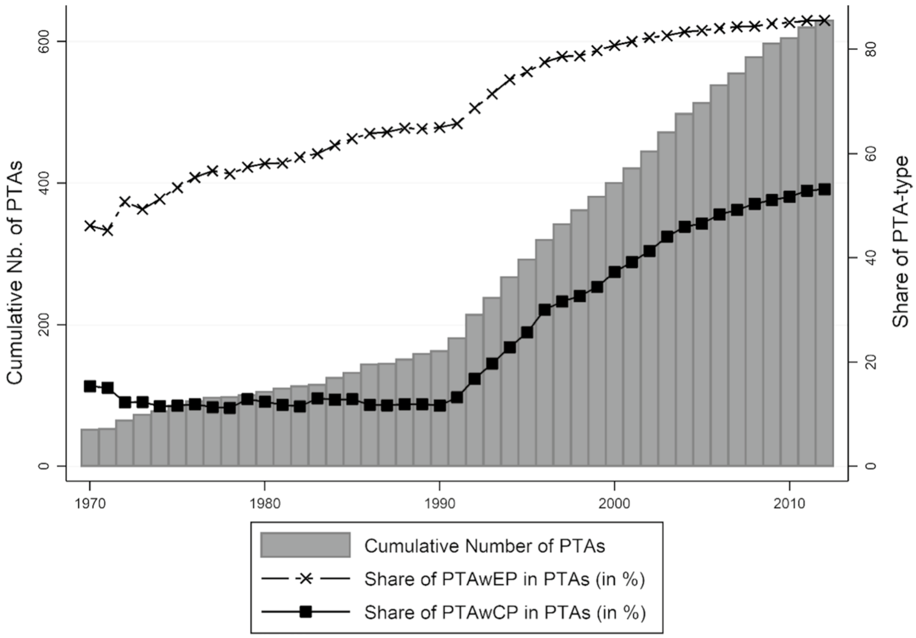

Fig. 1 Growth in the number of preferential trade agreements worldwide. *Source*: Authors, created with data from "TRade and ENvironment Database"—TREND. *Note*: PTAwEP means PTAs with environmental provisions; PTAwCP means PTAs with climate-related provisions. The term "cumulative PTAs" means the number of PTAs effective in year *t* (including existing agreements and agreements that became effective in year *t*)

influence emissions after the current period. This indicates that there is an adjustment process and that the short- and long-term effects of trade on emissions are different" (Managi et al. (2009) p. 354), studies on the relationship between trade and emissions are presumed to require an autoregressive model. Furthermore, the Prob > F associated with the Wooldridge test for autocorrelation is < 0.05 in our case, suggesting rejection of the null hypothesis (see Wooldridge 2002).[8] The error term in period (t) is related to the error of the previous (t−1) period. The dependent variables therefore display a first-order autocorrelation, and the lag (t−1) of the dependent variable (i.e., Em^{g}_{it-1} for the per capita emissions from country *i* at period *t−1*) must be included in the model. The dependent variable and its lag are measured in kilograms of each emission per capita.

As is well established in the empirical literature on trade policy and environment (e.g., Copeland and Taylor 2005; Frankel and Rose 2005; Managi et al. 2009; Baghdadi et al. 2013; Zhou et al. 2017; Cherniwchan et al. 2017; Martínez-Zarzoso and Oueslati, 2018), our model controls for scale, technique, and composition effects to assess the effect of climate provisions on GHG emissions. It thus includes the usual determinants of emissions such as population density, per capita GDP, and trade openness.

[8] It consists to compute the Wooldridge's test for first order serial correlation of residuals in panel models. The null hypothesis (H0) is: "No serial correlation of order one".

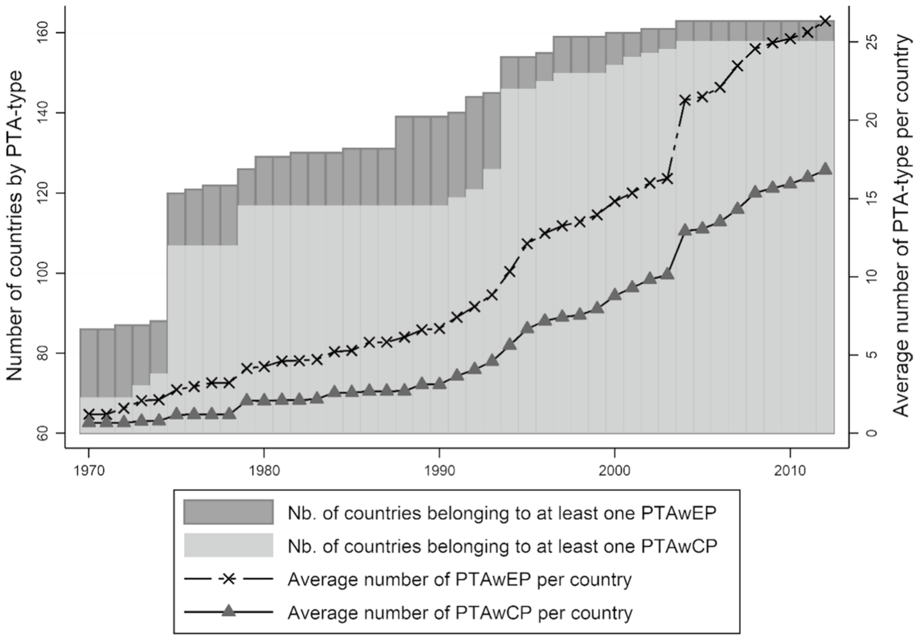

Fig. 2 Distribution of PTAs with environmental and climate-related provisions. *Source*: Authors, created with data from "TRade and ENvironment Database"—TREND. *Note* PTAwEP means PTAs with environmental provisions; PTAwCP means PTAs with climate-related provisions

The variable ($Open_{it}$), defined as the sum of trade (exports + imports) divided by GDP, captures some of the potential direct effect of trade openness on environmental quality. It serves as a proxy for the composition effect, and its effect on environmental quality could be either positive or negative. The variable $\left(Popdens_{it}\right)$ accounts for the population density, measured as the average number of inhabitants per square kilometer (km^2) in country *i* in year *t*. Population density is a proxy for the 'scale effect' and is expected to have a negative impact on the environment. Since an economy of scale exists for pollutant emissions, a higher number of inhabitants per km^2 can lead to lower emissions per capita.[9] The control variable $\left(GDPcap_{it}\right)$, defined as GDP per capita in constant US dollars in country *i* in year *t*, serves as a proxy for the 'technological effect'. Time-fixed effects $\left(FE_t\right)$ are added to capture linear time-trend effects (see Martínez-Zarzoso and Oueslati, 2018) and country fixed effects $\left(FE_i\right)$ to control for country-associated time-invariant factors. The term ε_{it} represents measurement error.

The 'interest' variable Reg_{it}^{pta} measures the willingness of country *i* (in year *t*) to deal with climate change, its coefficient being proportional to the effect of the PTA on emissions. Instead of using a dummy variable to specify whether a PTA has CPs or not, we start

[9] The relationship between population density and pollutant concentration is not defined clearly in the literature. The sign of this correlation depends on the type of pollutant and the formula used for calculating the population density (number of inhabitants per km^2 or land area per capita in km^2). For example, analyzing the effect of population density (as population per km^2) on urban air pollution in Germany, Borck and Schrauth (2021) find that the NO_2 concentration increases with population density while the O_3 concentration decreases. Measuring the population density as land area per capita, Baghdadi et al. (2013) find an insignificant coefficient for the relationship between population density and per capita emissions of CO_2.

from the assumption that the willingness of a country to deal with climate change issues is measured by the number and PTA-type it signs. Hence we compute the different sums of PTA-types (PTAs with EPs, PTAs without EPs, PTAs with CP, or PTAs without CPs) by country *i* in force at year *t*. As presented in the Table 1, in other studies, the interest variable is weighted using the number of trading partners (j) with which country (i) has signed a PTA (Baghdadi et al. 2013; Martínez-Zarzoso and Oueslati, 2018).

4.2 Data Description

The sources of the dataset constructed for this study and the statistics for the covariates used are summarized in Tables 2 and 3. The 164 countries are listed in the online Appendix B.[10]

The sources for variables used in the estimated Eq. (1) are presented in Table 2. Gross domestic product (GDP), land area and population data are from World Development Indicators (WDI).[11] Data on PTAs are from the TRade and ENvironment Database (TREND).

According to Fig. 3, unlike CO_2 and N_2O emissions, the CH_4 emissions is slow growing with a bowl-shaped decreasing part between 1997 and 2004. The increase of CO_2 and N_2O emissions began to accelerate in the year 2000 with a decrease during the economic crisis 2008/2009. However, between 1997 and 2000, the N_2O emissions clearly decreased while the CO_2 emissions continuously increased over the same period.

5 Estimation Strategy and Results

5.1 Pre-treatment for the Endogeneity Problem

As emphasized in the literature, the variables "GDP" and "trade openness" may be determined endogenously together with environmental regulation (e.g., Martínez-Zarzoso and Oueslati, 2018; Zhou et al. 2017; Baghdadi et al. 2013; Managi et al. 2009; Frankel and Rose 2005).[12] In addition, covariates such as trade (trade openness) and production (GDP) may contribute simultaneously to regulatory stringency and our dependent variable "pollutant emissions" (Brunel and Levinson 2016). We therefore first define these using a set of instrumental variables.

An income Eq. (2) derived from the growth-empirics literature was used to instrument GDP for each country, based on predicted values of income (GDP_{it}). An OLS model was run to regress GDP on overall trade $\left(Trade_{it}\right)$, investment $\left(Inv_{it}\right)$ calculated as the stock of inward foreign direct investment, population (Pop_{it}) and human capital $\left(Sch_{it}\right)$ approximated by school enrolment. With an error term (υ_{it}), the income equation is given by:

$$\log\left(GDP_{it}\right) = \left[\omega_0 + \omega_1 \log\left(Trade_{it}\right) + \omega_2 \log\left(Inv_{it}\right) + \omega_3 \log\left(Pop_{it}\right) + \omega_4 \log\left(Sch_{it}\right) + FE_t + \upsilon_{it}\right] \tag{2}$$

[10] The study was implemented using a data panel of 164 countries over 18 years (164 × 18 = 2,952 observations).

[11] All values are in 2005 constant US dollars.

[12] The correlation matrix in Table 6 (Appendix A) suggests that all explanatory variables in Eq. 1 are not exogenous, e.g., "per capita GDP", and "trade openness" are highly correlated with our interest variable (number of PTA with CP).

As reported in Table 3, data on Foreign direct investments (FDIs) are from the UNCTAD database.[13] School enrollment data[14] are from the WDI database. The variable $Trade_{it}$ represents the sum of exports and imports over all its trade partners j for a country i at time t: $Trade_{it} = \sum_j Export_{ijt} + \sum_j Imports_{ijt}$. Trade data are from the UN COMTRADE database. After using Eq. 2, GDP is predicted for each country in year t (denoted $\widehat{GDP_{it}}$).[15]

To the estimate national "trade openness", we ran a pair-wise gravity model (Eq. 3) that predicts aggregate bilateral trade, an instrumentation approach that addresses the above-mentioned endogeneity and simultaneity problems (e.g. Millinet and Roy 2016). The value of $\widehat{Open}_{it}$ is calculated by dividing the predicted total trade by the predicted GDP in year t. Predicted total trade ($\widehat{T}_{it}$) also comes from Eq. 3. The gravity approach to instrumenting the "trade openness" variable has been described previously (e.g., Baghdadi et al. 2013; Frankel and Romer 1999). A PPML gravity model predicts bilateral trade between two partners based on GDP, population, and geographical distance between them.[16] Dummy variables indicating common borders and language are also used.

$$T_{ijt} = \begin{bmatrix} \eta_0 + \eta_1 \log\left(dist_{ij}\right) + \eta_2 \log\left(GDP_{it}\right) + \eta_3 \log\left(GDP_{jt}\right) + \\ \eta_4 \log\left(Pop_{it}\right) + \eta_5 \log\left(Pop_{jt}\right) + \eta_6 CB_{ij} + \eta_7 CL_{ij} + FE_t + \pi_{ijt} \end{bmatrix} \tag{3}$$

where T_{ijt} denotes bilateral trade (exports *plus* imports) between partners i and j during period t. GDP and population (*Pop*) values were obtained from the WDI database (see Table 3). Gravity dummy variables are defined as follows: CB_{ij} equals to 1 if the countries share a common border, otherwise 0; CL_{ij} equals to 1 if the countries share a common official language, otherwise 0. Border and linguistic status as well as distance were obtained from the *Centre d'Études Prospectives et d'Informations Internationales* (CEPII) database (see Table 3). Time fixed effects $\left(FE_t\right)$ factor represents the trend over time, and π_{ijt} is an error term. Predicted bilateral trade $\widehat{T}_{ijt}$ values are aggregated to obtain predicted total trade $\widehat{T}_{it}$ for each country in year t, in other words: $\widehat{T}_{it} = \sum \widehat{T}_{ijt}$.

The results obtained using Eqs. 2 and 3 are reported in Tables 7 and 8 (Appendix B). All estimated coefficients are statistically significant with the expected sign (based on the literature). In addition, based on R^2 for both equations, the variables used in the models explain more than 80% of the observed variance. These statistics show that the correct covariates were chosen.

Finally, instead of their observed values, we used the instrumented variables "trade openness" and "per capita income", that is, predicted income per capita ($\widehat{GDPcap}_{it}$) calculated as predicted GDP divided by the population, and predicted "trade openness" ($\widehat{Open}_{it}$) calculated as predicted total trade divided by predicted GDP, by which Eq. 1 becomes:

[13] See UNCTAD Stat: http://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=fr. [Accessed June 5, 2018].

[14] Average educational attainment was computed as described in Barro and Lee (2013) as an index ranging from 0 to 1 where 1 represents 16 years of education.

[15] As the predicted values of GDP directly obtained from the OLS estimation (Eq. 2) are in logarithmic form, we transform them by taking their exponential in order to have the predicted values needed.

[16] The Poisson pseudo maximum likelihood (PPML) estimator has been suggested to compensate for heteroscedasticity and the zero problem frequently encountered in trade data (Silva and Tenreyro 2006). In our case, unlike the OLS model, the PPML gravity model gives the predicted values in directly usable (not logarithmic) form.

Table 2 Descriptive statistics for variables used into our main model (Eq. 1)

	Obs.	Mean	SD	Min.	Max.	Source
Emissions of CO_2 in gigagrams	2952	166,337.4	686,148.9	13.791	9,918,456	EDGAR
Emissions of CH_4 in gigagrams	2952	1878.82	5462.892	0.0700	66,296.83	
Emissions of N_2O in gigagrams	2952	48.84334	156.3949	0.0017	1762.989	
Nb. of PTAs with environmental provisions	2952	19.07205	23.73095	0	100	TREND
Nb. of PTAs without environmental provisions	2952	2.413131	2.746141	0	15	
Nb. of PTAs with climate change provisions	2952	11.60438	12.68798	0	62	
Nb. of PTAs without climate change provisions	2952	7.467677	11.64987	0	46	
Area in square kilometers (km^2)	2952	780,958.7	2,048,573	316	$1.71e^{+07}$	WDI
Population	2952	$3.77e^{+07}$	$1.35e^{+08}$	17,255	$1.35e^{+09}$	

Source: Data are from the European Union Emissions Database for Global Atmospheric Research (EDGAR), the World Bank World Development Indicators (WDI), and the Université Laval TRade and ENvironment Database (TREND). S.D. is standard deviation

Table 3 Descriptive statistics of variables used in the treatment of the endogeneity problem

	Obs.	Mean	SD	Min.	Max.	Source
Total imports (yearly)	2952	376,483.9	3,852,653	0	$1.78e^{+08}$	COMTRADE
Total exports (yearly)	2952	383,011	4,102,908	0	$1.88e^{+08}$	
Stock FDI—at current prices (in millions of $US)	2952	67,770.03	251,437.1	0.26	3,915,538	WDI
Pop. at age 15 + with secondary schooling (in %)	2952	23.92534	15.49427	0.68	71.8	
GDP in US dollars	2952	$2.76e^{+11}$	$1.13e^{+12}$	$7.66e^{+07}$	$1.62e^{+13}$	
Bilateral distance (in km)	2952	7234.95	4185.477	213.126	19,475.95	CEPII
Dummy for sharing a common official language	2952	0.135017	0.341799	0	1	
Dummy for sharing a common border (contiguity)	2952	0.020875	0.142991	0	1	

Source: The UNCTAD database (COMTRADE), World Bank World Development Indicators (WDI), Université Laval TRade and ENvironment Database (TREND), and *Centre d'Études Prospectives et d'Informations Internationales* (CEPII). S.D. is standard deviation

$$\log\left(Em_{it}^{g}\right) = \left[\begin{array}{l} \alpha_0 + \alpha_1 \log\left(Em_{it-1}^{g}\right) + \alpha_2 \log\left(_{it}\right) + \alpha_3 \log\left(Popdens_{it}\right) \\ +\alpha_4 \log\left(_{it}\right) + \alpha_5 Reg_{it}^{pta} + FE_t + FE_i + \varepsilon_{it} \end{array}\right] \tag{4}$$

5.2 Estimation Methods and Results

Environmental quality was modeled using two dynamic panel methods. Instead of a first-difference generalized method of moments (GMM) estimator (proposed by Arellano and Bond (1991) and used by Martínez-Zarzoso (2018) and Martínez-Zarzoso and Oueslati (2018)), we used the system GMM estimator (Arellano and Bover 1995; Blundell and

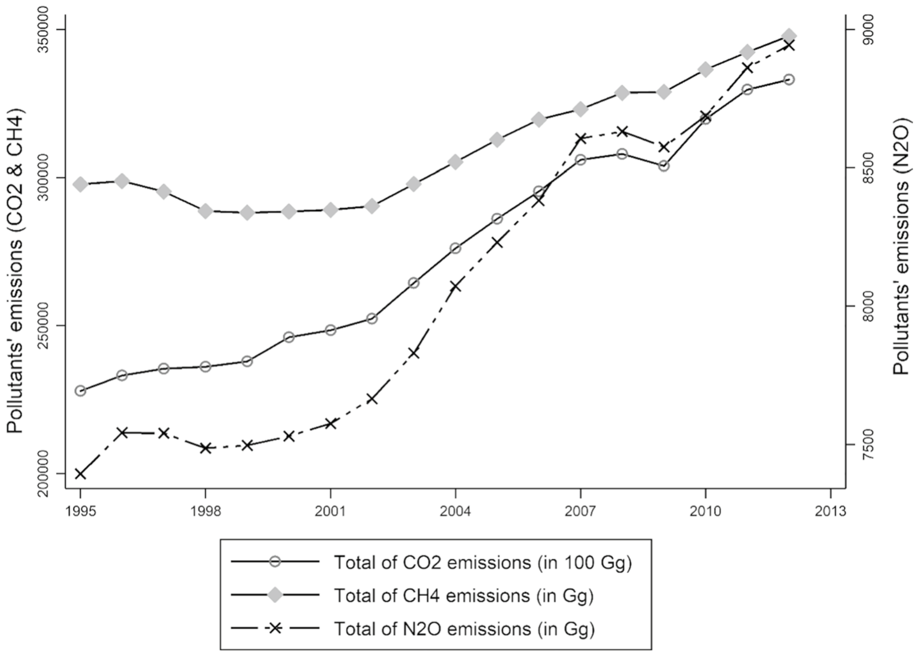

Fig. 3 Evolution of GHG emissions between 1995 and 2012. *Source*: "TRade and ENvironment Database", and Emissions Database for Global Atmospheric Research (EDGAR)

Bond 1998), which contains an additional set of level moment conditions as well as difference moment conditions to estimate dynamic panel data, whereas the difference GMM estimator uses moment conditions from the estimated first differences of the error term. Our benchmark results are system GMM estimates that compensate for heteroskedasticity.[17] The difference estimator is inadequate when model errors are heteroskedastic (see Windmeijer 2005) and when time-invariant regressors are used (see Blundell and Bond 1998).[18] This could explain the unexpected findings of statistically significant negative coefficients for PTAs without environmental provisions (Martínez-Zarzoso, 2018; Martínez-Zarzoso and Oueslati, 2018).[19] When the endogenous variable is very persistent or follows an almost random path, these instrumented variables become weak predictors of endogenous changes, making the Arellano-Bond difference GMM unsuitable (Blundell and Bond 1998).

Using the system GMM, the lagged dependent variable (Em_{it}^{g}) and the variables related to a PTA (Reg_{it}^{pta}) are considered as endogenous variables while "population density", time

[17] The White test for heteroscedasticity shows a chi-square probability of less than 0.05, meaning that the null hypothesis of constant variance can be rejected with 95% confidence, and implies the presence of heteroscedasticity in the residuals.

[18] Windmeijer (2005) proposes using the two-step GMM estimator (a first-step estimation to obtain the estimation error covariance matrix) to correct for model error heteroskedasticity. In the case of time-invariant regressors in the model, the system GMM estimator rather than the difference GMM estimator is proposed (see Arellano and Bover 1995; Blundell and Bond 1998).

[19] See also Baghdadi et al. (2013) and Zhou et al. (2017).

dummy variable (years 1996 to 2012) and the differences of the lagged endogenous variables $(\Delta Reg_{it-1}^{pta})$ are considered as instruments.[20] These *differences* $(\Delta Reg_{it-1}^{pta})$ are exploited as a new set of instruments for the *levels* of the lagged PTA-variables (Reg_{it-1}^{pta}). All GMM estimations are carried out using the xtabond2 package in Stata (see Roodman 2009). Specific instrumental variables are validated using the Hansen test of over-identifying restrictions (results are reported in GMM estimates tables).[21] For robustness, we also report estimates using the fixed effects approach (FE-GLS). This is a panel data technique which, by introducing fixed effects, allows us to deal with the potential endogeneity of the PTA variable. The FE-GLS approach was proposed by Baier and Bergstrand (2007) and has also been implemented by Martínez-Zarzoso and Oueslati (2018).

Instrumental variable estimation proposed by Anderson and Hsiao (1982) as a solution when the strict exogeneity assumption is violated was later found to be asymptotically inefficient by Arellano and Bond (1991), who proposed a more efficient estimation procedure using moment conditions in which lags of the dependent variable and first differences of the exogenous variables are instruments for the first-differenced equation. This empirical strategy allows us to determine if the effects of PTAs with climatic provisions are found similar regardless of whether system GMM or panel data techniques are used.[22] After using instrumental variables to address the endogeneity of the income and trade variables, both estimation methods (i.e., GMM and FE-GLS) allow us to address potential endogeneity and reverse causality[23] of our dependent variable. Results are reported for the following three specifications:

1. The effects of all PTAs with environmental provisions (PTAwEP).
2. The effects of PTAs with climate-related provisions (PTAwCP).
3. The effects of PTAs with and without climate provisions, simultaneously.

Given that in the Specification 1 we simultaneously introduce PTAwEP and PTAs without environmental provisions (PTAw/oEP), this specification allows us to compare our results to those of previous studies, even though these studies use a different measure of the PTA-variable (see Table 1) and a different PTA database to TREND. Specifications 2 and 3 are our main contributions. These seek to show that the impact of environmental provisions on climate change issues is heterogeneous, by separating agreements with and without climate-related provisions and then isolating the impact of the latter on GHG emissions

[20] The excluded instruments in the GMM estimation are population density and time dummy variables. The logic of the system GMM is that both first difference and level equations are included in the estimation. The lags of the first differences are used as instruments of the variables in levels, and vice versa. The number of lags used depends on the different specification tests.

[21] Under the null hypothesis, all instruments are uncorrelated with the error term, the test has a large sample $\chi 2$ (r) distribution where r is the number of over-identifying restrictions, that is, the number of excluded instruments minus the number of endogenous variables. Rejection of the null hypothesis means that the instruments used are valid.

[22] The test for fixed effects suggests including time and country in the model. Based on the associated Prob > F being < 0.05, the null hypothesis that the coefficients for all years or all countries jointly equal zero is rejected. Time and country are therefore introduced as fixed effects in the robustness estimation. However, only the time effect will be included in the GMM estimation since our system GMM model considers unobserved country-specific components.

[23] In other words, if we know that accumulating PTAs with EPs (PTAwEP) may lead to a cleaner environment, a country seeking to improve its environmental quality may also be eager to negotiate such agreements.

Table 4 Results of system GMM regression

	Specification 1			Specification 2			Specification 3		
	CO_2 em	CH_4 em	N_2O em	CO2 em	CH_4 em	N_2O em	CO_2 em	CH_4 em	N_2O em
Lag of per capita emissions	0.8862*** (0.0062)	0.8892*** (0.0061)	0.7627*** (0.0112)	0.8904*** (0.0058)	0.8822*** (0.0064)	0.7380*** (0.0120)	0.8880*** (0.0056)	0.8846*** (0.0058)	0.7409*** (0.0101)
Trade openness (instrumented)	0.00009 (0.0002)	0.0001* (0.0000)	0.00009 (0.0000)	0.00007 (0.0000)	0.0001** (0.0000)	–0.00007 (0.0000)	0.0001 (0.0002)	0.0003** (0.0001)	0.0004** (0.0002)
Number of PTAs without EPs	0.0194*** (0.0017)	0.0206*** (0.0011)	0.0255*** (0.0021)	0.0187*** (0.0013)	0.0158*** (0.0008)	0.0270*** (0.0018)	0.0126*** (0.0022)	0.0029* (0.0015)	0.0083*** (0.0024)
Number of PTAs with EPs	–0.0016*** (0.0001)	–0.0024*** (0.0000)	–0.0019*** (0.0001)	–	–	–	–	–	–
Number of PTAs without CPs	–	–	–	–	–	–	0.0004 (0.0004)	0.0029*** (0.0003)	0.0023*** (0.0004)
Number of PTAs with CPs	–	–	–	–0.0034*** (0.0001)	–0.0027*** (0.0019)	–0.0039*** (0.0002)	–0.0024*** (0.0002)	–0.0035*** (0.0001)	–0.0032*** (0.0002)
Pop. density (inhabitants/km^2)	–0.0016* (0.0008)	–0.0258*** (0.0000)	–0.0576*** (0.0030)	0.00003 (0.0008)	–0.0279* (0.0019)	–0.0620*** (0.0032)	–0.0023*** (0.0008)	–0.0304*** (0.0017)	–0.0631*** (0.0026)
Per-capita GDP (instrumented)	0.0240*** (0.0018)	0.0076*** (0.0011)	0.0036*** (0.0013)	0.0187*** (0.00185)	0.0059*** (0.0012)	0.0010 (0.0014)	0.0246*** (0.0018)	0.0116*** (0.0012)	0.0151*** (0.0015)
Constant	–1.1387** (0.4507)	–0.4230 (0.3493)	–1.9154** (0.8460)	–1.1236*** (0.3903)	–0.8046* (0.4207)	–2.1954** (1.0455)	–1.1649** (0.4599)	–0.9014** (0.3934)	–3.0158*** (1.1023)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^-squared (R^2)	0.994	0.990	0.983	0.995	0.991	0.979	0.995	0.992	0.967
Nb. of observations	2773	2773	2773	2773	2773	2773	2773	2773	2773
Nb. of countries	164	164	164	164	164	164	164	164	164
AR (1)	–7.18***	–5.30***	–3.41***	–7.33***	–5.21***	–3.34***	–7.10***	–5.31***	–3.32***
AR (2)	–0.73	–0.25	–0.58	–0.79	–0.26	–0.60	–0.75	–0.15	–0.60
Hansen Test (Prob.)	0.248	0.195	0.146	0.217	0.156	0.242	0.145	0.118	0.328

Bootstrapped standard errors, in parentheses, are robust to heteroskedasticity and arbitrary patterns of autocorrelation within individuals. Asterisks indicate significance (***1% level, **5%, and *10%). The variables "trade openness" and "per capita GDP" are instrumented as predicted values. Time fixed effects are not reported. EP means environmental provisions. CP means climate-related provisions. Variable of interest: Number of PTAs with CPs = Total number of PTAs—Number of PTAs without EPs—Number of PTAs without CPs = Number of PTAs with EPs—Number of PTAs without CPs

Table 5 Results of FE-GLS regression with AR (1) disturbances

	Specification 1			Specification 2			Specification 3		
	CO_2 em	CH_4 em	N_2O em	CO_2 em	CH_4 em	N_2O em	CO_2 em	CH_4 em	N_2O em
Lag of per-capita emissions	0.8302*** (0.0202)	0.8842*** (0.0148)	0.7904*** (0.0222)	0.8273*** (0.0202)	0.8829*** (0.0146)	0.7833*** (0.0227)	0.8228*** (0.0201)	0.8803*** (0.0145)	0.7782*** (0.0235)
Trade openness (instrumented)	0.0003 (0.0007)	0.0003 (0.0004)	0.0004 (0.0006)	0.0004 (0.0007)	0.0003 (0.0004)	0.0004 (0.0006)	0.0004 (0.0007)	0.0003 (0.0005)	0.00004 (0.0006)
Number of PTAs without EPs	0.0101** (0.0044)	0.0032 (0.0033)	0.0144*** (0.0051)	0.0113*** (0.0036)	0.0040 (0.0027)	0.0143*** (0.0047)	0.0003 (0.0054)	-0.0023 (0.0034)	0.0069* (0.0040)
Number of PTAs with EPs	-0.0012*** (0.0004)	-0.0006** (0.0003)	-0.0015*** (0.0004)	–	–	–			
Number of PTAs without CPs	–	–	–	–	–	–	0.0040*** (0.0013)	0.0022*** (0.0008)	0.0027** (0.0012)
Number of PTAs with CPs	–	–	–	-0.0026*** (0.0006)	-0.0013*** (0.0004)	-0.0029*** (0.0007)	-0.0044*** (0.0009)	-0.0023*** (0.0006)	-0.0042*** (0.0011)
Pop. density (inhabitants/km^2)	-0.0886*** (0.0263)	-0.0818*** (0.0210)	-0.1348*** (0.0242)	-0.1049*** (0.0266)	-0.0903*** (0.0210)	-0.1517*** (0.0256)	-0.1221*** (0.0290)	-0.0999*** (0.0226)	-0.1640*** (0.0274)
Per capita GDP (instrumented)	0.0104 (0.0097)	0.0048 (0.0052)	0.0075 (0.0046)	0.0118* (0.0064)	0.0045 (0.0051)	0.0071 (0.0045)	0.0111* (0.0064)	0.0041 (0.0051)	0.0066 (0.0045)
Constant	-0.7307*** (0.1623)	-0.8295*** (0.1716)	-2.3920*** (0.3198)	-0.6680*** (0.1615)	-0.8001*** (0.1712)	-2.4043*** (0.3179)	-0.5916*** (0.1696)	-0.7692*** (0.1711)	-2.4015*** (0.3174)
Fixed effects: Country and Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R$^-$squared (R^2)	0.79	0.83	0.67	0.79	0.83	0.68	0.79	0.83	0.68
Nb. of observations	2970	2970	2970	2970	2970	2970	2970	2970	2970
Nb. of countries	164	164	164	164	164	164	164	164	164

Bootstrapped standard errors, in parentheses, are robust to heteroskedasticity and arbitrary patterns of autocorrelation within individuals. Asterisks indicate significance (***1% level, **5%, and *10%. The variables "trade openness" and "per capita GDP" are instrumented as predicted values. Time fixed effects are not reported. EP means environmental provisions. CP means climate-related provisions. Variable of interest: Number of PTAs with CPs = Total number of PTAs—Number of PTAs without EPs—Number of PTAs without CPs = Number of PTAs with EPs—Number of PTAs without CPs and testing for sensitivity by including both types conjointly. In all three specifications, we add the PTAw/oEP which is expected to have a positive sign. PTAwEP and PTAwCP are both expected to have a positive sign. The sign for PTAs without climate-related provisions (PTAw/oCP) is expected to be either significantly positive, or negative but not significant.

The GMM results are shown in Table 4 and the fixed-effect general least squares robustness test results are shown in Table 5. As reported in Tables 4, results on AR-tests (i.e., the non-significance of the hypothesis of no second-order autocorrelation) show that there is no serial correlation in the error term and our GMM estimations are valid. All Hansen tests are statistically insignificant with $p < 1$. The null hypothesis (H0) cannot be rejected. The instruments used to address the endogeneity of the PTA variable are also valid. The coefficient of the lagged dependent variable using GMM lies between that obtained with fixed effects and OLS.[24] These results overall confirm that the use a dynamic model for our discussion of the impact of climate-related provisions is justified.

Regarding the control variables, the lagged emissions terms are statistically significant with a positive sign and their values are less than unity in all specifications. Except for CO_2 in specification 2, the “population density” coefficients estimated for CH_4 and N_2O are significant with the expected sign in all specifications. All estimated “per capita GDP” coefficients are significant with the expected sign, except for N_2O in specification 2 where it is non-significant. Higher per capita income has a positive impact on GHG emissions, confirming the strong correlation between economic output and air pollution.

Except for the negative and insignificant coefficient for N_2O in specification 2, all estimated “trade openness” coefficients have the expected sign. The positive coefficient indicates that openness to trade tends potentially to increase GHG emissions. However, trade openness does not appear to have a statistically significant impact on national CO_2 emissions. Moreover, its impact on N_2O emissions is inconclusive: only in specification 3 is the coefficient positive and significant. The non-significant effect of “trade openness” might be indicating that the effects of PTAs with environmental or climate provisions on trade are ambiguous. This echoes with Brandi et al. (2020) who found that a participation to PTAwEP could be potentially harmful for the trade of some products, and while at the same time increase the trade of other products.

We controlled for the effects of PTAs without EPs when estimating the effects of EPs. The effect of EPs on CO_2 emissions has been estimated by considering their presence and absence in separate estimations (Baghdadi et al. 2013). When considering them jointly in the same estimation, we found significant coefficients of −0.0016 for EPs and 0.019 when EPs are not included (see Specification 1, Table 4), while previous studies (Martínez-Zarzoso and Oueslati, 2018; Zhou et al. 2017; Baghdadi et al. 2013) found either a positive but not significant coefficient, or even a significant negative coefficient for PTAw/oEP. For example, Martínez-Zarzoso and Oueslati (2018) found a significant negative coefficient (−0.004) for EPs but also a negative and significant coefficient (−0.002) for PTAw/oEP. Intuitively, we would expect PTAs without EPs to increase trade between countries without constraining emissions.

Specification 2, with estimated coefficients of −0.0034 for CO_2 emissions, −0.0027 for CH_4 emissions, and −0.0039 for N_2O emissions under agreements with climate provisions, yields results similar to those of specification 3, in which effects of PTAs with and

[24] We thank the Editor for this suggestion.

without CPs were assessed separately in the same equation.[25] These results indicate, *ceteris paribus*, that entering into a PTA with CPs reduces per capita emissions on average by 0.24 – 0.34% for CO_2 (399.21 – 565.54 Gg), by 0.27 – 0.35% for CH_4 (5072.81 – 6575.87 Mt), and by 0.32 – 0.39% for N_2O (156.29 – 190.48 Mt).[26] Moreover, in specification 3, the coefficients for PTAs with EPs other than climate-related are positive and statistically significant, except for CO_2 emissions. Climate-related provisions in PTAs thus can be expected to have an overall positive impact on environmental quality. It also underlines that a PTA with EP not targeting climate change issues specifically leads to an increase in pollutant emissions per capita, and for CH4 in the same amount as a PTAw/oEP.

Robustness was tested by running Eq. 4 using the fixed effects-GLS estimator (proposed by Baier and Bergstrand 2007).[27] The results were also reported in Table 5 for the three specifications described above. Except for CH_4 emissions associated with PTAs without environmental provisions in the specification 3 (for which we obtained unexpected but an insignificant coefficient), all coefficients have the expected sign.[28]

For our interest variables, the FE-GLS results resemble those in Table 4. The estimates in Table 5 support the idea that climate-related commitments led to a lowering of per capita emissions of GHG. For example, the estimated coefficients for specification 3 are negative and statistically significant: −0.0044 for CO_2 emissions, −0.0023 for CH_4 and −0.0042 for N_2O. Regarding the other PTA variables, the FE-GLS estimates confirm negative and significant coefficients for PTAs with EPs, while PTAs with EPs other than climate-related are positive and statistically significant. For PTAs without EPs, the coefficients are generally positive and significant.[29]

[25] Since PTAs with CPs (PTAwCP) and those without CPs (PTAw/oCP) are two disjoint sets constituting the set of PTAs with EPs (PTAwEP), climate-related provisions are in fine environmental provisions, and PTAs without CPs are PTAs with EPs but not climate-focused, in summary: PTAwEP = PTAwCP + PTAw/oCP. Thus, PTAw/oCP = PTAwEP – PTAwCP.

[26] Yearly average emissions per country are 166,337.4 Gg of CO_2, 1878.82 Gg of CH_4 and 48.84 Gg of N_2O. To convert to grams or to metric tons: 1 gigagram (Gg) = 10^9 g (g) = 10^3 metric tons (Mt).

[27] We ran a model with time dummy variables where the disturbance term is first-order autoregressive, as described previously by Martínez-Zarzoso and Oueslati (2018). The Stata command used is *xtreg* for AR(1) with inclusion of the lagged dependent variable as explanatory variable. To choose between fixed effects and random effects for estimation, the Hausman test was used, which tests the null hypothesis of no correlation between errors and regressors. The p value was lower than 0.05. In specification 3, CO_2 emissions gave a p value of 0.0000, meaning that the null hypothesis should be rejected and that a fixed effects model should be used.

[28] All estimated coefficients for "trade openness" have the expected sign. Even if non-significant, these positive coefficients indicate that openness to trade tends potentially to increase GHG emissions. All estimates for "population density" are negative and significant. Also, all coefficients for "per-capita GDP" have the expected sign.

[29] Except for CH_4 in all specifications and CO_4 in the specification 3. Using the same estimator, Martínez-Zarzoso and Oueslati (2018) find a significant and negative coefficient for PTAs without EPs and cite the missing data for domestic environmental regulation to explain these unexpected results. In contrast to their results, our negative coefficients for PTAs without EPs in the specification 3 are non-significant. This could be due to the inability of the fixed-effects GLS method to consider some unobservable factors related to domestic regulations for CH_4 emissions.

6 Concluding Remarks

This study investigates whether climate-related commitments in international trade agreements contribute to mitigation of per capita greenhouse gas emissions, specifically CO_2, CH_4 and N_2O, believed responsible for global warming, a major element of climate change. It also answers the question of whether all trade agreements with environmental provisions have an impact on GHG emissions, and how effective they are in terms of emissions reduction, which has not been studied previously because of the scantness of detailed data on PTAs.

Running a simplified model of environmental quality to assess the effect of climate provisions on GHG emissions, controlling for scale, technological and composition effects, and considering income and trade variables endogeneity using instrumental variables with data on 164 countries from 1995 to 2012, we find climate provisions to be statistically associated with reduced GHG emissions. This confirms that by enforcing the climate-related commitments in their PTAs, governments could potentially contribute to mitigation of global warming.

Our results from the system GMM estimation show that the negative effect of environmental provisions on GHG emissions found in previous studies is driven by the specific climate-related provisions included in these PTAs. They indicate that countries participating in recent PTAs reduce their per capita emissions on average by 0.24–0.34% for CO_2, 0.27–0.35% for CH_4, and 0.32–0.39% for N_2O. Moreover, the effect of climate-specific provisions is stronger than that of provisions covering a range of environmental factors not necessarily related to climate change. The effect of PTAs without climate provisions is positive in the GMM results and significant for CH_4 and NO_2. This is an important result, since it implies that a PTA with EP not focused specifically on climate change can lead to greater per capita GHG emissions or the same methane emissions as under PTAs without EPs. Our robustness analysis confirms the GMM results with some variation in the coefficient magnitudes.

The evidence presented here suggests that to be effective at mitigating climate change, a PTA should contain climate-related commitments. Environmental provisions, though well-intentioned, are not relevant to the reduction of greenhouse gases unless they specifically address these emissions. Our analysis is the first to provide evidence that signing a PTA with climate provisions could play an important role in climate-oriented governance by committing countries to continue emissions abatement efforts. Such commitment should strengthen national regulations related to climate change issues and orient policy towards climate-friendly legislation that affects or modifies the behavior of economic actors, both producers and consumers and thereby substantially mitigates GHG emissions. This is a possible explanation for the empirical results we obtained in this paper. Empirical testing of this hypothesis is a possible direction for future work. This will require data on national legislations related to environment/climate protection to identify countries that have honored their international commitments with domestic legislation.

Appendix A

See Table 6.

Table 6 Partial correlation matrix

	CO2 per capita	CH4 per capita	N2O per capita	Trade open-ness	GDP per capita	Nb. of PTAwCP	Nb. of PTAw/oCP	Nb. of PTAwEP	Nb. of PTAw/oEP	Pop. Density
CO2 per capita	1									
CH4 per capita	0.718***	1								
N2O per capita	0.262***	0.215***	1							
Trade open-ness	0.162***	0.0823***	–0.00752	1						
GDP per capita	0.641***	0.292***	0.343***	0.103***	1					
Nb. of PTAwCP	0.179***	–0.0974***	0.240***	0.103***	0.539***	1				
Nb. of PTAw/oCP	0.198***	–0.0819***	0.273***	0.0863***	0.532***	0.501***	1			
Nb. of PTAwEP	0.209***	–0.0609**	0.295***	0.0633***	0.497***	0.977***	0.973***	1		
Nb. of PTAw/oEP	0.253***	0.0298	0.185***	0.0131	0.370***	0.598***	0.712***	0.669***	1	
Pop. Density	0.0883***	–0.0655***	–0.0479**	0.399***	0.149***	0.0176	–0.0163	0.00142	–0.0669**	1

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. PTAwEP are PTAs with environmental provisions; PTAwCP means PTAwEP containing climate-related provisions; PTAw/oCP means with EP but no provision related to climate change. As shown the partial correlation matrix, PTAwCP and PTAw/oCP are both highly correlated with PTAwEP (r^2 close to 1). However, the effects of PTAwEP, PTAwCP and PTAw/oCP are not the same. The test of equality of regression coefficients on PTAwEP and PTAwCP in specification 1 and 2 respectively gives a p value much smaller than 0.05, meaning that the null hypothesis that PTAwEP and PTAwCP are statistically equal is rejected

Appendix B

See Tables 7 and 8 .

Table 7 Results of the income Eq. (2)

Dependent variable: Income ("GDP")	
Trade (exports *plus* imports)	0.0302*** (0.0044)
Investment stock	0.5958*** (0.0117)
Population	0.4377*** (0.0136)
Human capital ratio	0.3310*** (0.0236)
Constant	12.6771*** (0.2096)
Fixed effects (time)	Yes
R-squared	0.89
P value (F test of overall significance)	0.0000
Observations	1,816

Standard error is in parentheses. ***significant at the 1% level. Time fixed effects are not reported. R^2 is high (89%): the observed variance is explained almost entirely by the variables used in the model. The p value (Fisher test of overall significance) is very small: model 2 provides a better fit than the intercept-only model. These statistics show that the adequacy of the equation. The set of explanatory variables fits with model

Table 8 Results of the gravity Eq. (3)

Dependent variable: bilateral trade ("exports *plus* imports")	
Log distance (between trading partners)	–0.7079*** (0.0245)
Log population (exporter)	0.0979*** (0.0260)
Log population (importer)	0.0979*** (0.0260)
Log GDP (exporter)	0.7941*** (0.0211)
Log GDP (importer)	0.7941*** (0.0211)
Common language (between trading partners)	0.3288*** (0.0753)
Common border (between trading partners)	0.5132*** (0.0886)
Constant	–25.45718*** (0.6359)
Fixed effects (time)	Yes
R-squared	0.82
P value (F test of overall significance)	0.0000
Observations	487,080

Standard error is in parentheses. ***significant at the 1% level. Time fixed effects are not reported. R^2 is high (82%): the observed variance is explained almost entirely by the variables used in the model. The p value (Fisher test of overall significance) is very small: model 3 provides a better fit than the intercept-only model. These statistics show that the adequacy of the equation. The set of explanatory variables fits with model

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