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Targeted Trade Policy Instruments and Climate Change Mitigation: The Case of Environmental Provisions in Trade Agreements

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ABSTRACT

This article examines the effect of including environmental provisions (EPs) in preferential trade agreements (PTAs) on climate change mitigation and explores whether these effects vary based on the heterogeneity of the EPs. Our analysis combines country-level data on climate change mitigation with details on 300 types of EPs in 775 trade agreements. Empirically, we estimate a generalised method of moments regression and address potential endogeneity using instrumental variables. Our results show that the inclusion of EPs in PTAs significantly improves climate change mitigation, regardless of whether we measure performance using the Climate Change Performance Index, the Environmental Performance Index or CO_2 emissions data. The effectiveness of these provisions, however, depends on their diversity. Key benefits include reduced greenhouse gas emissions, increased renewable energy use, improved energy efficiency and enhanced climate policies. More importantly, PTAs with direct climate provisions yield greater improvements in climate change mitigation outcomes compared to those addressing environmental issues more generally or indirectly. Finally, we show that PTAs with climate change provisions are an effective tool for climate change mitigation, regardless of the development status of the signatories. However, the effects are more pronounced for North–South PTAs.

JEL Classification: F14, Q17, Q18

1 | Introduction

Globalisation has increased interactions between firms across countries, even over long distances, often with drastic consequences for social, economic and environmental sustainability. As trade grows, however, so does the coupling of consumer choices in one part of the world to resource use elsewhere in production areas. This relationship is a key driver of climate change as international trade can intensify deforestation (Abman et al. 2024), biodiversity loss (Bjelle et al. 2021) and emissions of carbon and other GHGs (Zu Ermgassen et al. 2020). On the positive side, international trade and trade policies increase the worldwide diffusion and deployment of lower-emission goods and services, capital equipment and know-how (World Trade Organisation 2022) while reducing their costs through efficiency gains, economies of scale and learning-by-doing (Berthou et al. 2019). Concurrently, climate change also negatively affects international trade by increasing trade costs and disrupting production and supply chains (World Trade Organisation 2022). As a result, there is a growing effort to leverage trade, trade policy and international cooperation to tackle climate change, exemplified by initiatives like the EU Deforestation Regulation. But how effective are these policy measures in supporting climate change mitigation and adaptation strategies? This paper addresses this question by investigating whether the inclusion of environmental provisions (EPs) and climate change provisions (CPs)—defined as rules that are incorporated in an international treaty that address or govern environment-related issues (Blümer et al. 2020)—in preferential trade agreements (PTAs) affects climate change mitigation at the country level.

The last decade has seen a proliferation of 'deep PTAs' that extend provisions beyond liberalising tariffs to substantially cover a broad range of issues including services trade, investments, standards, public procurement, competition and intellectual property rights (Dür et al. 2014). This is often credited for the concurrent proliferation of global and regional value chains (Fan et al. 2024; Laget et al. 2020; Zhang et al. 2021). Since 1990, the number of PTAs with an EP has increased from 111 to 680 in 2021. Whereas this increase is noteworthy, there may be different rationales for incorporating EPs in PTAs. It could be a strategic move to garner the support of sections of society that oppose economic liberalisation (Blümer et al. 2020; Martínez-Zarzoso 2018). This is because EPs are considered more effective instruments to promote higher environmental standards (Jinnah and Lindsay 2016; Johnson 2015) as they help diffuse cleaner technologies worldwide and contribute to global climate governance (George and Yamaguchi 2018). Including EPs in PTAs can, however, also be disguised forms of protectionism and/or 'green imperialism' (Bastiaens and Postnikov 2017; Blümer et al. 2020), for instance, if they target cheap imports. Despite the ubiquity and heterogeneity of EPs in PTAs, empirical evidence on their effects on climate change mitigation and environmental health is scant (Morin and Jinnah 2018; Sorgho and Tharakan 2022). Yet, the parallel development of trade liberalisation and climate change policies calls their interplay into question (Himics et al. 2018). Our work contributes to extending this literature.

We assess how the inclusion of EPs in PTAs affects climate change mitigation using a combination of data on environmental quality outcomes from Germanwatch e.V. and the Socioeconomic Data and Applications Center, and data on PTAs from the TRade and ENvironment Database (TREND). The databases on environmental quality contain various indicators of environmental performance, from which we use two indices that proxy for climate change mitigation: a Climate Protection Performance Index (CCPI) and an Environmental Performance Index (EPI). The CCPI measures a country's performance in protecting its environment from climate change through improvements in climate policy, energy efficiency, renewable energy and GHG emissions. Similarly, the EPI measures broader environmental protection efforts, focusing on environmental health, ecosystem vitality and climate change. We compliment these indices with CO_2 emissions data from the Emissions Database for Global Atmospheric Research (EDGAR). These climate change performance measures are combined with data on 775 PTAs, encompassing approximately 300 EPs. Empirically, we estimate an autoregressive panel data model in an exponential fractional regression framework using two-step system generalised method of moments on a sample of 57 countries from 2000 to 2020. We address the endogeneity of trade policy variables using instrumental variables and panel data estimation techniques.

Our initial descriptive evidence shows that over the study period, global climate change mitigation performance has been modest, with average CCPI and EPI scores of 0.52 and 0.56, respectively (with both indices measured on a 0–1 scale). This means that countries, on average, have met just over half of their climate change mitigation targets. Moreover, this performance is not entirely determined by a country's development status or income level, as some developing countries such as Morocco outperform developed ones such as Australia and the USA. Our empirical estimates show that PTAs with EPs improve climate change mitigation efforts, while PTAs without EPs reduce them. The effects of the latter are, however, not statistically significant. Specifically, a unit increase in the number of PTAs with EPs is associated with a 0.017 percentage point increase in the CCPI and a 0.007 percentage point increase in the EPI. Furthermore, the overall increase in climate change mitigation performance is driven by reductions in GHG emissions and improvements in climate policy. Finally, the positive climate change mitigation effects of PTAs with EPs outweigh the negative impact of PTAs without EPs.

Further heterogeneous analyses reveal that whereas PTAs with climate change provisions that address climate change issues either directly and/or indirectly enhance environmental performance, PTAs that directly tackle climate change achieve greater environmental benefits. Finally, we show that PTAs with climate change provisions are an effective tool for climate change mitigation, regardless of the development status of the signatories. However, the effects are more pronounced for North–South PTAs compared to North–North and South–South PTAs.

Our work fits into the growing literature on the environmental impacts of trade agreements, particularly the role of PTAs in shaping sustainability outcomes. Previous research has examined both the direct and indirect environmental effects of PTAs. For example, Ghosh and Yamarik (2006) found that PTAs have no direct effect on pollution levels, but indirectly increase pollution through increasing trade and growth. Others focus on the inclusion of EPs in PTAs as a potential mechanism for improving environmental quality. Baghdadi et al. (2013) showed that PTAs with EPs significantly reduce CO_2 emissions, while those without EPs tend to increase them. Zhou et al. (2017) found similar patterns for particulate matter ($PM_{2.5}$), and Martínez-Zarzoso and Oueslati (2018) extended the analysis to multiple pollutants including $PM_{2.5}$, SO_2, CO_2 and NO_x, finding that only PTAs with EPs contribute to emission reductions. Sorgho and Tharakan (2022) distinguished between EPs and climate-related provisions, showing that only the latter yield significant reductions in CH_4, CO_2 and N_2O emissions. Trade agreements with provisions targeting forests and biodiversity have also been shown to offset deforestation otherwise associated with trade liberalisation (Abman et al. 2024). While these studies highlight the potential of PTAs in advancing environmental goals, they generally measure mitigation outcomes narrowly, relying solely on emissions data.

We contribute to the literature by offering two key innovations. First, unlike existing studies that focus solely on GHG emissions, we adopt a comprehensive measure of climate change mitigation. We use the Climate Change Performance Index, which combines 14 indicators across four pillars—GHG emissions, renewable energy, energy use and climate policy—to assess climate action in 57 countries covering over 90% of global emissions (Burck et al. 2023). This allows us to capture both emissions outcomes and policy efforts and energy transitions. To broaden coverage, we complement the CCPI with the Environmental Performance Index, available for 180 countries. Together, these indices provide a more holistic view of global climate performance than emissions data alone.

Second, we advance the literature by distinguishing between general EPs and those that explicitly address climate change. Whereas Sorgho and Tharakan (2022) introduced a similar classification, our approach is more restrictive in that we focus exclusively on direct climate change provisions, excluding more general or indirect provisions. We define direct climate change provisions as EPs that directly tackle issues related to climate change such as reducing GHG emissions or harmonising climate regulations. In contrast, indirect provisions include indirect measures such as promoting trade in environmental goods or encouraging stakeholder participation. This distinction ensures that we accurately capture the intentionality of signatories in addressing climate change, reflecting their genuine commitment to mitigating its effects. Our findings also show why this distinction is important: PTAs with direct climate provisions consistently show stronger positive effects on climate mitigation outcomes compared to those with broader or indirect EPs.

Our work also contributes to the literature examining the impact of PTAs on the agricultural and food sector. Many of these studies focus on their effects on export performance (Fiankor et al. 2025; Afesorgbor et al. 2024; Jafari et al. 2023; Scoppola et al. 2018) and food security (Ritzel and Fiankor 2024; Gordon 2024), largely overlooking their interaction with climate change. Yet, agriculture is both a major contributor to greenhouse gas emissions and one of the most vulnerable sectors to climate variability and shocks. Given that trade has played a key role in enhancing global food security over recent decades (Anderson 2022; Brown et al. 2017; Timsina and Culas 2020), understanding how PTAs can support the sustainability of food systems is critical. Our study highlights that to maintain these gains in a changing climate, PTAs must go beyond market access and incorporate strong, enforceable environmental provisions.

As preferential trade agreements proliferate, they need to be deepened to ensure that food systems remain sustainable. Our findings show that deep trade agreements with environmental provisions have positive effects on climate change mitigation. This suggests that the inclusion of environmental provisions in trade agreements could be an effective trade policy instrument in the existential fight against climate change. By joining trade agreements that have environmental provisions, countries are more likely to put environmental issues at the centre of trade and environmental policy debates, leading to improved domestic environmental (climate) policy formulation and regulation and improved climate change mitigation efforts. Our work complements existing works (e.g., Baghdadi et al. 2013; Martínez-Zarzoso and Oueslati 2018; Sorgho and Tharakan 2022; Zhou et al. 2017) that show that the inclusion of environmental provisions in trade agreements is associated with improvements in environmental quality outcomes such as reductions in GHG emissions. Our work, however, extends the existing evidence in stressing the fact that effective designing of PTAs is crucial. If PTAs are to achieve climate change mitigation efforts and address other environmental problems, they must directly address climate change issues (i.e., have climate change provisions).

The rest of the article is organised as follows. Section 2 briefly describes the theoretical framework linking PTAs and environmental provisions to trade and environmental quality indicators. We describe our analytical framework and econometric procedure in Section 3 and present key data sources in Section 4. We present and discuss our main results in Section 5 and policy implications in Section 6 before drawing our conclusions in Section 7.

2 | Theoretical Framework

While trade liberalisation and environmental outcomes are deeply intertwined, empirical evidence shows that the way in which they affect each other is rather complex. Increased trade openness can benefit or destroy a country's environment and natural resources depending on the size and interactions among the so-called scale, composition and technique effects (Grossman and Krueger 1991). The pioneering work of Grossman and Krueger (1991) has been used many times in the literature to assess how international trade interacts with the environment (e.g., Copeland and Taylor 2004; Grossman and Krueger 1991; Managi et al. 2009). This section presents a review of the theoretical literature that forms the basis for our analysis and provides the theoretical predictions that inform the interpretation of our findings.

As trade increases global economic activity, it can lead to more environmental pollution and degradation. This is the *scale effect*. Although this is the general expectation, there is also empirical evidence suggesting that higher incomes, often resulting from increased trade, can improve environmental quality (Antweiler et al. 2001; Copeland and Taylor 2004; Grossman and Krueger 1991). This aligns with the Environmental Kuznets Curve, which describes an inverted U-shaped relationship where environmental quality initially declines with rising income but improves after reaching a certain threshold. Second, the *technique effect* indicates that trade liberalisation positively impacts the environment by promoting the diffusion of improved knowledge and production technologies, resulting in the extensive adoption and use of cleaner technologies which contribute to reducing pollution. Trade is a conduit for technology transfers and improved technologies can benefit the environment if they reduce emission intensities. Finally, it is argued that trade liberalisation alters comparative advantage and the mix of goods produced by economies, and this affects environmental quality. This is the so-called *composition effect*. Based on economic theory, it is difficult to predict, a priori, the net impact of the composition effect of trade liberalisation on the environment because it depends on the specific sectors in which a particular economy has comparative advantage. In the end, the direction of the effect is an empirical question.

Moreover, comparative advantage can arise from cross-country differences in both resource endowments and environmental regulations. On the one hand, if an economy's comparative advantage is mainly determined by its relative factor endowment, such as capital relative to labour, the Factor Endowment Hypothesis (FEH) postulates that economies in which capital is relatively abundant are likely to export capital-intensive (and therefore often pollution-intensive) goods. Thus, the FEH predicts that pollution should increase in capital-intensive countries and decrease in countries where capital is scarce. Alternatively, if a country's comparative advantage emanates from lax environmental regulations, the Pollution Haven Hypothesis (PHH) suggests that 'trade liberalisation in goods will lead to the relocation of pollution-intensive production from countries with high income and more stringent environmental regulations to countries with low income and less stringent environmental regulations' (Martínez-Zarzoso 2018, 13). The PHH predicts that environmental damage could increase particularly in developing countries because their lax environmental regulations could make them pollution havens. A number of researchers (e.g., Cherniwchan et al. 2017; Millimet and Roy 2016; Wilting et al. 2021) have provided evidence to support the existence of the PHH. Overall, numerous scientific studies that directly investigate the impact of PTAs on the environment conclude that PTAs, generally, improve environmental quality outcomes by increasing trade, quality of traded goods and income per capita (Baghdadi et al. 2013; Ghosh and Yamarik 2006; Bastiaens and Postnikov 2017; Brandi et al. 2020; Martínez-Zarzoso 2018).

3 | Analytical Framework and Econometric Strategy

This section sets out the analytical framework and econometric estimation strategy that we use to test the theoretical predictions set out in Section 2.

3.1 | Empirical Strategy

We follow Martínez-Zarzoso and Oueslati (2018) and Sorgho and Tharakan (2022) and estimate the effects of environmental provisions in PTAs on climate change mitigation using the following empirical model:

$$\begin{aligned} CPP^{\rho}_{it} = \; & \alpha_1 PTAwoEP_{it} + \alpha_2 PTAwEP_{it} + \alpha_3 CPP^{\rho}_{it-1} + \alpha_4 \log Openness_{it} \\ & + \alpha_5 \log GDPcap_{it} + \alpha_6 \log Popdensity_{it} + \alpha_7 Demoindex_{it} \\ & + \tau_i + \delta_t + \mu_{it} \end{aligned} \quad (1)$$

where CPP^{ρ}_{it} is measure ρ for the climate change mitigation performance of country i in year t. ρ denotes the two indicators of climate change mitigation performance, that is, the Climate Change Performance Index and its components (i.e., GHGs emissions, climate policy, energy efficiency and renewable energy) as well as the Environmental Performance Index and its components (i.e., environmental health, and climate and energy). We measure a country's willingness to deal with climate change by the number of the different types of PTAs that it has in year t. $PTAwoEP_{it}$ is the cumulative count of PTAs that do not include environmental provisions while $PTAwEP_{it}$ is the cumulative number of PTAs that include such provisions. $PTAwoEP_{it}$ and $PTAwEP_{it}$ are our key variables of interest. In further heterogeneity analyses, we will assess the effects of PTAs with general climate change provisions (PTAwCPs) and those with direct climate change provisions (PTAwDCPs).[1] Figure 1 shows how the different types of PTAs are related.

To control for the scale, technique and composition effects that feature in our theoretical framework, we include further controls in Equation (1). We define $Openness_{it}$ as a ratio of total trade to gross domestic product (GDP) and use it as a control for the direct effect of trade intensity on climate change mitigation. $Openness_{it}$ proxies the composition effect (Antweiler et al. 2001; Copeland and Taylor 2004; Frankel and Rose 2005; Baghdadi et al. 2013). GDP per capita in constant US dollars, $GDPcap_{it}$, is our proxy for the technique effect and captures the direct effect of income on climate protection performance. We proxy the scale effect using population density ($Popdensity_{it}$) defined as the average number of people inhabiting a square kilometre of land area in country i in year t. A priori, we expect population density to negatively impact environmental quality (Antweiler et al. 2001; Martínez-Zarzoso and Oueslati 2018), though empirical evidence on this relationship remains mixed (Sorgho and Tharakan 2022). $Demoindex_{it}$ captures a country's political structure, measuring the extent of democracy or autocracy in its governance and accounting for the role of political institutions in addressing market failures including environmental externalities (Frankel and Rose 2005). Time-fixed effects δ_t capture global trends like economic downturns, while country-fixed effects τ_i account for country-specific factors that remain constant over time and influence climate change mitigation efforts. μ_{it} is the random error term with mean zero, which we cluster at the country level.

3.2 | Addressing Endogeneity of Trade and Climate Protection Performance

Equation (1) may suffer from several sources of endogeneity that could affect identification. First, there is potential endogeneity stemming from omitted variable biases due to observed and unobserved confounding factors (e.g., country-specific quality of economic and environmental institutions) that we cannot control for. We address this concern using country and time fixed effects. Second, there is potential reverse causality of the PTA and environmental quality performance relationship. For instance, while having more PTAs with EPs may improve environmental performance, the severity of environmental concerns in a country may induce it to sign up to PTAs with EPs (Martínez-Zarzoso 2018). We use dynamic panel data estimation techniques to address this concern (Arellano and Bond 1991). We, additionally, use 1- and 2-year lags of the PTA variables to assess the existence of phase-in effects. Third, there is a risk that our indices (i.e., CCPI and EPI) may suffer from measurement bias because they involve subjective weights and are influenced by country-specific factors. However, this risk is mitigated by the fact that both indices use standardised criteria across countries and potential measurement errors are unlikely to be systematic. Nevertheless, we also use emissions data measured as CO_2 equivalents in sensitivity analysis.

Fourth is the endogeneity of the relationship between income (GDP) and trade. This is a common issue in the trade openness and economic growth literature (Baghdadi et al. 2013; Frankel and Rose 2005; Managi et al. 2009; Martínez-Zarzoso and

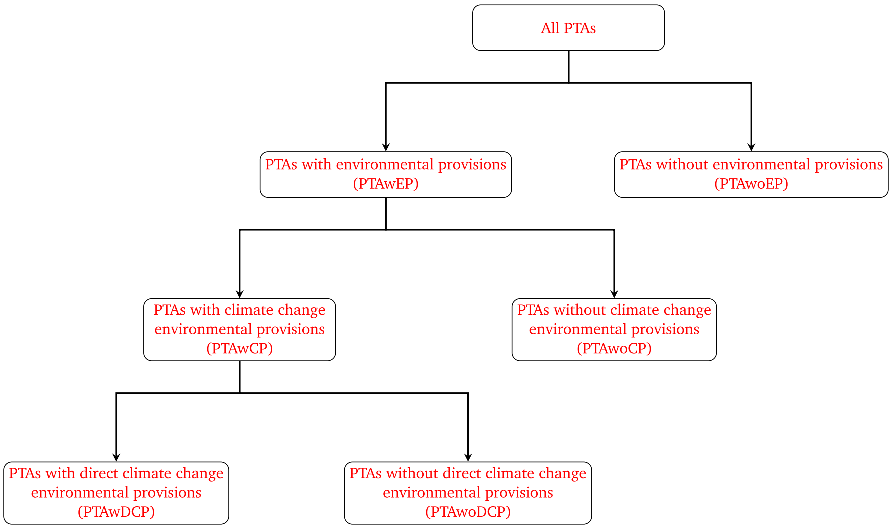

FIGURE 1 | Schematic diagram showing the relationships between different types of preferential trade agreements. *Source:* Authors' illustration.

Oueslati 2018; Sorgho and Tharakan 2022), which we address using instrumental variable (IV) techniques, requiring suitable instruments for trade openness and GDP in our estimation.

We instrument for trade flows using the theory and empirics of the gravity model of trade (Anderson and Van Wincoop 2003). The gravity model postulates that trade between two countries is influenced positively by their sizes and negatively by the bilateral distance between them. This is the workhorse model for studying how trade-related policies such as standards, trade agreements or global shocks affect international trade (Larch and Yotov 2024; Fiankor et al. 2024). We estimate the following theory-consistent structural gravity model:

$$X_{ijt} = \exp\left[Z'_{ij}\beta + \Pi_{it} + \omega_{jt}\right] \times \varepsilon_{ijt} \quad (2)$$

where total bilateral trade values between countries i and j in year t, X_{ijt}, is regressed on a vector $Z'_{ij}\beta$ of country-pair variables (including bilateral distance, contiguity, linguistic similarity and colonial ties), and a host of time-varying exporting country (Π_{it}) and importing country (ω_{jt}) fixed effects. The country-time fixed effects control for all country-time specific variables (e.g., GDP, production, institutional quality, population). These fixed effects also control for the theoretical outward and inward multilateral resistance terms which capture the fact that trade depends not only on bilateral trade barriers but also on average trade barriers across all trade partners (Anderson and Van Wincoop 2003). ε_{ijt} is the random error term, which we cluster at the exporter-importer-year level. We estimate Equation (2) using the Poisson Pseudo-Maximum Likelihood (PPML) estimator to address potential inconsistencies due to heteroskedasticity of trade data (Silva and Tenreyro 2006). The estimates of the gravity model are reported in Table S1 of Appendix S1. All estimated coefficients have the expected signs and are statistically significant. Next, we predict total bilateral trade and sum it across all trading partners for each country, $\sum_{j \neq i} \widehat{X}_{ijt}$, to obtain the predicted total trade for country i in year t. We then use the predicted trade values as an instrument for the observed trade (Frankel and Rose 2005; Millimet and Roy 2016; Sorgho and Tharakan 2022).

To instrument the income effect, we estimate the following income equation based on the theories and empirics of income growth (Baghdadi et al. 2013; Frankel and Rose 2005):

$$\begin{aligned}\log GDPpc_{it} = {} & \theta_1 \log GDPpc_{it-1} + \theta_2 \log Pop_{it} + \theta_3 \log Invest_{it} \\ & + \theta_4 \log Tradecap_{it-1} + \theta_5 \log Openness_{it} + \theta_6 \log HCI_{it} \\ & + \theta_7 Popgrowth_{it} + \varphi_i + \sigma_t + u_{it}\end{aligned} \quad (3)$$

where we regress GDP per capita ($GDPpc_{it}$) for country i in year t on its lag ($GDPpc_{it-1}$), population (Pop_{it}), investment rate ($Invest_{it}$) proxied by gross capital formation, trade per capita ($Tradecap_{it-1}$) defined as the ratio of total trade to population, human capital proxied by the human capital index (HCI_{it}), population growth rate ($Popgrowth_{it}$), country-fixed effects (φ_i) and year-fixed effects (σ_t). The term u_{it} is random error with mean zero, which we cluster at the country level. We estimate Equation (3) using ordinary least squares (OLS) and present the results in Table S2 of the Appendix S1. Thereafter, we predict income per capita (i.e., $\widehat{GDPpc_{it}}$) and use it as an instrument for the observed GDP per capita. In addition, we calculate predicted trade openness as the ratio of predicted total trade we obtained from Equation (2) to predicted GDP per capita (i.e., $\widehat{Openness_{it}} = \sum_{j \neq i} \widehat{X}_{ijt} / \widehat{GDPpc_{it}}$) and use it as an instrument for observed trade openness in Equation (1).

3.3 | Empirical Estimation

We specify our estimation Equation (1) as an auto-regressive panel data model because the indicators of climate change mitigation exhibit state/path dependence (Blundell and Bond 1998; Managi et al. 2009; Sorgho and Tharakan 2022). This implies that a country's current climate change mitigation performance depends on its past performance. Thus, in the absence of a large exogenous negative shock, high performing countries are likely to consistently perform high. Econometrically, these time dynamic effects pose estimation challenges because they cause the incidental parameter problem (Neyman and Scott 1948). As a result, we use the two-step system generalised method of moments (GMM) estimator (Arellano and Bover 1995; Blundell and Bond 1998) instead of the difference GMM estimator (Arellano and Bond 1991) because the former performs well in the presence of heteroskedasticity and time-invariant independent variables (Blundell and Bond 1998; Windmeijer 2005). We use $\widehat{Openness}_{it}$ and $\widehat{GDPpc}_{it}$ as instruments for the endogenous variables $Openness_{it}$ and $GDPpc_{it}$, respectively. Furthermore, regressors $Popdensity_{it}$, $Demoindex_{it}$ and δ_t are used as excluded instruments while 'internal instruments' (i.e., differences of the lags of endogenous variables ΔCPP^{ρ}_{it-2} and PTA^{j}_{it}) were used to address the endogeneity of the lagged regressor CPP_{it} and the PTA variables (Blundell and Bond 1998; Sorgho and Tharakan 2022). As our dependent variable CPP^{ρ}_{it} is bounded between 0 and 1, we specify our estimation equations as an exponential fractional regression model following Ramalho et al. (2018).

4 | Data

Our analysis combines data from two main sources: one on environmental provisions in preferential trade agreements and another on indicators of climate change mitigation performance. This section discusses these data sources and provides descriptive statistics.

4.1 | PTAs and Environmental Provisions

We use the TRade and ENvironment Database (TREND) that systematically collects detailed information on PTAs and the different types of environmental provisions (EPs) they contain. TREND identifies close to 300 EPs in 775 trade agreements.[2] Following Morin and Jinnah (2018) and Sorgho and Tharakan (2022), we categorise EPs into those that address climate change (directly and indirectly) and those that address other environmental issues. But we take our approach a step further and make a stricter distinction between PTAs that directly address climate change and those that only address general environmental concerns. We argue that, by joining PTAs that have direct climate change provisions, countries signal their willingness to consciously address climate change issues. Based on this categorisation of EPs, we classify PTAs into six categories as follows: (i) PTAs with EPs (PTAwEPs), (ii) PTAs without EPs (PTAwoEPs), (iii) PTAs with direct climate change provisions (PTAwDCPs), (iv) PTAs without direct climate change provisions (PTAwoDCPs), (v) PTAs with either direct or indirect climate change provisions (PTAwCPs) and (vi) PTAs without climate change provisions (PTAwoCPs).

Figure 2 shows the growth in the number of the different types of PTAs based on the categories outlined above. Overall, the number of PTAs and the share of PTAs with EPs has increased steadily since the early 1990s, but most of these PTAs do not directly address climate change issues. In 2021, only 144 out of the 775 PTAs (i.e., around 18.63%) directly addressed climate change. Moreover, it was only in 1979 that PTAs began to include direct provisions on climate change. Our work exploits this variation in the various types of environmental provisions in PTAs over time and across countries to assess how they affect environmental outcomes.

4.2 | Measuring Environmental Performance

The data for our climate protection performance measures (i.e., the CCPI and its components) are provided by Germanwatch

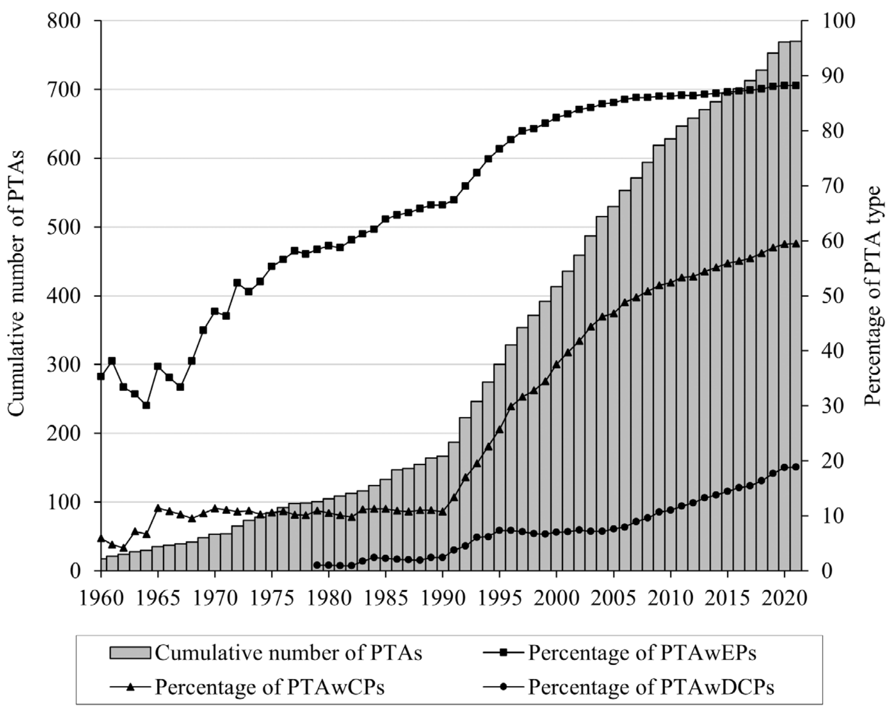

FIGURE 2 | Global evolution of PTAs by type. PTAs means preferential trade agreements; PTAwEPs means PTAs with environmental provisions; PTAwCPs means PTAs with climate change provisions that either directly or indirectly address climate change issues; PTAwDCPs means PTAs with climate change provisions that directly address climate change issues. *Source:* Authors' calculations based on data from TRade and ENvironment Database (TREND).

e.V. The CCPI examines 14 indicators in four categories using standardised criteria: 40% for GHG emissions, 20% for renewable energy, 20% for energy efficiency and 20% for climate policy. While the climate policy component qualitatively captures the most recent developments in national and international climate policy frameworks that a country is pursuing in its efforts to address climate change, the energy use component accounts for improvements in energy efficiency that are essential to achieving global decarbonisation and overall greenhouse gas neutrality by mid-century (Burck et al. 2023). Similarly, the renewable energy component captures the critical role that the substitution of fossil fuels with renewable energy plays in transforming an economic system towards limiting global warming to 1.5°C in a cost effective manner.[3]

Countries' progress in enacting and/or implementing policies aimed at achieving the goals of the Paris Agreement[4] is assessed using the CCPI's climate policy section. Broadly speaking, the index captures how climate policy, when effective, affects energy efficiency and renewable energy, ultimately leading to reductions in GHG emissions over time (Burck et al. 2023) and thus improvements in protecting the environment from climate change. Higher scores on the index (and its components) signify that a country performed better in terms of protecting its environment and climate. The data cover 57 countries over the period 2006 to 2019. Overall, global climate protection performance has been modest, with mean CCPI scores of around 50% (see Figure 3). In terms of CCPI components, Figure 3, for example, shows that countries around the world generally experienced great improvements in energy use (i.e., improvements in energy efficiency, globally) and GHG emissions (i.e., reduced emissions of GHGs) between 2017 and 2018. The data also show that climate protection performance is not entirely determined by a country's development status (Figure 4 below). For example, Morocco (a developing country) outperforms developed countries such as Australia and the United States of America.

To provide broader and robust evidence (i.e., based on more countries) on how well countries perform in terms of climate change performance, environmental health and ecosystem vitality, we complement our analyses on CCPI using data on the Environmental Performance Index. These data come from the Socioeconomic Data and Applications Center (SEDAC).[5] Using standardised criteria, the EPI evaluates 58 performance indicators across 11 issue categories (for details see Figure S2 in Appendix S1) in three policy objectives: climate change (30% of the overall score),[6] environmental health (25%),[7] and ecosystem vitality (45%)[8] (Block et al. 2024). A higher EPI score indicates that a country is doing a better job of protecting its environment and climate. Overall, EPI scores vary widely, ranging from 0.184 in Mali to 0.935 in Iceland, with a mean of 0.560 (Table 1). For details on the variations in mean EPI scores across countries over the sample period, see Figure S3 in Appendix S1. The standardised nature of both the CCPI and EPI minimises measurement errors and related potential bias.

4.3 | Other Data Sources

The rest of the variables used in the empirical analyses come from different sources. Data on GDP per capita, population, investment and population growth rate are from the World Bank's World Development Indicators (WDI) whereas the human capital index comes from the Penn World Table version 10.01 (Feenstra et al. 2015). Bilateral trade flows and gravity variables (i.e., bilateral distance, contiguity, colonial relationship and common language) are from the Base pour l'Analyse du Commerce International (Gaulier and Zignago 2010). Data on

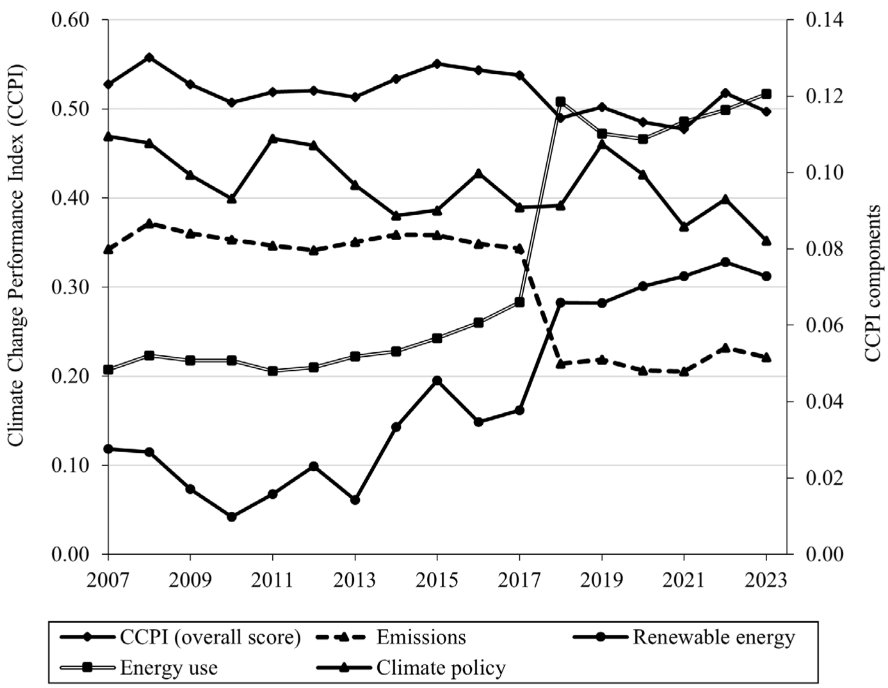

FIGURE 3 | Global trends in Climate Change Performance Index and its components from 2007 to 2023. The primary vertical axis captures scores for overall CCPI and emissions while scores for climate policy, renewable energy (i.e., increased renewable energy use) and energy use (i.e., improved energy efficiency) are on the secondary y-axis. *Source:* Authors' calculations based on data from Germanwatch e.V.

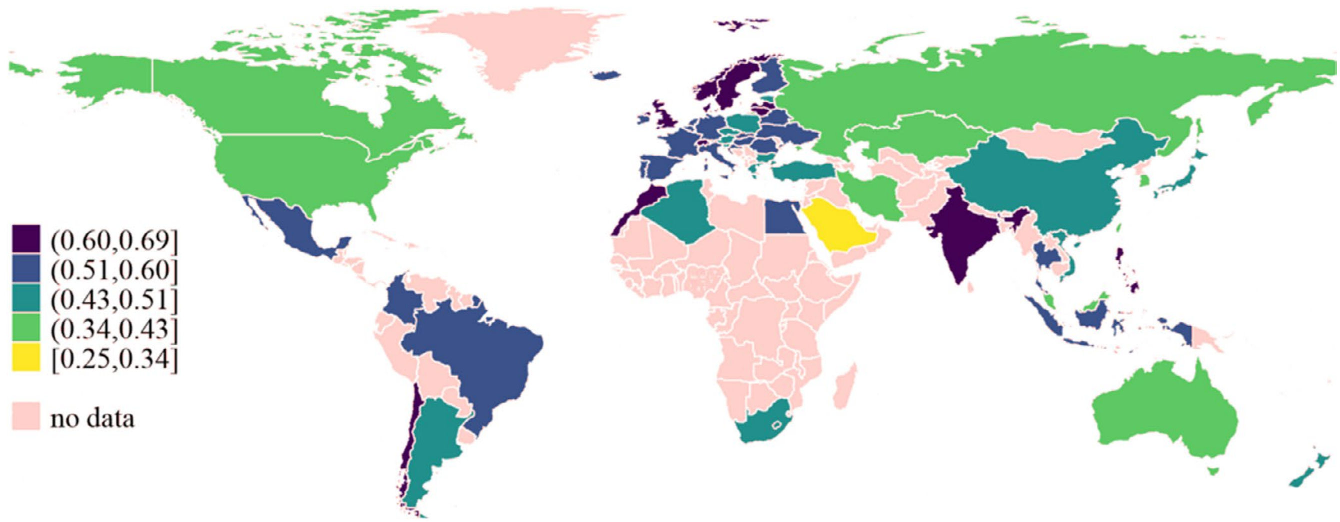

FIGURE 4 | Variations in mean CCPI scores across countries over the sample period. The darker shade (from yellow to purple), the larger the average CCPI score. Pink-shaded regions refer to missing data (i.e., where CCPI is not tracked). *Source:* Authors' illustration based on data from Germanwatch e.V.

the democracy index comes from the Economic Intelligence Unit. Table S4 defines our key variables and outlines the data and data sources we used in our econometric estimations, while Table 1 presents the summary statistics.

5 | Results and Discussion

5.1 | Benchmark Regression Analysis

Our main results are presented in Column (1) of Table 2 and suggest that international trade cooperation through PTAs enhances a country's ability to mitigate and adapt to climate change. The results show that the number of PTAs with EPs is positively associated with a statistically significant increase in the Climate Change Performance Index (CCPI). Specifically, a unit increase in the number of PTAs with EPs is associated with a 0.017 percentage points increase in the CCPI. This result is quite significant considering that real-world climate change policies have produced negligible impacts. For instance, empirical evidence shows that the Paris Agreement reduced CO_2 emissions by roughly 1% between 1995 and 2019 in France, Spain and Germany (Sadr et al. 2022). Eskander and Fankhauser (2020) also found that each new climate law, on average, resulted in an annual reduction of CO_2 emissions per unit of GDP by 0.78% and 1.79% in the short-term and long-term, respectively. On the contrary, PTAs without EPs are associated with a reduction in the CCPI, although the coefficient present high standard errors and thus not statistically significant at conventional levels. As a form of sensitivity analyses, we analyse whether our findings are influenced by potential phase-in effects of the targeted trade policy, specifically the environmental provisions in PTAs. To do this, we use 1- and 2-year lags of the variables of interest, and the results are presented in Tables S5 and S6, respectively. We find no evidence of phase-in effects.[9] Moreover, we use the Kernel Regularised Least Squares (KRLS) estimator to analyse the robustness of our main results to the choice of estimator. The results presented in Tables S10 and S11 in Appendix S1 show that our main results are consistent across the two estimators.

To assess the channels through which the PTAs with EPs affect environmental performance, we assess how it affects the different components that make up the CCPI. The results are presented in Columns (2)–(5) of Table 2. We find that PTAs with environmental provisions have a positive effect on GHG emissions reduction, energy efficiency and climate policy. Moreover, PTAs without environmental provisions significantly undermine performance in areas such as climate policy. These results suggest that the significant positive effect of PTAs with environmental provisions on climate change mitigation is driven by improvements in domestic environmental and climate policy initiatives and energy efficiency as well as reductions in GHG emissions.

As expected, we find that all coefficients on the lag of the outcome variables (i.e., CPP^{ρ}_{it}) are positive and statistically significant. This implies that a country's capacity to address climate change depends in part on the effectiveness of its past efforts. We further observe that all coefficients on trade openness are positive except for GHGs emissions and improved energy efficiency. On the one hand, the negative and statistically significant effect of trade openness on GHGs emissions (Column (2) of Table 2) implies that countries that trade more tend to have higher levels of GHGs emissions. This is consistent with the findings of Sorgho and Tharakan (2022) that trade openness increases emissions of CH_4 and CO_2. On the other hand, the positive effect of trade openness on renewable energy (Column (3), Table 2) suggests that countries that are more open use more renewable energy. These results indicate that increased trade openness can benefit or hurt a country's climate change mitigation efforts depending on the size and interactions among the scale, composition and technique effects (Copeland and Taylor 2004; Grossman and Krueger 1991; Managi et al. 2009). Except for energy efficiency, all coefficients on the income

TABLE 1 | Descriptive statistics for selected variables.

	N	Mean	SD	Min	Max
Climate related variables					
CCPI (overall score)	983	0.518	0.105	0.088	0.796
Emissions	983	0.304	0.090	0.093	0.466
Renewable energy	983	0.042	0.034	0	0.194
Energy efficiency	983	0.075	0.037	0.006	0.187
Climate policy	983	0.097	0.042	0	0.200
EPI (overall score, [0 1])	1779	0.560	0.127	0.184	0.935
Environmental health	1959	0.625	0.276	0.001	0.999
Climate and energy	1737	0.498	0.226	0.002	0.998
PTA variables					
All PTAs	1840	27.118	24.164	1	113
PTAwEPs	1840	24.942	23.406	1	110
PTAwoEPs	1840	2.177	2.459	0	16
PTAwCPs	1840	17.299	16.121	0	77
PTAwoCPs	1840	9.819	10.262	0	41
PTAwDCPs	1840	8.980	11.401	0	57
PTAwoDCPs	1840	18.138	14.705	1	60
Auxiliary data					
Trade (annual total, billion current US$)	1840	239.390	512.145	0.413	4235.529
Trade openness (%)	1840	88.848	58.852	1.219	442.620
GDP per capita (000 constant 2017 US$)	1840	21.635	21.758	0.730	120.648
Investment rate (%)	1840	24.611	7.720	1.571	79.401
Population growth (annual %)	1840	1.456	1.649	−2.258	5.320
Population (million)	1840	51.742	165.715	0.304	1407.745
Population density (people/km^2)	1840	254.406	887.120	1.657	7965.878
Human capital index	1840	2.584	0.702	1.126	4.352
Democracy index (ranging from 0 to 1)	1840	0.590	0.211	0.113	0.993
GHGs emissions (annual total, teratonnes)	1826	340.308	1243.764	1.557	14,300
Bilateral distance (000 km)	1,210,282	8.557	4.712	0.002	19.939
Contiguity (Yes = 1)	1,210,282	0.013	0.112	0	1
Colonial relationship (Yes = 1)	1,210,282	0.188	0.390	0	1
Common language (Yes = 1)	1,210,282	0.006	0.079	0	1

Note: Equality between observed and predicted trade values is not a mistake. PTAwEPs means PTAs with environmental provisions; PTAwoEPs means PTAs without environmental provisions; PTAwCPs means PTAs with climate change provisions; PTAwoCPs means PTAs without climate change provisions; PTAwEPwoCPs means PTAs with environmental provisions but without climate change provisions.
Abbreviations: *N*, number of observations; SD, standard deviation.
Source: Authors' calculations based on data from Germanwatch e.V., Socioeconomic Data and Applications Center (SEDAC), TRade and ENvironment Database (TREND), Base pour l'Analyse du Commerce International (BACI), World Bank's World Development Indicators (WDI), Penn World Table version 10.01 and Economic Intelligence Unit (EIU).

variable (i.e., GDP per capita) are positive whenever they are statistically significant. This implies that countries with high income levels have more capacity to reduce GHGs emissions and increase the use of renewable. They can invest in green production technologies to reduce their carbon footprints and/or import more environmental goods. Population density is negatively associated with all our outcome variables. The same is true for the democracy index. As such, climate change

TABLE 2 | Effects of environmental provisions in PTAs on climate change mitigation.

Dependent variable	CCPI (1)	Emissions reduction (2)	Increased renewable energy (3)	Improved energy efficiency (4)	Climate policy (5)
$PTAwoEP_{it}$	−0.010	0.080	−0.077	−0.323	−0.182***
	(0.037)	(0.169)	(0.132)	(0.268)	(0.050)
$PTAwEP_{it}$	0.017***	0.004***	−0.001	0.031***	0.036***
	(0.005)	(0.001)	(0.009)	(0.011)	(0.009)
CPP^{ρ}_{it-1}	0.158**	0.501***	0.105***	−0.120***	0.534***
	(0.089)	(0.113)	(0.311)	(0.193)	(0.084)
$\log Openness_{it}$	0.079	−0.453***	0.040**	−0.668*	0.358
	(0.214)	(0.160)	(0.022)	(0.352)	(0.223)
$\log GDPcap_{it}$	0.506	0.807**	0.034**	0.828	0.797*
	(0.533)	(0.391)	(0.017)	(0.494)	(0.483)
$\log Popdensity_{it}$	−0.478*	−0.576***	−0.048	0.206	−0.493*
	(0.272)	(0.206)	(0.113)	(0.174)	(0.283)
$Demoindex_{it}$	−2.853***	−4.633***	−0.399	−0.221	−3.422***
	(1.003)	(1.401)	(0.923)	(1.109)	(0.530)
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	727	727	727	727	727
Countries	57	57	57	57	57
Hansen test (Prob)	0.117	0.123	0.128	0.166	0.137

Note: CCPI means Climate Change Performance Index. $PTAwoEP_{it}$ is the number of preferential trade agreements without environmental provisions in force for country i in year t. $PTAwEP_{it}$ is the number of PTAs with environmental provisions. Standard errors, clustered at the country level, are in parentheses. ***, ** and *Significance at 1%, 5% and 10%, respectively. Intercepts included but not reported for brevity. The Hansen test results fail to reject the validity of the instruments. All models are estimated using two-step system generalised method of moments.

mitigation performance decreases with increasing levels of democracy.[10]

5.2 | Accounting for Climate-Specific Provisions

The effects of environmental provisions on environmental quality outcomes also depend on the heterogeneity of the specific environmental provisions included in the trade agreements (Blümer et al. 2020; Brandi et al. 2020). To assess whether this heterogeneity matters for climate change mitigation, we categorise the EPs included in a trade agreement into direct, indirect and neutral (i.e., neither address climate change issues directly nor indirectly) climate change provisions. For instance, Article V of the PTA signed between China and Singapore in 2008 prescribes standards on the promotion of renewable production of energy and energy efficiency. This is an example of a PTA with direct climate change provisions. An example of a PTA that includes indirect climate change provisions is the trade agreements signed between Mexico and Panama in 2014, which provide measures that call for the conservation of natural resources and the establishment of contact points on environmental matters. Based on this classification, we categorise PTAs into four groups: (i) PTAs with direct climate change provisions (PTAwDCPs), (ii) PTAs without direct climate change provisions (PTAwoDCPs), (iii) PTAs with climate change provisions (PTAwCPs) and (iv) PTAs without climate change provisions (PTAwoCPs). By specifically focusing on PTAs that have EPs that address climate change issues, this allows us to assess whether the explicit inclusion of climate change provisions in PTAs matters for climate change mitigation.

We present the results in Table 3. The estimates in Column (1) of Table 3 show that PTAs with any form of climate change provisions (i.e., the provisions address climate change issues directly and/or indirectly) are associated with a positive and statistically significant effect on climate change mitigation. Specifically, a one unit increase in the number of such PTAs is associated with a 0.17 percentage point increase in the CCPI. We find, however, that PTAs with environmental provisions that directly address climate change issues are associated with an even larger positive effect on climate protection performance (Column (2)) with a unit increase in the number of such PTAs leading to a 0.45 percentage point increase in the CCPI. In essence, to achieve greater climate change mitigation

TABLE 3 | Effects of direct climate change provisions on climate change mitigation.

	CCPI		Emissions reduction		Increased renewable energy use		Improved energy efficiency		Climate policy	
Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
$PTAwoCP_{it}$	−0.002		−0.040**		0.014		0.021		0.004**	
	(0.025)		(0.020)		(0.015)		(0.016)		(0.002)	
$PTAwCP_{it}$	0.017***		0.024***		−0.006		0.019**		0.002**	
	(0.006)		(0.001)		(0.010)		(0.008)		(0.001)	
$PTAwoDCP_{it}$		−0.015		0.050***		0.028		0.049***		0.061
		(0.043)		(0.017)		(0.029)		(0.016)		(0.057)
$PTAwDCP_{it}$		0.045**		0.008**		−0.008		−0.004		0.010
		(0.023)		(0.003)		(0.010)		(0.009)		(0.014)
CPP^{ρ}_{it-1}	0.263***	0.244***	0.436***	0.180***	0.149***	0.137***	−0.132***	−0.116***	0.445***	0.437***
	(0.040)	(0.041)	(0.050)	(0.067)	(0.522)	(0.045)	(0.152)	(0.013)	(0.148)	(0.100)
$\log Openness_{it}$	0.312	0.269	−0.425	−0.128	0.151**	0.005	−0.543**	−0.289	0.191	0.232
	(0.236)	(0.247)	(0.348)	(0.349)	(0.009)	(0.296)	(0.229)	(0.227)	(0.457)	(0.221)
$\log GDPcap_{it}$	−0.294	−0.127	1.320	0.417	0.048**	0.071	0.676*	0.458	−0.044	1.011**
	(0.597)	(0.639)	(0.844)	(1.047)	(0.029)	(0.313)	(0.383)	(0.360)	(0.424)	(0.515)
$\log Popdensity_{it}$	0.090	0.117	0.272	−0.789***	−0.065	−0.086	0.167	0.192	0.075	−0.213
	(0.167)	(0.212)	(0.187)	(0.220)	(0.121)	(0.129)	(0.130)	(0.146)	(0.132)	(0.259)
$Demoindex_{it}$	−0.977	0.324	−0.067	−0.158	−0.971	−0.230	−0.118	−1.512*	0.914	−2.993***
	(1.133)	(1.065)	(0.435)	(0.958)	(1.102)	(1.071)	(0.850)	(0.775)	(1.363)	(0.838)
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	727	727	727	727	727	727	727	727	727	727
Countries	57	57	57	57	57	57	57	57	57	57
Hansen test (Prob)	0.133	0.107	0.202	0.269	0.264	0.272	0.135	0.101	0.123	0.167

Note: CCPI stands for the Climate Change Performance Index. $PTAwoCP_{it}$ is the number of preferential trade agreements (PTAs) that do not include environmental provisions addressing climate change-related issues (directly, indirectly or both) and are in force in country i in year t. $PTAwCP_{it}$ is the number of PTAs that include environmental provisions addressing climate change-related issues (directly, indirectly or both). $PTAwoDCP_{it}$ is the number of PTAs that do not include environmental provisions that directly address climate change-related issues. $PTAwDCP_{it}$ is the number of PTAs that include environmental provisions that directly address climate change-related issues. Standard errors, clustered at the country level, are in parentheses. ***, ** and *Significance at the 1%, 5% and 10% levels, respectively. Intercepts, as well as country and year fixed effects, are included but not reported for brevity. The Hansen test results fail to reject the validity of the instruments. All models are estimated using the two-step system generalised method of moments (GMM).

outcomes, the EPs included in the PTAs must address climate change issues precisely.

In terms of channels through which different types of EPs in PTAs influence the overall climate change mitigation performance, we find that PTAs with climate change provisions that address climate change issues more broadly are associated with significant positive effects on GHG emissions (i.e., reduce GHGs emission) (Column (3)), energy efficiency (Column (7)) and climate policy (Column (9)). Moreover, PTAs that do not have any climate change provisions are associated with significant negative and positive effects on GHG emissions reduction efforts (i.e., increase GHGs emissions) and climate policy, respectively. On climate policy, our findings in Column (9) indicate that enhanced international trade collaboration through PTAs can facilitate the adoption and implementation of environmental and climate policies, irrespective of whether the provisions within the agreement specifically address climate change.

The positive direct effect of PTAs with climate change provisions on CCPI, GHG emissions, energy efficiency and climate policy supports the conclusion by Sorgho and Tharakan (2022) that the inclusion of climate change-related provisions in PTAs can have an overall positive effect on environmental quality. Our work is, however, novel in showing that we achieve even larger positive effects when the provisions on climate change are direct and explicit. The results are presented in the even-numbered columns of Table 3. We find that PTAs with climate change provisions that directly address climate change issues are associated with an overall significant positive effect on climate change mitigation and GHG emissions (Columns (2) and (4)). We also observe that PTAs without direct climate change provisions are associated with increased GHG emissions and improved energy efficiency (Columns (4) and (8)).

5.3 | Alternative Measures of Climate Performance

Our findings so far confirm the positive effects of PTAs with EPs on climate change mitigation. The use of the CCPI index allows us to capture climate change effects more broadly, but the downside is that the CCPI covers a limited set of countries, which calls into question the generalisability of our findings. To address this concern and provide a broader and more robust evidence on how different types of PTAs affect environmental quality outcomes, we measure climate change mitigation using alternative indicators.

5.3.1 | Environmental Performance Index

Our first alternative measure of climate change mitigation is the Environmental Performance Index (EPI) and its components (i.e., environmental health, and climate and energy). The EPI covers 180 countries. Specifically, we estimate Equation (1) but replace the outcome variable CCPI with EPI. The results are presented in Table 4. First, we assess whether EPs matter for climate change mitigation and present the results in Columns (1), (4) and (7). Consistent with our findings in Table 2, we find that PTAs with environmental provisions have a positive effect on EPI, but also its components—environmental health and climate and energy. PTAs without EPs, however, have no discernible effects on EPI and climate and energy, but have a negative effect on environmental health. The significant positive direct effect of PTAs with EPs on the three environmental quality indicators reaffirms our main findings and the notion that the inclusion of environmental provisions in trade agreements could be an effective trade policy instrument in the existential fight against climate change and other environmental issues (Abman et al. 2024; Brandi et al. 2020; Sorgho and Tharakan 2022).

Consistent with Section 5.2, we also examine whether the climate change mitigation effects of PTAs depend on whether the provisions address climate change directly or indirectly. In Columns (2), (5) and (8), PTAs with climate change provisions are associated with positive and statistically significant effects on EPI, environmental health and climate and energy. Moreover, PTAs without climate change provisions are negatively associated with all three environmental quality indicators. The results in Columns (3), (6) and (9) of Table 4 further show that PTAs with direct climate change provisions are associated with an overall significant positive effect on climate protections performance. Here, again, the effects of PTAs with direct climate change provisions on climate mitigation performance are larger in magnitude than the effects of PTAs with more broadly defined climate provisions.

5.3.2 | Emissions Data

There may be concerns about the objectivity of the different climate indices we use as some may argue that these indices often involve subjective weights and are influenced by country-specific factors, which may introduce measurement bias. To strengthen our claim that PTAs with EP improve climate change mitigation efforts, we use emissions by country data from the Emissions Database for Global Atmospheric Research (EDGAR) maintained by the European Commission.[11] The results are presented in Table 5. Consistent with our main results in Tables 2 and 3, we find that PTAs with EPs are associated significant decrease in GHGs emissions (i.e., CO_2 equivalents). The estimates also show that PTAs with the provisions that address climate change issues directly and/or indirectly are associated with a negative and statistically significant effects on GHGs emissions. These results replicate the findings of Sorgho and Tharakan (2022) and provide strong support for our paper's main claim that PTAs with EPs help improve climate change mitigation performance by reducing GHG emissions. This also reinforces the confidence that our results are not driven by the specific datasets and indices we employed.

5.4 | Heterogeneous Effects Across North–North, North–South and South–South PTAs

The effectiveness of environmental regulations can be mitigated by several factors. For instance, the effectiveness of EPs in PTAs could depend on whether they are signed between developed (North), or developed and developing (South), or developing countries (Bastiaens and Postnikov 2017). Therefore,

TABLE 4 | Effects of environmental provisions in PTAs on environmental quality outcomes.

	Environmental Protection Index			Environmental health			Climate and energy		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$PTAwoEP_{it}$	0.009			−0.423***			−0.005		
	(0.064)			(0.061)			(0.057)		
$PTAwEP_{it}$	0.007**			0.026**			0.015**		
	(0.003)			(0.012)			(0.006)		
$PTAwoCP_{it}$		−0.020			−0.074***			−0.002	
		(0.025)			(0.028)			(0.016)	
$PTAwCP_{it}$		0.002**			0.057***			0.025***	
		(0.001)			(0.018)			(0.009)	
$PTAwoDCP_{it}$			−0.025*			−0.059*			0.013
			(0.015)			(0.031)			(0.012)
$PTAwDCP_{it}$			0.003**			0.147***			0.012**
			(0.001)			(0.051)			(0.004)
CPP^{ρ}_{it-1}	0.618***	0.461**	0.525**	0.543***	0.794***	0.226**	0.607***	0.671**	0.392***
	(0.221)	(0.225)	(0.246)	(0.076)	(0.019)	(0.114)	(0.130)	(0.333)	(0.065)
$\log Openness_{it}$	0.352***	0.330**	0.412***	0.216	0.616**	0.313***	−0.419**	−0.561***	−0.381**
	(0.135)	(0.134)	(0.128)	(0.332)	(0.278)	(0.118)	(0.204)	(0.202)	(0.192)
$\log GDPcap_{it}$	0.038	−0.054	−0.121	0.547	0.053**	0.787***	−0.484**	−0.562***	−0.515**
	(0.239)	(0.235)	(0.192)	(0.472)	(0.027)	(0.225)	(0.218)	(0.213)	(0.224)
$\log Popdensity_{it}$	−0.263	−0.114	−0.134	−0.060	−0.049	−0.349**	0.092	0.088	0.097
	(0.199)	(0.190)	(0.222)	(0.166)	(0.198)	(0.149)	(0.120)	(0.116)	(0.121)
$Demoindex_{it}$	0.036***	0.048***	0.043***	0.024***	0.035***	0.046***	0.026***	0.038***	0.046***
	(0.011)	(0.010)	(0.009)	(0.007)	(0.005)	(0.012)	(0.006)	(0.004)	(0.005)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	787	787	787	905	905	905	794	794	794
Countries	114	114	114	132	132	132	115	115	115
Hansen test (Prob)	0.162	0.163	0.155	0.148	0.123	0.173	0.141	0.142	0.153

Note: $PTAwoEP_{it}$ is the number of preferential trade agreements (PTAs) that do not have environmental provisions and are in force in country i in year t. $PTAwEP_{it}$ is the number of PTAs that have environmental provisions. $PTAwoCP_{it}$ is the number of PTAs that do not have environmental provisions addressing climate change-related issues either directly, indirectly or both, and are in force in country i in year t. $PTAwCP_{it}$ is the number of PTAs that have environmental provisions addressing climate change-related issues either directly, indirectly or both. $PTAwoDCP_{it}$ is the number of PTAs that do not have environmental provisions directly addressing climate change-related issues, while $PTAwDCP_{it}$ is the number of PTAs that have environmental provisions directly addressing climate change-related issues. Standard errors, clustered at the country level, are in parentheses. ***, ** and *Significance at the 1%, 5% and 10% levels, respectively. Intercepts, as well as country and year fixed effects, are included but not reported for brevity. The Hansen test results fail to reject the validity of the instruments. All models are estimated using the two-step system generalised method of moments.

we extend our analyses and examine whether the climate change mitigation effects of EPs in PTAs vary between South and South PTAs, North and North PTAs and North and South PTAs. We use the United Nations Conference on Trade and Development classification to divide countries into two mutually exclusive and collectively exhaustive groups: North and South (Hoffmeister 2020, see also Table S3). We then split up PTAs based on whether they were signed between South and South, North and North or North and South countries and estimate Equation (1) on these sub-samples. In this section, our analysis is limited to the EPI, rather than the CCPI, due to the former's larger sample size of developed and developing

TABLE 5 | Effects of environmental provisions in PTAs on GHGs emissions (CO_2 equivalents).

Dependent variable	CO_2 equivalents (1)	CO_2 equivalents (2)	CO_2 equivalents (3)
$PTAwoEP_{it}$	0.033		
	(0.035)		
$PTAwEP_{it}$	−0.004***		
	(0.001)		
$PTAwoCP_{it}$		0.008	
		(0.021)	
$PTAwCP_{it}$		−0.004***	
		(0.002)	
$PTAwoDCP_{it}$			−0.008
			(0.020)
$PTAwDCP_{it}$			−0.002***
			(0.001)
CPP_{it-1}	0.900***	0.905***	0.909***
	(0.031)	(0.033)	(0.035)
$\log Openness_{it}$	−0.076	−0.101	−0.027
	(0.084)	(0.066)	(0.073)
$\log GDPcap_{it}$	0.072**	0.068**	0.101**
	(0.035)	(0.040)	(0.034)
$\log Popdensity_{it}$	−0.055**	−0.070**	−0.054**
	(0.027)	(0.026)	(0.018)
$Demoindex_{it}$	−0.279***	−0.240***	−0.022***
	(0.043)	(0.049)	(0.009)
Country fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	1826	1826	1826
Countries	132	132	132
Hansen test (Prob)	0.119	0.125	0.115

Note: $PTAwoEP_{it}$ is the number of preferential trade agreements (PTAs) that do not have environmental provisions and are in force in country i in year t. $PTAwEP_{it}$ is the number of PTAs that have environmental provisions. $PTAwoCP_{it}$ is the number of PTAs that do not have environmental provisions that address climate change-related issues either directly, indirectly or both, and are in force in country i in year t. $PTAwCP_{it}$ is the number of PTAs that have environmental provisions that address climate change-related issues either directly, indirectly or both. $PTAwoDCP_{it}$ is the number of PTAs that do not have environmental provisions that directly address climate change-related issues, while $PTAwDCP_{it}$ is the number of PTAs that have environmental provisions that directly address climate change-related issues. Standard errors, clustered at the country level, are in parentheses. ***, ** and *Significance at the 1%, 5% and 10% levels, respectively. Intercepts are included but not reported for brevity. The Hansen test results fail to reject the validity of the instruments. All models are estimated using the two-step system generalised method of moments (GMM).

countries, which provides sufficient variation for analysis. The results are presented in Table 6 (see Tables S7–S9 in Appendix S1 for detailed results).

The top panel of Table 6 assesses the effects of PTAs with some form of climate provisions on climate change mitigation, while the lower panel assesses the effects of PTAs with direct climate change provisions. Consistent with our findings presented in Table 4, we find that PTAs with climate change provisions are associated with positive and significant effects on EPI, environmental health and climate and energy irrespective of the development status of the signatories. The same is true for PTAs with direct climate change provisions. The magnitudes of the estimated effects are, however, larger for PTAs with direct climate change provisions. We also observe that climate change provisions have larger climate change mitigation effects in North–South PTAs than in either North–North or South–South PTAs. Moreover, North–North PTAs without climate change

TABLE 6 | Effects of climate-change related environmental provisions on environmental quality outcomes.

Dependent variable	North–North PTAs EPI (1)	North–North PTAs Env. health (2)	North–North PTAs Climate & energy (3)	North–South PTAs EPI (4)	North–South PTAs Env. health (5)	North–South PTAs Climate & energy (6)	South–South PTAs EPI (7)	South–South PTAs Env. health (8)	South–South PTAs Climate & energy (9)
Panel a									
$PTAwoCP_{it}$	−0.021	−0.042	−0.043	0.014	−0.018	0.023	0.058	0.018	0.026
	(0.028)	(0.051)	(0.036)	(0.137)	(0.088)	(0.049)	(0.053)	(0.047)	(0.046)
$PTAwCP_{it}$	0.031***	0.052**	0.023***	0.080**	0.271***	0.017**	0.011**	0.037***	0.010**
	(0.004)	(0.026)	(0.008)	(0.036)	(0.052)	(0.008)	(0.005)	(0.008)	(0.004)
Hansen test (Prob)	0.194	0.165	0.159	0.201	0.125	0.150	0.144	0.155	0.140
Panel b									
$PTAwoDCP_{it}$	−0.006	−0.026	0.102***	0.066**	0.122**	−0.002	0.012	0.024***	0.002
	(0.028)	(0.032)	(0.020)	(0.027)	(0.048)	(0.025)	(0.032)	(0.007)	(0.031)
$PTAwDCP_{it}$	0.180***	0.063**	0.103***	0.079***	0.096***	0.042***	0.363***	0.247***	0.162**
	(0.063)	(0.028)	(0.025)	(0.019)	(0.027)	(0.012)	(0.141)	(0.041)	(0.087)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	298	298	298	731	841	738	490	607	497
Countries	43	43	43	106	123	107	71	89	72
Hansen test (Prob)	0.167	0.134	0.263	0.140	0.136	0.179	0.151	0.153	0.162

Note: EPI refers to the Environmental Performance Index. $PTAwoCP_{it}$ is the number of preferential trade agreements (PTAs) that do not have environmental provisions addressing climate change-related issues either directly, indirectly or both, and are in force in country i in year t. $PTAwCP_{it}$ is the number of PTAs that have environmental provisions addressing climate change-related issues either directly, indirectly or both. $PTAwoDCP_{it}$ is the number of PTAs that do not have environmental provisions directly addressing climate change-related issues, while $PTAwDCP_{it}$ is the number of PTAs that have environmental provisions directly addressing climate change-related issues. Standard errors, clustered at the country level, are in parentheses. ***, ** and *Significance at the 1%, 5% and 10% levels, respectively. Intercepts, as well as country and year fixed effects, are included but not reported for brevity. The Hansen test results fail to reject the validity of the instruments. All models are estimated using the two-step system generalised method of moments (GMM).

provisions are negatively associated with all three environmental quality indicators but the effects are statistically non-significant. On the contrary, North–South and South–South PTAs without climate change provisions are generally associated with non-significant positive effects on EPI, environmental health and climate and energy.

We further assess whether environmental provisions that directly address climate change-related issues have heterogeneous environmental quality effects across North–North, North–South and South–South PTAs and present the results in panel b of Table 6. We find that PTAs with direct climate change provisions are associated with significant positive effects on all environmental quality indicators. This further reaffirms that PTAs with direct climate change provisions can contribute to improving environmental sustainability. We also observe that direct climate change provisions have larger environmental quality-promoting effects in South–South PTAs than in either North–North or North–South PTAs. In addition, North–North PTAs without direct climate change provisions are associated with significant positive effects on climate and energy. Moreover, North–South PTAs and South–South PTAs without direct climate change provisions are generally positively associated with all three environmental quality indicators but the effects are significant for EPI and environmental health.

6 | Policy Implications

Our findings offer clear guidance for policymakers who want to integrate climate goals into trade policy. First, our results show that PTAs with environmental provisions, particularly those that directly address climate change, can significantly contribute to climate change mitigation. This underscores the need for policymakers to move beyond generic environmental language and prioritise the inclusion of concrete, enforceable climate-related commitments in trade agreements.

Our findings complement prior studies (e.g., Baghdadi et al. 2013; Martínez-Zarzoso and Oueslati 2018; Sorgho and Tharakan 2022; Zhou et al. 2017) that link EPs in PTAs to improved environmental outcomes such as reduced greenhouse gas emissions. However, our work emphasises that the effectiveness of PTAs depends on their design; to effectively support climate goals, PTAs must incorporate specific climate change provisions. Policymakers should focus on negotiating PTAs that include specific, measurable and enforceable climate provisions.

As global trade in the past three decades has lifted millions out of poverty, keeping food markets open to trade remains crucial for global food security (Anderson 2022; Brown et al. 2017). As preferential trade agreements proliferate, they need to be deepened to ensure that food systems remain sustainable. Our findings show that deep trade agreements with environmental provisions have positive effects on climate change mitigation. This suggests that the inclusion of environmental provisions in trade agreements could be an effective trade policy instrument in the existential fight against climate change. By joining trade agreements that have environmental provisions, countries are more likely to put environmental issues at the center of trade and environmental policy debates, leading to improved domestic environmental (climate) policy formulation and regulation and improved climate change mitigation efforts.

Evolving carbon market mechanisms—such as the EU's Carbon Border Adjustment Mechanism—highlight the growing intersection between trade and climate policy. As carbon pricing schemes become more widespread, aligning PTA provisions with these mechanisms could ensure coherence and avoid regulatory conflict. EPs can also provide a platform for mutual recognition of standards and help harmonise approaches across countries.

7 | Conclusion

International trade and climate change are intricately intertwined. While climate change can have enormous negative effects on international trade (e.g., by increasing trading costs, disrupting production and supply chains; World Trade Organisation 2022), international trade can also worsen climate change effects by contributing to deforestation (Abman et al. 2024; DeFries et al. 2010; Leblois et al. 2017), loss of biodiversity (Bjelle et al. 2021; Chaudhary and Brooks 2019; Lenzen et al. 2012; Marques et al. 2019; Wilting et al. 2021) and increased emissions of carbon and GHGs (Zu Ermgassen et al. 2020; Johansson et al. 2020; Karstensen et al. 2013; Saikku et al. 2012). However, trade and well-designed trade policies remain crucial avenues for mitigating and adapting to climate change (World Trade Organisation 2022). But, do targeted trade policy instruments such as environmental provisions in trade agreements contribute to improved climate protection performance?

In this study, we analyse the effects of environmental provisions and climate change provisions in PTAs on environmental quality. We use the Climate Change Performance Index and the Environmental Performance Index to objectively measure cross-country differences in addressing climate change and other environmental issues. We assess how heterogeneous environmental provisions in PTAs affect environmental quality outcomes. Our primary contribution is to provide comprehensive direct evidence on the effects of the heterogeneity of environmental and climate change provisions in PTAs on climate change mitigation.

We use an autoregressive panel data model to estimate the effects of including environmental provisions and climate change provisions in PTAs on climate protection performance controlling for scale, composition and technique effects. We address potential endogeneity concerns using dynamic panel data estimation techniques and instrumental variables approaches. We find that, ceteris paribus, the inclusion of environmental provisions and climate change provisions in PTAs enhances a country's performance in improving its environmental health, ecosystem vitality and adapting to and mitigating climate change. The environmental quality–enhancing effects are primarily driven by gains in the areas such as emissions, renewable energy and climate policy. Moreover, PTAs that have direct climate change provisions (i.e., directly address climate change issues) have larger effects on climate protection performance, environmental health and ecosystem vitality than PTAs that either address environmental issues in general and/or indirectly address climate change issues. It is important that trade agreements should include climate change provisions if they are to be an effective strategy for dampening potential negative environmental quality effects of trade and/or directly mitigating and adapting to climate change or addressing other environmental issues. Moreover, these should be complemented by effective political institutions.

Our analysis contributes to the contentious debate on trade, trade policy and climate change and their implications for environmental and economic sustainability. Our results also inform the design of future deep PTAs (or modification of the existing PTAs) that seek to address specific issues of concern such as climate governance. Although our findings have important implications for environmental- and climate protection, trade- and environmental policy, we recognise they could be limited in three ways. First, data on our main outcome variable (i.e., CCPI) is limited to selected countries that contribute to over 90% of global GHG emissions. These countries are most likely different from most countries that are not tracked by the index which might limit the external validity of our results. However, we complement our CCPI analyses with analyses based on the Environmental Performance Index to address the limited sample coverage problem and enhance the external validity of our results. Second, we independently modelled and estimated the effects of environmental provisions and climate change provisions on the four components of the CCPI by assuming that they are statistically independent. Finally, the effects of EPs and CPs likely vary by sector. However, due to data limitations, we could not test this hypothesis. While our country-level analysis provides valuable insights, it likely misses out on the nuances that transpire at granular levels.[12]

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

For legal reasons, we cannot share the data on our main outcome variable—the Climate Change Performance Index.

Endnotes

[1] PTAwCPs comprise all PTAs that have environmental provisions that address climate change related issues either directly, indirectly, or both while PTAwDCPs consist of all PTAs that have EPs that directly tackle climate change related issues. Thus, PTAwDCPs is a subset of PTAwCPs.

[2] Most trade agreements incorporate enforcement clauses in addition to the environmental provisions to ensure that signatory countries implement the stipulations of the environmental provisions. These enforcement mechanisms not only stipulate punitive measure against inaction or misaction but also dispute resolutions mechanisms in case of disagreements between the signatory countries.

[3] See Figure S1 in Appendix S1 for a detailed description of the components that make up the CCPI.

[4] This is a historic global deal on climate change, adopted in December 2015 during the UN Climate Conference (COP21) held in Paris, France. It officially took effect on 4th November 2016. The agreement marked a major turning point, as nearly all countries in the world came together with a shared commitment: to tackle climate change and prepare for its impacts, all while working to keep global warming within safe limits. It seeks to Limit global warming to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C.

[5] Data available at https://sedac.ciesin.columbia.edu/data/collection/epi/sets/browse.

[6] Issue areas: climate change mitigation (30%).

[7] Issue areas: air quality (17%), sanitation and drinking water (5%), heavy metals (2%) and waste management (1%).

[8] Issue areas: biodiversity and habitat (25%), forests (5%), fisheries (2%), air pollution (6%), agriculture (3%) and waste water (4%).

[9] This also ensures that we take into account, in part, the possible staggered nature of policy adoption across different countries and trade agreements, which could lead to significant heterogeneity in the timing and magnitude of the policy's effects.

[10] Whereas, we find that democracy is negatively associated with environmental quality outcomes, we acknowledge that the empirical evidence on this relationship is rather mixed. Acheampong et al. (2022) show that high-level democracy indicators moderate energy consumption to increase carbon dioxide emissions in West Africa and Central Eastern Africa but not Sub-Saharan Africa and Southern Africa. Povitkina and Jagers (2022) show that the type of democracy matters for environmental policy outputs. They find that 'democracies with stronger deliberative features adopt more, but not necessarily stricter or more effective, environmental policies. Instead, democracies with stronger social-liberal features adopt both stricter and more effective policies'.

[11] https://edgar.jrc.ec.europa.eu.

[12] We are grateful to one of the anonymous reviewers for pointing this out.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Appendix S1:** ajar70057-sup-0001-AppendixS1.pdf.