

Onofrei, Mihaela; Fîrțescu, Bogdan; Cojocaru, Dana Claudia; Grosu, Maria; Boghicevici, Claudia

Article

Do anti-dumping measures count? The emissions adjustment in sustainable development policies

Economies

Provided in Cooperation with:

MDPI – Multidisciplinary Digital Publishing Institute, Basel

Suggested Citation: Onofrei, Mihaela; Fîrțescu, Bogdan; Cojocaru, Dana Claudia; Grosu, Maria; Boghicevici, Claudia (2024) : Do anti-dumping measures count? The emissions adjustment in sustainable development policies, *Economies*, ISSN 2227-7099, MDPI, Basel, Vol. 12, Iss. 12, pp. 1-24,
<https://doi.org/10.3390/economies12120348>

This Version is available at:

<https://hdl.handle.net/10419/329275>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by/4.0/>

Article

Do Anti-Dumping Measures Count? The Emissions Adjustment in Sustainable Development Policies

Mihaela Onofrei ¹, Bogdan Narcis Firțescu ¹, Dana Claudia Cojocaru ^{1,*}, Maria Grosu ¹
and Claudia Pantea (Boghicevici) ²

¹ Faculty of Economics and Business Administration, Alexandru Ioan Cuza University of Iași, Carol I Boulevard, No. 22, 700505 Iași, Romania; onofrei@uaic.ro (M.O.); firtescu@uaic.ro (B.N.F.); maria.grosu@uaic.ro (M.G.)

² Faculty of Business and Administration, Bucharest University of Economic Studies, 6 Piata Romana, 1st District, 010374 Bucharest, Romania; panteaclaudia24@stud.ase.ro

* Correspondence: claudia.cojocaru@uaic.ro

Abstract: Following the economic shocks of recent decades, characterized by the destabilization of markets and pressure on national economies, protectionist policies have seen a significant increase. Thus, anti-dumping has become a convenient and frequently used tool in the political game of trade. In the context of the transition toward a climate-neutral economy, anti-dumping measures have become a topic of great interest due to their indirect effects on CO₂ emissions. Often used to protect domestic industries from unfair trade practices, these measures influence trade and the geographical redistribution of production, contributing to the phenomenon of “carbon leakage”. By transferring emissions from countries with strict climate regulations to economies with more permissive standards, anti-dumping measures can undermine global efforts to reduce emissions. Trade policies are becoming, in this context, an important tool in regulating international trade. Consequently, the objective of this paper is to analyze the impacts of anti-dumping measures, primary energy consumption, and urbanization on CO₂ emissions in OECD countries for the period 2000–2021. The methodology used is based on dynamic A.R.D.L. models using panel data. Our results suggest that anti-dumping measures and primary energy consumption influence CO₂ emissions and are statistically significant, at least at the 10% level. The results of this study are useful to both policymakers and environmental authorities in developing trade policies that support both economic development and emission-reduction targets.

Keywords: emissions adjustment; anti-dumping measures; sustainable development; environmental policies; economic factors



Citation: Onofrei, Mihaela, Bogdan Narcis Firțescu, Dana Claudia Cojocaru, Maria Grosu, and Claudia Pantea (Boghicevici). 2024. Do Anti-Dumping Measures Count? The Emissions Adjustment in Sustainable Development Policies. *Economies* 12: 348. <https://doi.org/10.3390/economies12120348>

Academic Editor: Sajid Anwar

Received: 17 October 2024

Revised: 9 December 2024

Accepted: 11 December 2024

Published: 17 December 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

In recent years, climate change caused by human activities has become one of the most pressing environmental policy issues. In this context, discussions and negotiations have taken place, leading to a global consensus on how to address it, namely the Paris Agreement, which aims to keep the global average temperature increase well below 2 °C above preindustrial levels (UNCC 2015). At the climate change conference in Paris (COP21), it was established that each member state should report national climate change action plans, to be submitted at regular intervals, usually every five years (Nationally Determined Contributions—NDCs). The main aim of these reports is to achieve net zero emissions and sustainable economic growth. Meanwhile, in 2015, the UN Conference on Sustainable Development (UNCSD) adopted the 17 Sustainable Development Goals (SDGs) to be reached by 2030 as part of the 2030 Agenda. These targets are a very ambitious commitment to end poverty and inequality, and protect the environment. In this context, most nations around the world have committed to achieving carbon neutrality by 2050, which would significantly reduce CO₂ emissions. Ultimately, this would slow the pace of global warming

and help to protect ecosystems. It is evident that the Kyoto Protocol, the Paris Agreement, the Conference of the Parties (COP) meetings, and the Sustainable Development Goals (SDGs) are among the many initiatives aimed at finding global solutions to environmental challenges. While these initiatives propose different approaches, they share common goals, such as reducing greenhouse gas emissions, limiting the global temperature rise, and achieving environmentally sustainable economies.

Substantial increases in GHGs have been mainly caused by traditional technologies that require a high level of energy consumption. This is justified by the fact that energy serves as an input in the processing of raw materials, but also ensures the operation of equipment and means of transport (Can et al. 2022). Moreover, trade also affects where production takes place (World Trade Organization 2021). According to the literature, developing economies tend to emit more emissions than developed economies due to socio-economic conditions, weaker environmental rules and regulations, and poorly developed infrastructure. In this context, some studies support international trade as a driver of new technological development (Antweiler et al. 2001).

The increasing attention paid to environmental quality concerns has led to many uncertainties about the environmental contingency of trade. Many of these uncertainties relate to the impact of environmental regulation on trade policies and the gains from trade. Where trade treaties fail, this is usually followed by “appropriate” legislative interventions and either a niche trade policy is reached or new international environmental standards are sought (Dean 1992). In the current context, we believe that the instruments used by the World Trade Organization have become a topic of interest on the public agenda, as the quality of the regulations applied affects the free exchange of goods between countries. With this in mind, the question that arises is: to what extent can the World Trade Organization ensure that environmental goals will not be misused as a reason to impose trade embargoes? The focus is on examining how trade protectionism affects the environment. According to the literature, an intelligent form of protectionism in international trade is anti-dumping (Prusa 2005). Anti-dumping has been intensively discussed in recent years, both in academic research and in policy debates, focusing mainly on their economic and trade impacts, as well as on the evolution of their enforcement. Despite this attention, it is now becoming increasingly important to analyze the impacts of anti-dumping measures on CO₂ emissions, a topic that remains largely unexplored. In the context of promoting a sustainable, net-zero-emission environment, it is essential to investigate this topic in more detail because, according to the existing literature, these measures are used to protect domestic industries, but this protectionism can lead to increased emissions.

To fill this gap, the main aim of our paper is to investigate the impact of trade policies (through anti-dumping measures), energy consumption (through primary energy consumption), and social development (through urbanization) on CO₂ emissions in OECD member states over a 22-year period from 2000 to 2001. In essence, the main question being answered is: do anti-dumping policies contribute to sustainable development?

This study contributes significantly to the existing literature in this domain. First, this paper is the first empirical analysis investigating the impact of trade policies, primary energy consumption, and urbanization on CO₂ emissions in developed and developing regions, regions that play a fundamental role in defining trade policies and promoting a sustainable environment. This is what we consider to be the motivational aspect of our research. We emphasize a global overview in which the overall objective is to decrease CO₂ emissions. By investigating the complex relationship between trade and the environment, this study adds a multidisciplinary and integrative perspective to this dilemma. Secondly, this study contributes to the literature by integrating these factors into a unified analytical framework, providing new insights into the interaction between trade, energy consumption, and urban development in the context of climate change. Third, in contrast to other studies, we use the Autoregressive Distributed Lag (A.R.D.L.) model, as this approach allows us to capture the immediate effects of trade policy and CO₂ emissions, as well as the long-term impacts in a framework that also incorporates recent events, such as the health crisis.

Fourth, investigating this relationship can help to establish appropriate recommendations for reducing CO₂ emissions from international trade.

Our research is further structured as follows: in the literature review part, relevant studies related in particular to the relationship between international trade and the environment are reviewed. Then, our attention is turned to the methodology, where the sample, data, and econometric models used are presented. A discussion of the empirical results is included in the part devoted to the interpretation of the results. Last, the study concludes with a series of conclusions, limitations, and recommendations for reducing emissions from international trade.

2. Literature Review

In recent years, many researchers have extensively studied the emissions of CO₂, the main greenhouse gas, to discover the factors that contribute to these emissions. A central topic in the trade policy debate has been the effects of trade on the environment and thus on climate change. The literature identifies three main perspectives on the relationship between international trade and the environment: 1. Expanding trade leads to more environmental pollution; 2. Trade facilitates environmental improvement through modern technologies; and 3. There is a non-linear and varied relationship between trade and the environment at different stages of trade. The first line of approach refers to studies that argue that the expansion of trade leads to the creation of a polluted environment, and the “Pollution Haven Hypothesis” (PHH) and the “Race to the Bottom Hypothesis” (RBH) are theories that support this point, also demonstrated by empirical analysis (Dean et al. 2009). In environmental policy, the Pollution Haven Hypothesis (PHH) is one aspect of a more general concept known as “carbon leakage”. Climate change policies are very different from country to country, as under the Paris Agreement, each country has set its own targets and policies for reducing pollution. In this context, some countries have implemented stricter measures on gas emissions (e.g., imposing a carbon tax), while others have been more permissive. According to them, CO₂ leakage can undermine global efforts to combat climate change, as emissions are transferred from one place to another and the overall environmental benefit is limited (Assogbavi and Déés 2023). In this context, we recognize that, in a world of uneven environmental policies, carbon leakage concerns and competitive disadvantages are the main arguments against implementing a more ambitious set of climate measures. By relocating carbon, we only postpone the problems and “transfer” them to future generations.

The second line of approach includes theories that contradict the effects mentioned above. There are authors who argue that trade can improve the environment by transferring modern, clean technologies (Erdogan 2014); clean energy technologies include renewable energy sources, energy efficiency technologies, carbon capture and storage technologies (Carbon Capture, Use and Storage—CCUS).

Today, environmental quality concerns are on the agenda of all countries around the world. For this reason, they are encountering the task of strategizing and directing their financial resources toward clean energy technologies to fulfill the SDGs (specifically SDG 7—Affordable and Clean Energy), with some studies finding that there are countries that will fail to achieve them unless they take the necessary measures. Moreover, SDG 9—Industry, Innovation and Infrastructure—promotes technological progress to strengthen energy infrastructure and improve energy efficiency (Pata et al. 2023). Aziz et al. (2024) investigated the effects of renewable energy on long-term economic progress and the environment over the period 1980–2019 on a data set from the Gulf Council of Countries. Based on OLS and DOLS modeling, the authors found that renewable energy and trade played an important role in mitigating environmental externalities. In contrast, Adams and Nsiah (2019) found that both renewable and non-renewable energy contribute to CO₂ emissions in Sub-Saharan African countries and thus to environmental degradation. Given these studies, we can conclude that the relationship between renewable energy and environmental quality is a broad one, influenced by several factors. In this context,

the best example is when the COVID-19 pandemic made history as an unprecedented challenge, highlighting the importance of energy security. In addition to the significant decrease in greenhouse gas emissions during the COVID-19 pandemic, there were also significant changes in the energy mix. During this period OECD countries implemented strict containment measures, which led to a major decline in economic activities, such as industrial production, construction, and transportation, resulting in a significant drop in energy demand. In 2020, renewable energy production accounted for 31.6% of total energy production in OECD countries, while coal's contribution to electricity generation continued to decline, producing 1983.3 TWh in that year, representing a 15.5% reduction from its energy production in 2019 (IEA 2021). At the same time, natural gas accounted for 29.5% of the energy mix. As an aside, the effects of the COVID-19 pandemic on the environment could be divided into two categories: beneficial effects on the environment (reduction in GHG emissions) and negative effects on the environment (use of medical masks, gloves and equipment leading to increased waste, increased transport of medical equipment) (Duceac et al. 2020).

Although the outbreak of the pandemic demonstrated that governments and communities are not prepared to manage such phenomena, the next global impact event, the war between Russia and Ukraine that started in February 2022, was not a complete surprise. However, the global energy crisis caused by the conflict between the two countries has highlighted two major problems. Firstly, the dependence on imports of fossil fuels from Russia has led to an alarming rise in fuel prices. As the conflict between the two states escalated, the United States, Canada, the United Kingdom, South Korea, Japan, and many other OECD economies imposed massive sanctions designed to impede Russia's ability to continue its aggression (Council of the European Union 2024). Sanctions imposed by Western states have created significant disruptions in the global energy market, leading to a significant increase in global energy prices (Sun et al. 2024), creating macroeconomic instability. Among OECD member states, Germany has been the most affected by the lack of Russian gas. The cost of imported energy increased by 129.5% compared with the same month of the previous year, and prices for energy produced in Germany increased by 68% (Statistisches Bundesamt 2024). Secondly, many OECD member states have realized their dependence on imported energy from a single country and have found that the technologies used do not meet requirements, exposing them to a possible blackout. The war between Russia and Ukraine can therefore be seen as having created an opportunity for new climate and energy policies in OECD countries, focusing on accelerated development of clean technologies and a shift away from fossil energy consumption.

The third line of research looks at studies that have suggested that there is a non-linear and varied relationship between trade and the environment at different stages of trade (Katircioğlu and Katircioğlu 2018). In this context, "The Environmental Kuznets Curve hypothesis" (EKC) was originally proposed to explore the link between environmental degradation and economic growth. The EKC theory suggests that environmental degradation worsens during the initial phases of economic development (Ahakwa et al. 2023). This is justified by the fact that, in the early stages of economic growth, awareness of environmental quality is low and not enough funds are allocated to environmental protection. However, in the later stages, environmental quality starts to improve with economic growth for various reasons, such as the implementation of environmental protection laws, allocation of funds for environmental protection, shift to various environmentally friendly technologies, etc.

Over the years, the history of trade has been marked by a series of events that have had numerous negative effects on trade relations between countries around the world. In addition to the above-mentioned events, the first phenomenon that shook international trade was the financial crisis of 2008, which had many negative repercussions on trade. These included the considerable increase in protectionism, which involved the imposition of tariffs and trade barriers aimed at protecting companies from foreign competition and increasing domestic production in their own market. Moreover, in a global context

dominated by economic uncertainty, the mechanisms that have fueled the spread of trade liberalization within the World Trade Organization have become channels for protectionism. But since 2010, international trade has experienced a period of gradual recovery. Economically, the situation even seemed to be improving, and international trade was flourishing again. However, in 2011, several factors, such as the sovereign debt crisis in the eurozone and political instability in the main oil-exporting countries, brought us back to the brink of economic collapse. All these events, followed by the decline in confidence in economic recovery, have been reflected in the rise of protectionist policies. So, because of a considerable number of protectionist measures, anti-dumping has become a convenient and frequently used tool in the political game of trade.

Anti-dumping is the most widely used trade protection measure of all non-tariff barriers (Zanardi 2004), aiming to protect local producers from imports that are sold at much lower prices than on the domestic market (a phenomenon called *dumping*).

In recent years, the literature has benefited from numerous studies investigating the relationship between anti-dumping measures and trade liberalization (Ahn and Shin 2011), the impact of anti-dumping policies on different economies in the world (Jabbour et al. 2019), how they are strategically used to protect specific industries (Bekker 2006), and their impact on technological innovations (Ao 2024). Some of these studies have made a significant contribution to the literature, highlighting the benefits of applying anti-dumping measures, while others have provoked intense debate. For example, some economists consider anti-dumping measures to be protectionist measures (Uyun et al. 2024) that should be used with prudence. Davis (2009) argues that this practice has raised concerns about the potential for the protectionist misuse of this trade defense instrument. In view of these concerns, there is a risk that, when anti-dumping measures are applied excessively, carbon leakage may occur, leading to increased CO₂ emissions (Assogbavi and Déés 2023). A recent study analyzed the impact of anti-dumping on the transfer of air emissions by looking at a sample of 189 countries and regions from the EORA input–output table from 2000–2016. The authors showed that developing countries tend to increase their merchandise exports when faced with a significant number of anti-dumping sanctions, leading to higher environmental costs and higher emissions consumption (Zheng et al. 2023). Andersen (2021) emphasized that anti-dumping legislation can be an impediment to trade in green goods. The available literature does not sufficiently explore the impact of anti-dumping measures, leaving many questions about trade policy and climate objectives. This identified gap highlights the need for a thorough analysis. Anti-dumping measures are, in the context of achieving carbon neutrality, a potential key economic driver in trying to control CO₂ emissions flowing through supply chains between entities in different countries by road, sea, or air transportation. Therefore, it is important to consider the influence of anti-dumping policies as an economic driver on the environment to promote sustainable development. Other environmental and social factors are also considered independent variables that could influence CO₂ emissions, such as primary energy consumption and urbanization. In identifying factors leading to increased CO₂ emissions, many studies have concluded that urbanization is considered a significant source of emissions (Zi et al. 2016). As we know, urbanization brings with it both positive aspects (e.g., economic growth, quality education) and negative aspects (e.g., more cars, lack of green spaces, pressure on infrastructure). Therefore, the negative aspects that come with urbanization lead to environmental degradation. Beyond economic and social factors, environmental factors, including primary energy consumption, which measures a country's total energy demand, influence CO₂ emissions (Goswami et al. 2023).

Considering that reducing CO₂ emissions is also the main concern of national governments, and that we did not identify in the literature a consistent investigation of the relationship between anti-dumping policies and CO₂ emissions, by developed and emerging regions, we found research on this topic useful to investigate the extent to which anti-dumping policies contribute to sustainable development. In addition to economic factors, studies have concluded that social factors, such as urbanization, are also a primary

source of emissions. This is characterized by economic growth and quality education, but also leads to environmental degradation (Zeng et al. 2021). Starting from the economic, social, and environmental factors identified in the literature, but also by identifying less studied variables (e.g., anti-dumping), we aim to show that anti-dumping measures, primary energy consumption, and urbanization change CO₂ emissions. This is also the research gap we identified. In this case, the null hypothesis is formulated as follows:

H₀. *Anti-dumping measures, primary energy consumption, and urbanization do not contribute to an adjustment in CO₂ emissions.*

Depending on statistical results, the null hypothesis can be rejected if the *p*-values of the coefficients are below 0.1 (10% statistical significance level). In this case, we can admit the alternative hypothesis that the analyzed factors increased or decreased the CO₂ levels.

The following are aspects of the data description and methodology used.

3. Data and Methodology

Anti-dumping policies have a well-established role to protect domestic producers from unfair practices. The majority of studies in the literature have focused on the historical development of these policies (Irwin 2005) and on identifying their effects on global economies (Jabbour et al. 2019) to determine whether anti-dumping is indeed a tool to protect against unfair trade. Moreover, in addition to affecting trade dynamics, anti-dumping cases also play a role in reshaping emissions in different regions, thus influencing the global environment. However, studies on the impact of anti-dumping policies on CO₂ emissions have been insufficiently explored. Investigating the relationship between the two variables can help in developing trade policies that promote fair and sustainable trade.

As mentioned above, the purpose of our research is to investigate the impacts of economic, social, and environmental factors such as *anti-dumping measures, fuel imports and exports, primary energy consumption, and urbanization* on CO₂ emissions in 36 member states of the Organisation for Economic Cooperation and Development. Among the *economic factors*, for the trade policies adopted, regarding the degree of economic openness, we chose, as a variable, the implementation of *anti-dumping measures* as a novel element of our research, given that this influence is scarcely addressed in the literature, and as control variables, *fuel imports and exports*. For energy consumption, as an environmental factor, the environmental variable identified was *primary energy consumption*, which measures a country's total energy needs, excluding consumption for non-energy purposes (such as gas used in the chemical industry). Specifically, the indicator—primary energy consumption—covers energy consumption by end-users (industry, transport, households, services, and agriculture) plus energy consumption in the energy sector needed to produce and transform energy (Energy Information Administration 2023). For social development, the variable identified as a *social factor* considered in our study that could modify CO₂ emissions is the degree of *urbanization* of each country in the sample analyzed.

3.1. Data Description

The study sample comprised 36 OECD member countries and was chosen considering that the countries included in the analysis had anti-dumping legislation in place, but also based on data availability, excluding countries where time series were not complete (South Korea and Luxembourg).

The data used in this study were obtained from various international databases (World Trade Organization database, OECD database, and World Bank database) and covered a period of 22 years (2000–2021), which facilitated a broad understanding of the evolution and fluctuations of the subject under analysis. From the data analyzed, we compiled all anti-dumping measures imposed by the 36 countries, as well as the data series for the other variables used. The period of analysis was justified by the following two aspects: (1) the availability of data needed to apply the econometric models and (2) during this period, many events with a significant impact on the economies of OECD Member States took

place, providing important details on trade policies and CO₂ emissions. The dependent variable is represented by the CO₂ emissions, as they are directly associated with various Sustainable Development Goals, including SDG 3.9—*Mortality from Environmental Pollution: Reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination* and SDG 11.6—*Reduce the Environmental Impact of Cities*. Of course, CO₂ emissions can also be linked to other SDGs, such as SDG 7—*Affordable and Clean Energy*, SDG 12—*Responsible Consumption and Production*, and SDG 13—*Climate Action*. Table 1 provides a description of the variables included in the panel data analysis, the references in which they were identified, and the results obtained, as well as the source of the data.

Table 1. Variable description, data source, references, and results.

Variable	Description	Source	References	Results
CO ₂	CO ₂ Emissions (metric tons per capita)	WDI		
AD_M	Anti-Dumping Measures—economic factor (proxy for trade policies)	WDI	Bildirici et al. (2023)	Trade opening↓ → renewable energy orientation↑ → CO ₂ ↓
			Dai et al. (2021)	Trade flows↓ → CO ₂ ↓
			Klotz and Sharma (2023)	Trade Barriers↓ → CO ₂ ↑
FI	Fuel Imports (% of merchandise imports)—economic factor (control variable)	WDI	Assogbavi and Déés (2023)	FI↑ → CO ₂ ↑
FE	Fuel Exports (% of merchandise exports)—economic factor (control variable)	WDI	Cloete et al. (2022)	FE↑ → Carbon capture → CO ₂ ↑
PEC	Primary Energy Consumption per capita (measured in kilowatt-hours per person per year)—environmental factor (proxy for energy consumption)	EIA	Goswami et al. (2023)	PEC↑ → CO ₂ ↑
URB	Urban Population (% of total population)—social factor (proxy for social development)	WDI	Goswami et al. (2023)	URB↑ → CO ₂ ↑

From Table 1, in the studies carried out, the authors found that carbon dioxide emissions were influenced, both favorably and unfavorably, by the factors identified and considered in our study as well.

3.2. Testing for the Stationarity of Data and Cointegration

A key problem in economic time series is the non-stationarity of data. This issue can be checked by specific tests, such as Levin-Lin-Chi, Harris-Tzavalis, Breitung, Breitung and Das, as well as Im-Pesaran-Shin ([Breitung 2000](#); [Breitung and Das 2005](#); [Harris and Tzavalis 1999](#); [Im et al. 2003](#); [Levin et al. 2002](#)) which had, as a null hypothesis, the fact that all panel series contain a unit root. Of course, there are also tests that take stationarity as the null hypothesis (e.g., the Kwiatkowski–Phillips–Schmidt–Shin test).

To prevent the implication of inconclusive results, we determined the stationarity of the implied series by applying the most widely used unit root tests (Augmented Dickey–Fuller test and Phillips–Perron test) to ensure that the statistical observations were obtained from the same process and did not change their statistical properties over time. According to Dickey and Fuller ([Dickey and Fuller 1981](#)), the statistics provide asymptotic results and highlight critical values for various tests and samples under the null hypothesis of a unit root. To verify the existence of a unit root, Equation (1) is used:

$$\Delta Y_T = \alpha + B_t + \gamma Y_{t-1} + \sum_{i=1}^p \delta_i \Delta Y_{t=1} + \varepsilon_t \quad (1)$$

In contrast, the [Phillips and Perron \(1988\)](#) test focuses on a non-parametric method to deal with serial correlation in error terms without adding lagged difference terms. The main peculiarity of the two tests is that the Phillips–Perron test provides a guarantee that the disturbances are uncorrelated and have constant variance. Compared with the first test, it (PP) does not include lag difference terms, but can include trend and intercept terms ([Pedroni 2004](#)). Equation (2) for the Phillips–Perron test is represented as follows:

$$Z(\tau) = \tau \left(\frac{\hat{\sigma}^2}{\hat{\sigma}_{sl}^2} \right) - \left(\frac{1}{2} \right) \left(\hat{\sigma}_{sl}^2 - \hat{\sigma}^2 \right) T \sqrt{\hat{\sigma}_{sl}^2} \sum_{t=2}^T (x_{t-1} - \bar{x}_{T-1})^2 \quad (2)$$

Economic time series are often affected by various events (e.g., strikes and political interventions). Most of the time, these events appear as large residuals or outliers in econometric models. According to [Nielsen \(2004\)](#), these outliers raise two major issues: (1) the inferential consequences of outliers if they are not detected and (2) how models can be modeled using dummy variables.

The stationarity in panels with first-order autoregression is tested using ([Breitung and Das 2005](#); [Choi 2001](#); [Harris and Tzavalis 1999](#); [Im et al. 2003](#); [Levin et al. 2002](#)), having at most of the tests, the null hypothesis H_0 that series contains a unit root, based on the following Equation (3):

$$y_{it} = \rho_i y_{i,t-1} + \mathbf{z}_{it}' \gamma_i + \epsilon_{it} \quad (3)$$

where $i = 1, \dots, n$, $t = 1, \dots, T_i$.

For the unit root, the value of ρ_i for $H_0 : \rho_i = 1$ is tested for all i versus the alternative $H_a : \rho_i < 1$. Equation is often written as:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \mathbf{z}_{it}' \gamma_i + \epsilon_{it} \quad (4)$$

so, the null hypotheses are $H_0 : \phi_i = 0$, for all i with the alternative $H_a : \phi_i < 0$.

To investigate the relationship between CO₂ emissions and anti-dumping measures in OECD countries, we applied unit root tests and found that some variables were stationary at the level and others were stationary at the first difference of the series.

3.3. The Error Correction Model (ECM)

The choice of the ECM methodology is based on data particularities: the series are panel type, referring to 36 OECD countries, with a time span of 22 years (2020–2021). Due to the interdependence between time-series and panel data, the choice of methodology should consider the following:

A fixed effect should incorporate the particularities of every unit (country), such as the level of economic and urban development, individuality of energy consumption, or anti-dumping policies;

The presence of non-stationarity in time series, usually encountered in data such as economic series, e.g., GDP, imports, exports, and CO₂ emissions;

Co-integration between variables, e.g., CO₂ emissions and primary energy consumption;

The subsistence of cross-sectional dependence, usually encountered in series with many observations in time.

Based on the facts presented above, we chose the Panel Model and Common Correlated Effects Estimators methodology. If we assume a dynamic model (ARDL 1,1), the panel model considering heterogeneous loadings/coefficients can be written as in (5)–(7).

$$y_{i,t} = \mu_i + \lambda_i y_{i,t-1} + \beta_{0,i} x_{i,t} + \beta_{1,i} x_{i,t-1} + u_{i,t} \quad (5)$$

where:

$$u_{i,t} = \sum_{l=1}^m q_{y,i,l} f_{t,l} + e_{i,t} \quad (6)$$

$$x_{i,t} = \sum_{l=1}^m \rho_{x,i,l} f_{t,l} + \zeta_{i,t} \quad (7)$$

with: $i = 1, \dots, N, t = 1, \dots, T$.

In the equations presented, $y_{i,t}$ represents the dependent variable (in our case—CO₂ emissions levels), $x_{i,t}$ represents the observed independent variables, which can include m unobserved common factors $f_{t,l}$. We want to estimate the long-run effect x on y , some further statistical properties of the variables being explained in the econometric literature (see (Bersvendsen and Ditzen 2021; Ditzen 2018)). Estimating the long-run movements can be achieved using the time-series error correction model. There is more research that captures short-term interactions and long-term interactions: in non-panel time series (Engle and Granger 1987) and for a panel data model with heterogeneous slope coefficients—pool mean group estimator—PMG (Blackburne and Frank 2007; Chudik and Pesaran 2013, 2015; Kripfganz and Schneider 2023; Pesaran et al. 1999, 2001). A problem commonly encountered in panels with large time observations and cross-sectional units (as in our case—multiple countries) is the presence of the cross-sectional dependence, which can cause inconsistent estimates—see also (Chudik and Pesaran 2015; Pesaran 2006). The methods estimate static and dynamic models—these are the so-called common correlated estimators. The idea is to add cross-sectional averages that approximate the cross-sectional dependence, being implemented in statistical software (e.g., Stata) using several modules (see (Chudik et al. 2016; Ditzen 2018; Eberhardt 2012)).

In the case of omitted variable bias due to correlation between common factors and explanatory variables, the Equation in (5) can be transformed into (8).

$$y_{i,t} = \mu_i + \lambda_i y_{i,t-1} + \beta_{0,i} x_{i,t} + \beta_{1,i} x_{i,t-1} + \sum_{l=0}^{p_T} \gamma'_{i,l} \bar{z}_{t-l} + e_{i,t} \quad (8)$$

where:

$$\bar{z}_t = (\bar{y}_t, \bar{x}_t)' = \left(1/N \sum_{i=1}^N y_{i,t}, 1/N \sum_{i=1}^N x_{i,t} \right)' \quad (9)$$

In equilibrium (steady state), the long-term effect of x is defined as in (10):

$$\theta_i = \frac{\beta_{0,i} + \beta_{1,i}}{1 - \lambda_i} \quad (10)$$

The long-term effects can be estimated in three ways, as ECM or a pooled mean group (PMG) model if it is an ARDL(1,1), or if it is a more general ARDL (py, px), directly without the short-term coefficients (CS-DL) or indirectly with the short-term coefficients (CS-ARDL) (Ditzen 2019). The error correction model, following (Lee et al. 1997) and (Chudik and Pesaran 2015), is assuming an ARDL(1,1) model with heterogeneous coefficients, as in (11):

$$\Delta y_{i,t} = \mu_i - \phi_i [y_{i,t-1} - \theta_{1,i} x_{i,t}] - \beta_{1,i} \Delta x_{i,t} + \sum_{l=0}^{p_T} \gamma'_{i,l} \bar{z}_{t-l} + e_{i,t} \quad (11)$$

with:

$$\theta_i = \frac{\beta_{0,i} + \beta_{1,i}}{1 - \lambda_i} \quad (12)$$

and

$$\phi_i = (1 - \lambda_i) \quad (13)$$

In the case without dependence on the residuals and homogeneous long-term, the model can be estimated by PMG as in (Blackburne and Frank 2007), while considering the dependence as in (Ditzen 2018, 2019). Where ϕ_i is the error-correction speed of the adjustment parameter, while $[y_{i,t-1} - \theta_{1,i} x_{i,t}]$ is the error correction term. The model is correctly specified (a long run relationship exists) if $\phi \neq 0$ (see (Lee et al. 1997)).

For cointegration, the Kao, Pedroni, and Westerlund tests combine statistics obtained from each individual panel, considering the general Equations (14) and (15).

$$y_{it} = x'_{it}\beta_i + z'_{it}\gamma_i + e_{it} \quad (14)$$

$$\hat{e}_{it} = \rho\hat{e}_{i,t-1} + v_{it} \quad (15)$$

4. Results and Discussion

The analytical part of the study begins with an analysis of descriptive statistics. Table 2 highlights the descriptive statistics for the data set analyzed.

Table 2. Description statistics.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.	Skew.	Kurt.
CO ₂	792	8.1014	3.9952	1.3102	21.3044	0.8880	7.5728
AD_M	792	1.0378	2.3361	0.0000	35.0000	3.2737	7.3021
FI	792	11.7850	5.8299	1.5355	37.5974	1.2847	5.4154
FE	790	9.2823	13.5013	0.0161	69.8156	2.7534	1.6217
PEC	792	47.8600	30.3338	7.8344	188.2940	1.9179	7.8857
URB	792	76.1588	11.1559	50.7540	98.1170	−0.2787	2.3750

The value of the dependent variable (CO₂) varies between a maximum of 21.304 and a minimum of 1.310, with a mean of 8.101 and a standard deviation of 3.995. Regarding the independent variable, anti-dumping measures (AD_M), it varies between a minimum value equal to 0 and a maximum value of 35, with an average of 1.037.

As the proposed methodology does not allow the series to be non-stationary, we applied some unit root tests. The results of the Im-Pesaran-Shin, Levin-Lin-Chu, Harris-Tzavalis, Breitung, and Hadri tests are highlighted in Table 3.

Table 3. Unit root tests results.

Tests (ρ_i)	IPS	LLC	HT	B	H
Variable name:	CO ₂				
Tests in levels	6.8075	2.8938	3.5533	4.5774	63.7152 ***
Tests in first-difference	−14.4429 ***	−10.5824 ***	−42.2419 ***	−12.5515 ***	−0.189
Variable name:	AD_M				
Tests in levels	−37.2251 ***	−37.2251 ***	−32.3215 ***	−7.1352 ***	6.9616 ***
Tests in first-difference	−12.6642 ***	−12.6642 ***	−54.3826 ***	−9.7318 ***	0.5433
Variable name:	FI				
Tests in levels	−1.8329 ***	−2.9232 ***	−4.7847 ***	−5.0434 ***	19.5815 ***
Tests in first-difference	−13.0463 ***	−9.9491 ***	−38.1261 ***	−16.8113 ***	−1.3292
Variable name:	FE				
Tests in levels	−1.6614 ***				
Tests in first-difference	−13.6022 ***				
Variable name:	URB				
Tests in levels	6.2514	−80.8348 ***	4.1586	18.2675	75.5126 ***
Tests in first-difference	1.157	5.7307	−2.3845 ***	5.8651	54.3957 ***

Note: Name of tests performed: IPS—Im-Pesaran-Shin, LLC—Levin-Lin-Chu, HT—Harris-Tzavalis, B—Breitung, H—Hadri. *** $p < 0.01$.

Table 3 highlights the results reported after running the unit root, level, and first difference tests. The unit root test for the variable *anti-dumping measures* (AD_M) reveals that it is stationary at the level. At the same time, unit root tests reveal similar results for the variables: *fuel exports* (FEs) and *fuel imports* (FIs). The null hypothesis in levels could not be

rejected for CO₂, but was rejected for other variables at 5% level. For the first-difference, the null hypothesis was rejected for all the variables. We can conclude that variable CO₂ was not stationary in level, but was stationary in the first-difference test and all other variables were stationary in levels, so the methodology was correctly chosen.

A first naive attempt to model the short-term interactions between the independent and dependent variables can be achieved by considering fixed or random effects. This methodology considered the particularities of the individual units—in our case, countries. The model was static; we did not consider in this phase the influences of the independent variable's lags, and the first difference of the variables was used to control for the non-stationarity in levels. The results are available in Appendix A and are in line with the dynamic models presented below. Due to possible biased results and the influence of lags and Nickel small-T bias, see (Chudik and Pesaran 2015), we continue our analysis with dynamic models.

To determine whether fixed effects panel data estimation is appropriate, we performed the Hausman test and checked fixed effects (FEs) against random effects (REs). After applying the Hausman test, the results highlighted the fact that the models with fixed effects were appropriate, since $p = 0.0000$, which is less than 0.05. Moreover, following the application of the F-test and the Hausman test (reported in the Results section), the results were similar, thus validating the choice of the fixed-effects models.

Country- and time-specific coefficients can be found in Appendix A. As for the time coefficients, there was a decrease compared with the average for most of the years of the analyzed period. At the same time, there was a significant reduction during the period of 2018–2020, being also the years marked by the COVID pandemic. Regarding the country coefficients (country fixed-effects coefficients), lower values compared with the average were found in the countries in the upper part of the table (the table was sorted in ascending order from the negative coefficients to the maximum of the positive ones). Further we investigated the presence of cointegration.

Tables 4 and 5 suggest that the analyzed factors (mainly anti-dumping measures and primary energy consumption) influence CO₂ emissions, being statistically significant, at least at the 10% level, in the long run. The error correction term (ECT) is negative and statistically significant at the 1% level in all five models.

Table 4. ECT model results (non-cross-sectional dependence).

Model		(1)	(2)	(3)	(4)	(5)
Short-Run Results	Variables	D.CO ₂	D.CO ₂	D.CO ₂	D.CO ₂	D.CO ₂
	D.AD_M	0.0235 (0.0182)	0.0422 * (0.0252)	0.0575 (0.0356)	0.0335 (0.0292)	0.0689 (0.0597)
	D.FI		0.116 *** (0.0346)	0.0158 (0.0160)		0.0442 (0.0365)
	D.FE			0.0500 (0.0415)	0.0262 (0.0294)	0.143 (0.116)
	D.PEC	0.0391 *** (0.0139)	0.0147 (0.0151)	0.00638 (0.0167)	0.0102 (0.0135)	0.0194 (0.0317)
	D.URB					−22.24 (13.89)
ECT	L.CO ₂	−0.650 *** (0.0355)	−0.785 *** (0.0458)	−0.832 *** (0.0482)	−0.773 *** (0.0472)	−0.892 *** (0.0843)
	AD_M	−0.0353 * (0.0483)	−0.0647 * (0.0538)	−0.0990 * (0.0588)	−0.0904 * (0.0500)	−0.144 * (0.178)
Long-Run Results	FI		−0.0344 (0.0224)	−0.0315 (0.0336)		−0.0369 (0.154)
	FE			−0.110 (0.0725)	−0.0683 (0.0515)	−0.150 * (0.313)
	PEC					−3.517 * (2.849)
	URB	0.0480 (0.0991)	0.116 *** (0.0346)	0.108 ** (0.0515)	0.127 *** (0.0377)	0.137 (0.0957)

Table 4. Cont.

Model	(1)	(2)	(3)	(4)	(5)
Observations	756	756	756	756	756
R-squared	0.127	0.093	0.069	0.091	0.024
Number of groups	36	36	36	36	36

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. ECT model results (controlling for cross-sectional dependence).

Model		(1)	(2)	(3)	(4)	(5)
Short-Run Results	Variables	D.CO ₂	D.CO ₂	D.CO ₂	D.CO ₂	D.CO ₂
	D.AD_M	0.00103 *	0.0107 *	0.00818 **	0.00394 *	0.0161 *
		(0.0157)	(0.0168)	(0.0220)	(0.0224)	(0.0207)
	D.FI	0.00141	0.00124		0.00644	0.00322
		(0.0140)	(0.00551)		(0.00843)	(0.00834)
	D.FE	0.443 ***		0.0240	0.0257	0.0205
Long-Run Results		(0.0405)		(0.0212)	(0.0273)	(0.0282)
	D.PEC	0.102 ***	0.0885 ***	0.0833 ***	0.0781 ***	0.0718 ***
		(0.0152)	(0.0156)	(0.0152)	(0.0159)	(0.0151)
	D.URB					−1.432
						(2.128)
ECT	L.CO ₂		−0.520 ***	−0.522 ***	−0.577 ***	−0.663 ***
			(0.0454)	(0.0450)	(0.0462)	(0.0584)
Long-Run Results	AD_M		−0.000187 *	−0.00986 *	−0.0136 *	−0.0386 *
			(0.0558)	(0.0206)	(0.0317)	(0.246)
	FI		−0.0408		−0.0407	−0.0210
			(0.0273)		(0.0302)	(0.145)
	FE			−0.0175	−0.0143	−0.0261
				(0.0166)	(0.0386)	(0.0947)
Long-Run Results	PEC					−0.177 **
						(2.090)
Long-Run Results	URB	0.0559 *	0.0520		0.0627	0.0576
		(0.0310)	(0.0524)		(0.0481)	(0.0708)
Observations		756	756	756	756	756
R-squared		0.163	0.137	0.121	0.121	0.100
Number of groups		36	36	36	36	36

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Regarding Table 4, the error-correction terms are negative and statistically significant at the 0.01 percentage level for all the models, implying: -0.650^{***} , -0.785^{***} , -0.832^{***} , -0.773^{***} , -0.892^{***} . The statistical explanation is that, in the long-term, there is convergence between series CO₂ emissions and other economic series. Negative and significant ECT means that the speed has a relatively high level of adjustment back to the long-run equilibrium (between -0.65 and -0.89). The result specifically states that deviation from the long-term DV path is corrected, for example, by 89 percent over the following year (model no. 5 in the fifth column). For the long-run, the increase with one unit in anti-dumping measures (our variable of interest) explains the decrease of around 0.4 in CO₂ emissions in terms of elasticity, ceteris paribus (see model no. 5, the effective coefficient is -0.0386^{*}). The other coefficients have the same interpretation: for one unit increase, the effect on the dependent variable is determined by the equation coefficients in models. In Table 5, the levels of adjustments calculated are slightly lower (-0.520^{***} , -0.522^{***} , -0.577^{***} , -0.663^{***}), which can be explained by the presence of extra terms in the model $\sum_{l=0}^{p_T} \gamma'_{i,l} \bar{z}_{t-l}$.

We can conclude that, regarding the long-run coefficients, all the models were correctly specified, with a speed of adjustment between independent and dependent variables considered in the models.

When performing a more analytical interpretation, it is found that, in the short term, the variables *AD-M*, *FI*, *FE*, and *PEC* lead to an increase in CO₂ emissions, which can be explained by the fact that restrictive trade policies accentuate the increase in production in the country and, consequently, negative effects on pollution. On the other hand, in the long term, the effects of the considered variables (*AD-M*, *FI*, *FE*, and *PEC*) are to reduce CO₂ emissions, from which it can be concluded that, over time, the measures taken are aimed either at the relocation of CO₂ emissions or toward the development of renewable energy sources. Our results are, for the most part, in line with the results of other studies (Bildirici et al. 2023; Goswami et al. 2023), which found that the impact of trade is not always significant from a statistical point of view and that only in some countries can it play an important role (Iwata et al. 2012). The variable urbanization (*URB*) inversely influences the dependent variable (CO₂). In the short term, this leads to lower carbon dioxide emissions, but in the long term, it leads to higher pollution. There is an explanation for these phenomena, in the sense that, in the short term, the transfer of the rural population to the urban environment could decrease the pollution generated by the transport carried out before the move, but in the long term, urban agglomeration will certainly generate an increase in emissions pollutants. The results obtained are similar to the results obtained in other studies (Goswami et al. 2023).

Related to the short-run analysis (fixed and random effects, available in Appendix A), after running the Hausman test to choose between the fixed-effects and the random-effects models, we noticed that the *p*-value was less than the 0.05 significance level. This proves that the fixed-effects model is appropriate, as the null hypothesis can be rejected (*anti-dumping measures, primary energy consumption, and urbanization do not contribute to the change in CO₂ emissions*). Empirical results are also included in Table A1 (from Appendix A), where we present panel data results for the pooled least-squares method: fixed effects (FEs) and random effects (REs). According to the results obtained, we can see that almost all coefficients were statistically significant and influenced CO₂ emissions. Therefore, the hypothesis is accepted that the three economic, environmental, and social factors considered (commercial policies, through the *AD-M* proxy variable; energy consumption, through the *PEC* proxy variable; and social development, through the *URB* proxy variable) have an influence on CO₂ emissions. Our results are in line with those of other studies in the literature, which show mixed evidence of asymmetric behavior or asymmetry between trade openness and CO₂ emissions (Moreira and Dolabella 2023). Our results also fit into the first line of research that international trade can affect the environment (see Section 2). Also, Tables A5 and A6 in Appendix A (full coefficient tables by countries are available on demand) present the results of the cointegration tests between the dependent variable (CO₂) and the independent variables: anti-dumping measures (*AD_Ms*) and primary energy consumption (*PEC*). Therefore, the alternative hypothesis is accepted, according to which the implementation of anti-dumping measures contributes to the change in CO₂ emissions. This aspect is justified by the fact that a stricter application of anti-dumping measures may increase production costs for some of the imported products (Jabbour et al. 2019), as producers have to bear the additional duties imposed or other trade restrictions. This aspect can lead to the phenomenon of production relocation, which is not necessarily seen as a solution, knowing that relocation is usually performed in less developed countries. So, producers could be driven to migrate to countries with less restrictive CO₂ emission regulations or lower production costs. Finally, the relocation of production leads to additional international transport, which can lead to higher CO₂ emissions (a result also obtained in our short-term study). To avoid additional taxes imposed or trade restrictions, organizations may also face pressure to cut costs in order to remain competitive in their own markets (Yu et al. 2021). In this context, organizations may be tempted to turn to less energy-efficient technologies and production methods, again generating a consider-

able amount of CO₂ emissions. Our suggestion is that authorities support producers in the direction of the development of renewable energy sources (through subsidies) and strengthen environmental policies that can promote the production and trade of ecological goods (taxation of trade in goods harmful to the environment), precisely to contribute to the reduction in pollution and, implicitly, to long-term sustainable development.

Our results are in line with those of some previous studies (that are limited in number at the date of the current paper), for example, [Zheng et al. \(2023\)](#), where the authors analyzed the impact of anti-dumping on the transfer of embodied air emissions. They employed data from 189 countries or regions and their 26 sectors in a database with 221 observations and found that the coefficients of anti-dumping independent variables were negative. They concluded that “decision-makers may increase the intensity of anti-dumping on highly polluting products”. Our paper differs from the actual literature in the following (the strengths): the sample is larger—791 observations; the countries refer to OECD countries; the timeline is longer—21 years—and contains the latest available data; the methodology is newer and controls for the presence of cross-sectional dependence; and we also include fixed and random effects that were previously used in the literature. Our findings are important for decision-makers that should use anti-dumping measures to control GHG emissions. On the other hand, we agree with previous findings that these instruments must be applied carefully, and mainly on highly polluting products. Similarly, [Widiarty \(2024\)](#) argued that anti-dumping laws should be applied wisely and without harming consumers.

When we talk about trade, either the current and digitized form, or its incipient form of barter, we cannot overlook the fact that, through exchange or trade, people obtain products or services that they cannot produce themselves. So, we refer to a vital component in everyday life, since the beginning of humanity until today. Let us not forget that any economy is based on trade and to oppose it is to oppose economic growth and development. As in any field, there must be an arbitration entity that is fair and impartial. In this case, in the field of trade, over the years, various institutions have appeared (e.g., GATT and WTO) which, with the passage of time, have increasingly difficult missions, from monitoring the fairness of trade to, more recently, protecting the environment, when exchanges or commercial disputes take place.

In the context of globalization and concerns for the development of a sustainable environment, the World Trade Organization is automatically interconnected with environmental protection regulations. In the fight to combat climate change, the World Trade Organization has implemented various measures to regulate trade in all aspects. Even though various anti-dumping measures are in place, which, according to our results, lead to changes in CO₂ emissions, we can analyze the reliability and appropriateness of the policies, as well as how they are adapted to contemporary needs, but designed for future needs. In no case can we stop trade, but we can implement, in a flexible and Avant Garde manner, possible policies that include both the environmental area and regional interests.

In the contemporary era, climate change has evolved from a peripheral concern to a “challenge of the 21st century” that requires urgent action to combat it. This challenge can be viewed from several perspectives: (1) that of mitigating climate change and, implicitly, global warming, in which national governments act by implementing various environmental strategies and policies; (2) that of adapting to climate change, in which, although the damage is already done, governments apply measures to reduce the impact of GHG emissions; and (3) that of disaster risk management, in which all of humanity must be prepared for the most gloomy scenarios.

This study aimed to address a significant gap in the literature by investigating the correlation between CO₂ emissions and anti-dumping policies in OECD member countries. This analysis attempts to shed light on the complex interplay between environmental concerns and trade regulation. Therefore, the additional knowledge brought by our study resides in the fact that the anti-dumping variable, less studied in the specialized literature, was considered, but also that the analyzed period is quite recent. Being identified as

the main variable in our study, anti-dumping can constitute an orientation regarding decision-making by the responsible authorities to achieve the objectives of sustainable development. The influence of anti-dumping measures on emissions is a negative collateral consequence of their application. Trade measures were designed strictly for trade and the financial implications of this, but as protectionism increased, unexpected results could also be observed, leading to increased CO₂ emissions. From the literature, we have already observed that anti-dumping measures can lead to the phenomenon of “carbon leakage”. Therefore, careful monitoring of the effects of anti-dumping measures on the environment is necessary to identify not only fluctuations in CO₂ emissions, but also their origin.

In conclusion, the relationship between CO₂ emissions and anti-dumping measures (AD_M) must still be analyzed in each country, because the effects can lead, in certain situations, to collateral damage to the environment, as other authors have also stated (Wang et al. 2023). However, it should be noted that there is no “elixir” solution that will save both the environment and international trade. To find the optimal compromise, there should be real, direct, and open international collaboration, where governments, instead of adopting large-scale unilateral measures, should set common standards to promote sustainable trade and production practices. Moreover, we believe that an assessment of the impact of anti-dumping measures before implementation is necessary to detect the possible unintended consequences on CO₂ emissions and to develop policies to minimize them all over the world.

The research results could lead to a review of anti-dumping policies and their applicability, considering their impact on natural resources in the country where the measures are applied in relation to the level of emissions in the countries to which production could be transferred. Therefore, we believe that the results obtained in our research could be useful in the environmental policy-making process, providing an important information base on which policy-makers can develop workable regulations. These results also help to understand the complexity of certain issues related to the application of anti-dumping measures and the effects they can have.

5. Conclusions

Economic crises, pandemic crises, climate change, and war are factors that are receiving increased attention from world organizations, regardless of the area covered. This paper turns its attention to the World Trade Organization (WTO) in its difficult mission of trade arbitration while caring for the environment. This study's main aim is to analyze the impact of anti-dumping trade policies on CO₂ emissions in OECD Member States over the period of 2000–2021. In fact, we analyzed which directions trade policies could be directed towards, so that we have a fair trade, but also a sustainable environment. In addition, the effects of energy consumption, through primary energy consumption, and social development, through urbanization, on CO₂ emissions were also analyzed, and the results indicate both favorable and unfavorable influences on the environment.

The results of the analysis showed that anti-dumping measures implemented by national authorities led to changes in CO₂ emissions, depending on the conditions. Although they have a well-defined role, sometimes, anti-dumping measures can take the form of protectionism and create a market monopolized by domestic producers, thereby bypassing the need to be stimulated to adopt environmentally friendly production practices. At the same time, we must also look at these measures from a positive perspective. For example, the introduction of the carbon tax creates a financial incentive for the exporter to improve the production process resulting in low carbon emissions. From the importer's point of view, it can force producers in other countries to meet certain ecological standards of production and, by implication, transport. Unfortunately, manufacturing practices differ from state to state. It becomes more difficult to establish generic measures that can address specific challenges. In this context, an extensive and flexible traceability system would be welcome.

However, the World Trade Organization has a major role in promoting business practices that could protect the environment. Trade measures could target, for example, products that significantly affect nature, such as illegal logging. The World Trade Organization can intervene in how these measures are applied and can require them to be based on scientific elements and not represent a means of disguised protectionism. Moreover, misdirected trade measures will primarily increase trade barriers, leading to a decline in economic development in developing countries.

The results of our empirical investigation broadly confirm the findings of previous empirical studies that have focused on assessing the impact of trade policies on air emissions (Zheng et al. 2023). In conclusion, when anti-dumping measures are imposed, they should consider specific environmental or regional management aspects. Although international trade is a fundamental pillar of economic and social life, it has a major impact on all of humanity, with influences on international relations and, above all, on the way people relate, work, and live. Regarding the relationship between trade and the environment, there will always be disputes and biased discussions when it comes to the implementation of restrictive public policies, where someone will always be dissatisfied. The optimal solution consists of trying to find a balance and choosing the option with the least negative effects from an economic or ecological point of view. By adopting various trade policies and sustainable strategies, we can support environmental protection and promote fair trade, thus creating a sustainable future globally. In this context, the green energy–equitable trade relationship can lead to the achievement of policy-makers' proposed targets.

The empirical results obtained following the application of econometric models are important for decision-makers in public institutions capable of implementing commercial and environmental policies. In a world characterized by globalization and international trade development, we do not advocate for the excessive usage of anti-dumping measures, our main conclusion being that such instruments can be carefully implemented, among others, for fighting CO₂ emissions. Our findings can also form the basis of further research carried out in the academic environment, because among the empirically obtained results, this paper has limitations, which could be research opportunities for future studies in the field. We only refer to the investigation of OECD countries over a period of 22 years and, by extending the analysis to a larger sample and a longer period and considering further economic variables, future results can be obtained to provide a detailed understanding of the relationship between trade and the environment. Future research may also focus on examining the effects of green technologies on reducing production-related emissions and investigating their integration into supply chains. These directions could provide a strong basis for developing more effective policies to minimize the transfer of CO₂ emissions between countries.

Author Contributions: Conceptualization, M.O., B.N.F., D.C.C., M.G. and C.P.; methodology, M.O., B.N.F., D.C.C., M.G. and C.P.; software, M.O., B.N.F., D.C.C., M.G. and C.P.; formal analysis, M.O., B.N.F., D.C.C., M.G. and C.P.; investigation, M.O., B.N.F., D.C.C., M.G. and C.P.; writing—original draft preparation, M.O., B.N.F., D.C.C., M.G. and C.P.; writing—review and editing, M.O., B.N.F., D.C.C., M.G. and C.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study are publicly available and sourced from The World Bank and the Energy Information Administration. Further details are included in Table 1 of this article.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Short-term analysis by fixed and random effects (in first difference). The results are the basis of further analysis in the text that control for cross-sectional dependencies and are in line with the findings in Tables 4 and 5.

Independent Variables	Dependent Variable—CO ₂ Emissions		
	Pooled OLS	Fixed Effect	Random Effect
AD_M	0.0301022 (0.0516614)	0.00828239 * (0.0156901)	0.00858615 (0.0159923)
FI	−0.0174788 (0.0150104)	0.02135445 ** (0.007689)	0.0200199 ** (0.0076996)
FE	0.0339964 *** (0.0070985)	−0.02862203 *** (0.0072265)	−0.02375409 *** (0.0070471)
PEC	0.0001217 *** (4.74 × 10 ^{−6})	0.00011638 *** (4.97 × 10 ^{−6})	0.00010677 *** (4.14 × 10 ^{−6})
URB	−0.0578991 *** (0.0094165)	0.00540627 (0.0140417)	−0.00797158 (0.0130117)
Cons	8.466953 *** (1.063399)	2.7348242 * (1.33305)	4.8740603 *** (1.20984)
Hausman		48.03 (0.0000)	
N	792	792	792
R ²	0.8174	0.6078	0.6626

Notes: Results include variance coefficient and standard errors that are reported in parentheses. Superscripts ***, **, and * show statistical significance at the 1%, 5%, and 10% levels (** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$).

Table A2. Variables description in panels. This table shows the description of variables in panels, calculating between and within results. This table also suggests that there is enough variability between panels, to consider panel data analysis.

Variable		Mean	Std. Dev.	Min	Max	Obs.
CO ₂	Overall	8.10141	3.99521	1.3102	21.3044	N = 792
	Between		3.88083	1.57585	18.12671	n = 36
	Within		1.14048	2.77793	11.8066	T = 22
AD_M	Overall	1.03788	2.33612	0	35	N = 792
	Between		1.57929	0.04545	7.18182	n = 36
	Within		1.74056	−5.14394	33.62879	T = 22
FI	Overall	11.78508	5.8299	1.5355	37.5974	N = 792
	Between		4.70389	4.96551	24.98217	n = 36
	Within		3.52826	0.83343	26.63124	T = 22
FE	Overall	9.28232	13.50132	0.0161	69.8156	N = 792
	Between		13.20374	0.33257	62.79943	n = 36
	Within		3.51112	−6.72789	27.30392	T = 21.94
PEC	Overall	47860.02	30333.84	7834.471	188294	N = 792
	Between		30173.06	9640.279	157829.7	n = 36
	Within		5822.251	7823.166	78324.28	T = 22
URB	Overall	76.15883	11.15593	50.754	98.117	N = 792
	Between		11.09607	52.82805	97.65595	n = 36
	Within		2.14494	63.56498	85.93798	T = 22

Table A3. VIF results. This table presents the results for variance inflation factors, as a check for possible multicollinearity problems.

Variable	VIF	1/VIF
AD_M	1.17	0.8569
FI	1.12	0.89157
FE	1.42	0.70292
PEC	1.73	0.57711
URB	1.57	0.63859
Mean VIF	1.42	

Table A4. Testing for the stationarity of the dependent variable—full results. This table synthesizes unit-root test results, a check for the stationarity of the series. Non-stationary series in levels must be transformed before applying OLS methodology.

Variable Name	CO ₂		
Number of observations	814		
Number of panels	36		
Number of periods	22		
Test name			
Im–Pesaran–Shin unit-root test			
Ho: All panels contain unit roots			
Ha: Some panels are stationary			
Z-t-tilde-bar			
	Statistic	Prob	Conclusion
Level	6.6328	1.0000	H(0)
First-difference	−14.5163	0.0000	Ha
Levin–Lin–Chu unit-root test			
Ho: All panels contain unit roots			
Ha: Some panels are stationary			
Adjusted t			
	Statistic	Prob	Conclusion
Level	2.6665	0.9962	H(0)
First-difference	−10.7708	0.0000	Ha
Harris–Tzavalis unit–root test			
Ho: Panels contain unit roots			
Ha: Panels are stationary			
z			
	Statistic	Prob	Conclusion
Level	3.4897	0.9998	H(0)
First-difference	−42.5366	0.0000	Ha
Breitung unit–root test			
Ho: Panels contain unit roots			
Ha: Panels are stationary			
lambda			
	Statistic	Prob	Conclusion
Level	4.507	1.0000	H(0)
First-difference	−12.7763	0.0000	Ha
Hadri unit–root test			
Ho: Panels are stationary			
Ha: Panels contain unit roots			

Table A4. *Cont.*

Variable Name	CO ₂		
	z		
	Statistic	Prob	Conclusion
Level	64.5403	0.0000	Ha
First-difference	−0.0548	0.5218	H(0)

Table A5. Testing cointegration between variables (CO₂ and AD_M). This table presents the co-integration tests results. The co-integration of series is needed for applying the ECM methodology.

Cointegration Test Name and Statistics	Name of Variables	
	CO ₂ and PEC	
Kao		
Modified Dickey–Fuller t	4.4621	***
Dickey–Fuller t	5.5166	***
Augmented Dickey–Fuller t	5.5209	***
Unadjusted modified Dickey–Fuller	2.3693	***
Unadjusted Dickey–Fuller t	2.427	***
Pedroni		
Modified Phillips–Perron t	−1.171	
Phillips–Perron t	−4.0023	***
Augmented Dickey–Fuller t	−4.0315	***
Westerlund		
Variance ratio	−0.5265	
H ₀ : No cointegration	2	
H _a : All panels are cointegrated	7	

Note: *** $p < 0.01$.**Table A6.** Testing cointegration between variables (CO₂ and PEC). The table presents the co-integration tests results. The co-integration of series is needed for applying the ECM methodology. After all the previous tests were carried out, the main results obtained from the processing and that allowed us to determine the influences of the independent variables on the dependent variable—carbon dioxide emissions—are presented in Tables 4 and 5.

Cointegration Test Name and Statistics	Name of Variables	
	CO ₂ and PEC	
Kao		
Modified Dickey–Fuller t	4.4621	***
Dickey–Fuller t	5.5166	***
Augmented Dickey–Fuller t	5.5209	***
Unadjusted modified Dickey–Fuller	2.3693	***
Unadjusted Dickey–Fuller t	2.427	***
Pedroni		
Modified Phillips–Perron t	−1.171	
Phillips–Perron t	−4.0023	***
Augmented Dickey–Fuller t	−4.0315	***
Westerlund		
Variance ratio	−0.5265	
H ₀ : No cointegration	2	
H _a : All panels are cointegrated	7	

Note: *** $p < 0.01$.

Table A7. Time effect results. This table presents the results; both in the short-term and long-term results, cross-sectional dependence is not controlled.

Dependent Variable: d.CO ₂				
Year	Coef	Std. Err.	t	P > t
2002	−0.1444	0.0907	−1.5900	0.1120
2003	0.1215	0.0903	1.3500	0.1790
2004	−0.1570	0.0908	−1.7300	0.0840
2005	−0.1941	0.0936	−2.0700	0.0380
2006	−0.0461	0.0906	−0.5100	0.6110
2007	−0.1113	0.0903	−1.2300	0.2180
2008	−0.3222	0.0964	−3.3400	0.0010
2009	−0.5590	0.0932	−6.0000	0.0000
2010	0.1126	0.0921	1.2200	0.2220
2011	−0.2730	0.0930	−2.9300	0.0030
2012	−0.2497	0.0911	−2.7400	0.0060
2013	−0.2156	0.0903	−2.3900	0.0170
2014	−0.3321	0.0917	−3.6200	0.0000
2015	−0.1887	0.0960	−1.9700	0.0500
2016	−0.1411	0.0913	−1.5500	0.1230
2017	−0.1347	0.0917	−1.4700	0.1420
2018	−0.1723	0.0920	−1.8700	0.0610
2019	−0.3815	0.0905	−4.2200	0.0000
2020	−0.5535	0.0966	−5.7300	0.0000
2021	0.0390	0.0978	0.4000	0.6900

Table A8. Country effects. This table presents the results, also in the short-term and long-term, controlling for cross-sectional dependence.

Country	Coef	Std. Err.	t	P > t
USA	−0.0981	0.1182	−0.8300	0.0407
ISL	−0.0789	0.1184	−0.6700	0.0506
DNK	−0.0677	0.1179	−0.5700	0.0566
EST	−0.0619	0.1183	−0.5200	0.0601
BEL	−0.0410	0.1179	−0.3500	0.0728
IRL	−0.0338	0.1184	−0.2900	0.0776
CZE	−0.0298	0.1181	−0.2500	0.0801
ISR	−0.0289	0.1210	−0.2400	0.0811
FIN	−0.0218	0.1179	−0.1800	0.0854
GBR	−0.0211	0.1195	−0.1800	0.0860
GRC	−0.0017	0.1201	−0.0100	0.0989
CAN	0.0010	0.1178	0.0100	0.0993
DEU	0.0137	0.1178	0.1200	0.0907
ESP	0.0320	0.1184	0.2700	0.0787
ITA	0.0358	0.1182	0.3000	0.0762
SWE	0.0535	0.1182	0.4500	0.0651
SVK	0.0567	0.1196	0.4700	0.0636
AUT	0.0720	0.1188	0.6100	0.0545
SVN	0.0769	0.1184	0.6500	0.0516
CHE	0.0789	0.1180	0.6700	0.0504
NZL	0.0815	0.1180	0.6900	0.0490
PRT	0.0869	0.1266	0.6900	0.0493
FRA	0.0880	0.1187	0.7400	0.0459
POL	0.0966	0.1191	0.8100	0.0417
NLD	0.1030	0.1328	0.7800	0.0438
MEX	0.1112	0.1193	0.9300	0.0352
HUN	0.1219	0.1204	1.0100	0.0312
LVA	0.1359	0.1181	1.1500	0.0250
CHL	0.1359	0.1179	1.1500	0.0249
NOR	0.1624	0.1201	1.3500	0.0177
JPN	0.1682	0.1279	1.3100	0.0189
COL	0.1687	0.1205	1.4000	0.0162
LTU	0.1813	0.1180	1.5400	0.0125
TUR	0.2304	0.1259	1.8300	0.0068
CRI	0.2547	0.1488	1.7100	0.0087

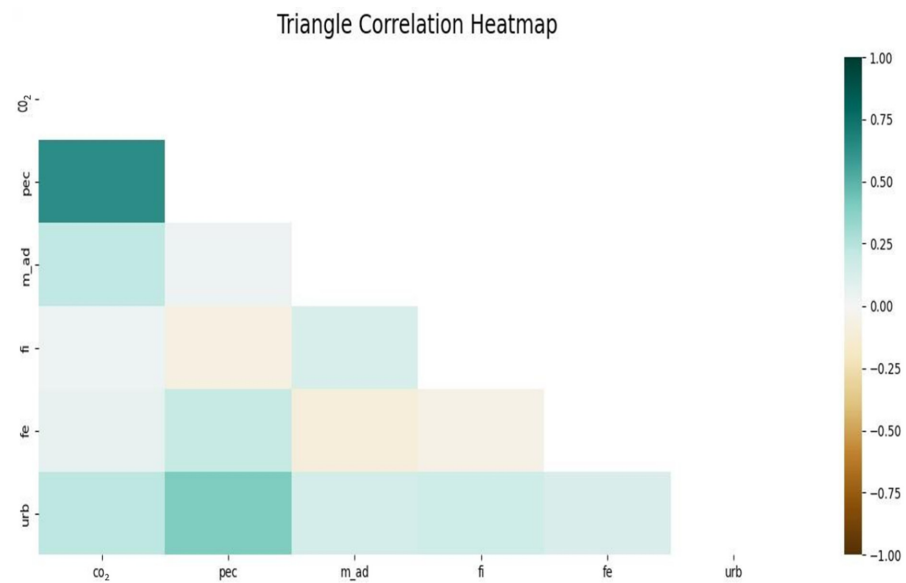


Figure A1. Triangle correlation heatmap. The figure is the basis for choosing the correct independent variables (with no high correlation between them).

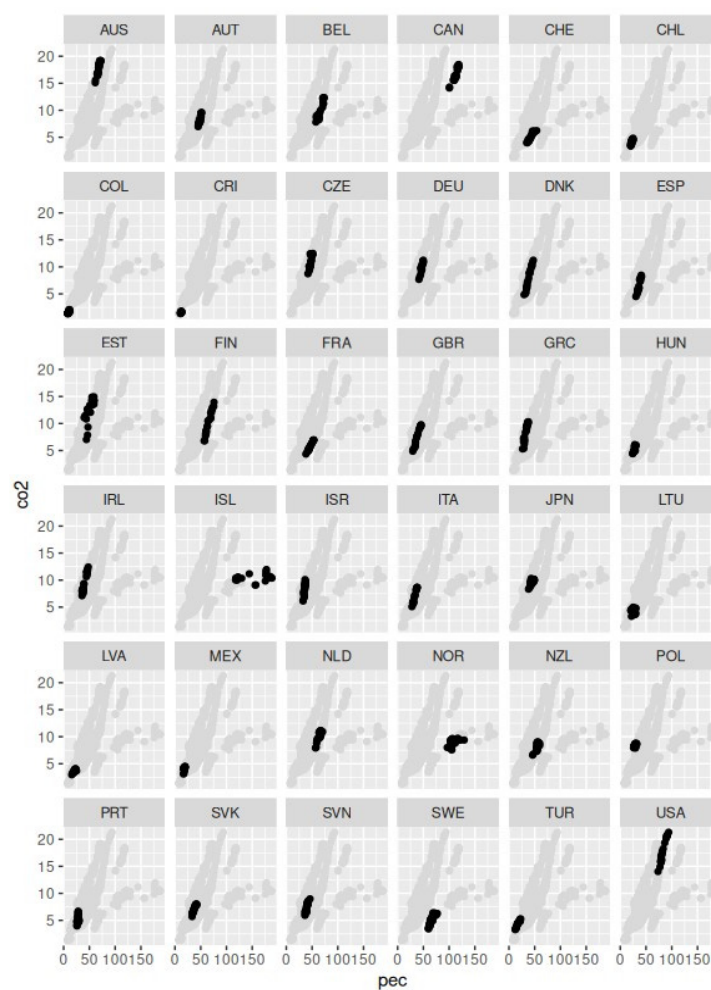


Figure A2. Relationship between CO_2 and PEC. This graphic shows the relationship between primary energy consumption and CO_2 levels by country. In all panels, the relation is positive and elastic—an increase in primary energy consumption determines an increase in CO_2 levels. The graphical analysis is visual proof that the signs of econometric coefficients are correctly determined.

References

- Adams, Samuel, and Christian Nsiah. 2019. Reducing carbon dioxide emissions; Does renewable energy matter? *Science of The Total Environment* 693: 133288. [CrossRef] [PubMed]
- Ahakwa, Isaac, Yi Xu, Evelyn Agba Tackie, Leslie Afotey Odai, Francis Atta Sarpong, Benard Korankye, and Elvis Kwame Ofori. 2023. Do natural resources and green technological innovation matter in addressing environmental degradation? Evidence from panel models robust to cross-sectional dependence and slope heterogeneity. *Resources Policy* 85: 103943. [CrossRef]
- Ahn, Dukgeun, and Wonkyu Shin. 2011. Analysis of Anti-dumping Use in Free Trade Agreements. *Journal of World Trade* 45: 431–56. [CrossRef]
- Andersen, Henrik. 2021. *Climate Concerns and Antidumping Law: Where is the Space for the Climate Argument?* Rochester: Social Science Research Network.
- Antweiler, Werner, Brian R. Copeland, and M. Scott Taylor. 2001. Is Free Trade Good for the Environment? *American Economic Review* 91: 877–908. [CrossRef]
- Ao, Lejing. 2024. Are anti-dumping investigations against China ineffective in curbing innovation? Evidence from firms' patent filings. *The Journal of International Trade & Economic Development*, 1–24. [CrossRef]
- Assogbavi, Koutchogna Kokou Edem, and Stéphane Déès. 2023. Environmental Policy and the CO2 Emissions Embodied in International Trade. *Environmental and Resource Economics* 84: 507–27. [CrossRef]
- Aziz, Ghazala, Suleman Sarwar, Rida Waheed, and Mohd Saeed Khan. 2024. The significance of renewable energy, globalization, and agriculture on sustainable economic growth and green environment: Metaphorically, a two-sided blade. *Natural Resources Forum* 48: 763–83. [CrossRef]
- Bekker, Doreen. 2006. The Strategic Use of Anti-Dumping in International Trade. *South African Journal of Economics* 74: 501–21. [CrossRef]
- Bersvendsen, Tore, and Jan Ditzén. 2021. Testing for slope heterogeneity in Stata. *The Stata Journal: Promoting Communications on Statistics and Stata* 21: 51–80. [CrossRef]
- Bildirici, Melike, Fazıl Kayıkçı, and Özgür Ömer Ersin. 2023. Industry 4.0 and Renewable Energy Production Nexus: An Empirical Investigation of G20 Countries with Panel Quantile Method. *Sustainability* 15: 14020. [CrossRef]
- Blackburne, Edward F., and Mark W. Frank. 2007. Estimation of Nonstationary Heterogeneous Panels. *The Stata Journal* 7: 197–208. [CrossRef]
- Breitung, Jörg, and Samarjit Das. 2005. Panel unit root tests under cross-sectional dependence. *Statistica Neerlandica* 59: 414–33. [CrossRef]
- Breitung, Jörg. 2000. The local power of some unit root tests for panel data. *Advances in Econometrics* 15: 161–77. [CrossRef]
- Can, Muhlis, Ihsan Oluc, Bodo Sturm, Ihsan Guzel, Beata Gavurova, and József Popp. 2022. Nexus Between Trading Non-Green Products and Environment: Introducing Non-Green Trade Openness Index. *Frontiers in Environmental Science* 10: 950453. [CrossRef]
- Choi, In. 2001. Unit root tests for panel data. *Journal of International Money and Finance* 20: 249–72. [CrossRef]
- Chudik, Alexander, and M. Hashem Pesaran. 2013. *Large Panel Data Models with Cross-Sectional Dependence: A Survey*. Working Paper no. 153. Dallas: Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute. [CrossRef]
- Chudik, Alexander, and M. Hashem Pesaran. 2015. Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics* 188: 393–420. [CrossRef]
- Chudik, Alexander, Kamiar Mohaddes, Mohammad Pesaran, and Mehdi Raissi. 2016. Long-Run Effects in Large Heterogeneous Panel Data Models with Cross-Sectionally Correlated Errors. *Advances in Econometrics*, 85–135. [CrossRef]
- Cloete, Schalk, Oliver Ruhnau, Jan Hendrik Cloete, and Lion Hirth. 2022. Blue hydrogen and industrial base products: The future of fossil fuel exporters in a net-zero world. *Journal of Cleaner Production* 363: 132347. [CrossRef]
- Council of the European Union. 2024. EU Sanctions against Russia Explained. Available online: <https://www.consilium.europa.eu/en/policies/sanctions-against-russia-explained/> (accessed on 3 December 2024).
- Dai, Zhe, Yunzhi Zhang, and Rui Zhang. 2021. The Impact of Environmental Regulations on Trade Flows: A Focus on Environmental Goods Listed in APEC and OECD. *Frontiers in Psychology* 12: 773749. [CrossRef] [PubMed]
- Davis, Lucy. 2009. Ten years of anti-dumping in the EU: Economic and political targeting. *Global Trade and Customs Journal* 4: 213–32. [CrossRef]
- Dean, Judith M. 1992. *Trade and the Environment: A Survey of the Literature*. Policy Research Working Paper Series. Available online: <https://econpapers.repec.org/paper/wbkwbrwps/966.htm> (accessed on 22 April 2024).
- Dean, Judith M., Mary E. Lovely, and Hua Wang. 2009. Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. *Journal of Development Economics* 90: 1–13. [CrossRef]
- Dickey, David A., and Wayne A. Fuller. 1981. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica* 49: 1057. [CrossRef]
- Ditzen, Jan. 2018. Estimating Dynamic Common-Correlated Effects in Stata. *The Stata Journal* 18: 585–617. [CrossRef]
- Ditzen, Jan. 2019. *Estimating Long Run Effects in Models with Cross-Sectional Dependence Using xtdcce2*. CEERP Working Paper Series from Centre for Energy Economics Research and Policy. Edinburgh: Heriot-Watt University, pp. 1–36.

- Duceac, Letiția-Doina, Lucian Eva, Marius Dabija, Tudor Ciuhodaru, Cristian Guțu, Laura Romila, and Smaranda Nazarie. 2020. Prevention and limitation of coronavirus SARS-CoV-2 cases in hospitals and dental medicine offices. *International Journal of Medical Dentistry* 24: 149–56.
- Eberhardt, Markus. 2012. Estimating Panel Time-Series Models with Heterogeneous Slopes. *The Stata Journal* 12: 61–71. [CrossRef]
- Energy Information Administration. 2023. Glossary—U.S. Energy Information Administration (EIA). Available online: <https://www.eia.gov/tools/glossary/index.php?id=Primary%20energy%20consumption> (accessed on 8 March 2024).
- Engle, Robert F., and C. W. J. Granger. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica* 55: 251. [CrossRef]
- Erdogan, Ayse M. 2014. Bilateral trade and the environment: A general equilibrium model based on new trade theory. *International Review of Economics & Finance* 34: 52–71. [CrossRef]
- Goswami, Arvind, Harmanpreet Singh Kapoor, Rajesh Kumar Jangir, Caspar Njoroge Ngigi, Behdin Nowrouzi-Kia, and Vijay Kumar Chattu. 2023. Impact of Economic Growth, Trade Openness, Urbanization and Energy Consumption on Carbon Emissions: A Study of India. *Sustainability* 15: 9025. [CrossRef]
- Harris, Richard, and Elias Tzavalis. 1999. Inference for unit roots in dynamic panels where the time dimension is fixed. *Journal of Econometrics* 91: 201–26. [CrossRef]
- IEA. 2021. Key electricity trends 2020—Analysis. IEA. Available online: <https://www.iea.org/articles/key-electricity-trends-2020> (accessed on 3 December 2024).
- Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin. 2003. Testing for unit roots in heterogeneous panels. *Journal of Econometrics* 115: 53–74. [CrossRef]
- Irwin, Douglas A. 2005. The Rise of US Anti-dumping Activity in Historical Perspective. *The World Economy* 28: 651–68. [CrossRef]
- Iwata, Hiroki, Keisuke Okada, and Sovannroeun Samreth. 2012. Empirical study on the determinants of CO₂ emissions. *Applied Economics* 44: 3513–19. [CrossRef]
- Jabbour, Liza, Zhigang Tao, Enrico Vanino, and Yan Zhang. 2019. The good, the bad and the ugly: Chinese imports, European Union anti-dumping measures and firm performance. *Journal of International Economics* 117: 1–20. [CrossRef]
- Katircioğlu, Setareh, and Salih Katircioğlu. 2018. Testing the role of urban development in the conventional Environmental Kuznets Curve: Evidence from Turkey. *Applied Economics Letters* 25: 741–46. [CrossRef]
- Klotz, Richard, and Rishi R. Sharma. 2023. Trade barriers and CO₂. *Journal of International Economics* 141: 103726. [CrossRef]
- Kripfganz, Sebastian, and Daniel C. Schneider. 2023. ARDL: Estimating autoregressive distributed lag and equilibrium correction models. *The Stata Journal* 23: 983–1019. [CrossRef]
- Lee, Kevin, M. Hashem Pesaran, and Ron Smith. 1997. Growth and Convergence in a Multi-Country Empirical Stochastic Solow Model. *Journal of Applied Econometrics* 12: 357–92. [CrossRef]
- Levin, Andrew, Chien-Fu Lin, and Chia-Shang James Chu. 2002. Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics* 108: 1–24. [CrossRef]
- Moreira, Mauricio Mesquita, and Marcelo Dolabella. 2023. Does trade policy help or hinder global warming? A case study of Latin America and the Caribbean. *The World Economy* 47: 779–805. [CrossRef]
- Nielsen, Heino Bohn. 2004. Cointegration analysis in the presence of outliers. *The Econometrics Journal* 7: 249–71. [CrossRef]
- Pata, Ugur Korkut, Abdullah Emre Caglar, Mustafa Tevfik Kartal, and Serpil Kılıç Depren. 2023. Evaluation of the role of clean energy technologies, human capital, urbanization, and income on the environmental quality in the United States. *Journal of Cleaner Production* 402: 136802. [CrossRef]
- Pedroni, Peter. 2004. Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. *Econometric Theory* 20: 597–625. [CrossRef]
- Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* 16: 289–326. [CrossRef]
- Pesaran, M. Hashem, Yongcheol Shin, and Ron P. Smith. 1999. Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association* 94: 621. [CrossRef]
- Pesaran, M. Hashem. 2006. Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure. *Econometrica* 74: 967–1012. [CrossRef]
- Phillips, Peter C. B., and Pierre Perron. 1988. Testing for a unit root in time series regression. *Biometrika* 75: 335–46. [CrossRef]
- Prusa, Thomas J. 2005. Anti-dumping: A Growing Problem in International Trade. *The World Economy* 28: 683–700. [CrossRef]
- Statistisches Bundesamt. 2024. Energy Prices: High Increases at All Stages in the Economic Process. Federal Statistical Office. Available online: https://www.destatis.de/EN/Press/2022/03/PE22_N016_61.html (accessed on 3 December 2024).
- Sun, Mingsong, Xinyuan Cao, Xuan Liu, Tingting Cao, and Qirong Zhu. 2024. The Russia-Ukraine conflict, soaring international energy prices, and implications for global economic policies. *Heliyon* 10: e34712. [CrossRef]
- UNCC. 2015. The Paris Agreement. Available online: <https://unfccc.int/process-and-meetings/the-paris-agreement> (accessed on 22 April 2024).
- Uyun, Ety, Sri Devi Zebua, Riza Firdaus, and Henry Aspan. 2024. Anti-Dumping Regulations in International Trade Law and Its Application in Indonesia. *MORFAI Journal* 3: 883–89. Available online: <https://radjapublika.com/index.php/MORFAI/article/view/1345> (accessed on 10 March 2024).

- Wang, Qiang, Lili Wang, and Rongrong Li. 2023. Trade protectionism jeopardizes carbon neutrality—Decoupling and breakpoints roles of trade openness. *Sustainable Production and Consumption* 35: 201–15. [CrossRef]
- Widiarty, Wiwik Sri. 2024. Economic Globalization in Protecting Domestic Products through Anti-Dumping Laws. *International Journal of Law and Politics Studies* 6: 1–5. [CrossRef]
- World Trade Organization. 2021. Trade and Climate Change Information Brief no. 4: The Carbon Content of International Trade. Available online: https://www.wto.org/english/news_e/news21_e/clim_03nov21-4_e.pdf (accessed on 22 April 2024).
- Yu, Biying, Qingyu Zhao, and Yi-Ming Wei. 2021. Review of carbon leakage under regionally differentiated climate policies. *Science of The Total Environment* 782: 146765. [CrossRef] [PubMed]
- Zanardi, Maurizio. 2004. Anti-dumping: What are the Numbers to Discuss at Doha? *The World Economy* 27: 403–33. [CrossRef]
- Zeng, Chen, Lindsay C. Stringer, and Tianyu Lv. 2021. The spatial spillover effect of fossil fuel energy trade on CO₂ emissions. *Energy* 223: 120038. [CrossRef]
- Zheng, Shuxian, Xuanru Zhou, Zhanglu Tan, Chan Liu, Han Hu, Shengnan Peng, and Xiaomei Cai. 2023. Impact of anti-dumping on global embodied air emissions: A complex network perspective. *Environmental Science and Pollution Research* 30: 56844–62. [CrossRef] [PubMed]
- Zi, Cao, Wei Jie, and Chen Hong-Bo. 2016. CO₂ emissions and urbanization correlation in China based on threshold analysis. *Ecological Indicators* 61: 193–201. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.