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The Role of Intra-Industry Trade, Foreign Direct Investment, and Renewable Energy on Portuguese Carbon Dioxide Emissions

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Abstract: This paper revisited the link between intra-industry trade (IIT) between Portugal and Spain and Portuguese carbon dioxide (CO_2) emissions. The research also considers the effects of foreign direct investment (FDI) on CO_2 emissions, pondering the arguments of the pollution haven hypothesis and the halo hypothesis. As an econometric strategy, this investigation has applied panel data, namely a Pooled Mean Group of an Autoregressive Distributed Lag (ARDL) model and Panel Quantile Regression (PQR). The preliminary unit root tests indicated that IIT, Portuguese and Spanish renewable energy, and Portuguese FDI are integrated into the first differences and stationary with the second generation test (Pesaran methodology). In the next step, this study applied the multicollinearity test and cross-dependence between the variables. The variance inflation factor test demonstrated that FDI and IIT have no multicollinear problems. However, as expected, collinearity exists between Portuguese and Spanish renewable energy. Regarding the cross-sectional dependence test, this investigation concluded that the variables have a dependence between them. The cointegration test revealed that the variables are overall cointegrated. In the econometric results with the ARDL estimator, this investigation has found that IIT between Portugal and Spain is negatively correlated with Portuguese CO_2 emissions, showing that this type of trade encourages environmental improvements. However, the PQR demonstrates that there is an opposite relationship. According to this, Portuguese and Spanish renewable energy is negatively impacted by CO_2 emissions, revealing that renewable energy aims to decrease pollution. Finally, Portuguese FDI reduces CO_2 emissions, which is explained by product differentiation, innovation, and monopolistic competition.

Keywords: foreign direct investment; bilateral trade; panel ARDL model; panel quantile regression; carbon dioxide emissions

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1. Introduction

The effects of intra-industry trade (IIT), foreign direct investment (FDI), and renewable energy have been studied in international economics and energy economics issues. Indeed, the theoretical models of IIT emerged in the 1980s and 1990s to explain product differentiation (e.g., Krugman [1]; Lancaster [2]; Falvey and Kierzkowski [3]; and Shaked and Sutton [4]). However, empirical studies of horizontal and vertical IIT became notable in the literature with the investigation, for example, by Greenaway et al. [5]. In this line, the researchers used countries and industry characteristics to explain the determinants of IIT (e.g., Faustino and Leitão [6]; Leitão and Faustino [7]; Jambor and Leitão [8]; and Doanh and Heo [9]). The determinants of IIT are explained by the gravity model, such as geographical distance, border, and economic dimension, or by industry explanatory variables, such as industrial concentration, product differentiation, scale economies, and FDI.

Another area of research concerns the issue of marginal IIT and structural adjustment issues in the labour market (e.g., Brülhart and Thorpe [10]; Thorpe and Leitão [11]; and Leitão et al. [12]). The empirical studies use wages, productivity, apparent consumption, and marginal IIT as independent variables in labour market adjustments. Moreover, they consider that the adjustment is smooth whenever the marginal IIT negatively correlates with changes in employment.

Recently, the empirical studies of Roy [13], Leitão and Balogh [14], Leitão [15], and Kazemzadeh et al. [16] showed that IIT and trade intensity could mitigate the damage to the environment, promote cleaner air quality and slow climate change. This assumption is explained by considering that IIT is associated with innovation and product differentiation. The internalisation process of multinational enterprises was developed based on the theories of international investments, namely organisations, localisation and internalisation theories and transaction costs (e.g., Dunning and Lundan [17]).

Considering the determinants of FDI, the empirical studies use the gravity model and organisation, localisation and internalisation advantages and characteristics, where the explanatory variables utilised are economic dimensions, the border, geographical distance, production costs, the exchange rate, or, more recently, the impact of corruption and democratisation on the FDI host country (e.g., Leitão [15]; and Egger and Pfaffermayr [18]). Furthermore, another issue of the investigation into FDI is the question of economic growth, i.e., the linkage between FDI and economic development (e.g., Alfaro et al. [19]; and Alfaro and Charlton [20]). Academics and scholars have investigated the relationship between FDI and the pollution haven hypothesis versus the pollution halo hypothesis (e.g., Cole et al. [21]; Singhania and Saini [22]; and Kisswani and Zaitouni [23]).

Although the literature has widely explored the relationship between IIT, FDI, renewable energy and CO_2 emissions, no investigations have explored the IIT between Portugal and Spain and the impact of FDI and renewable energy on Portuguese CO_2 emissions. In other words, existing gaps in the literature regarding these topics need to be filled and explored to understand this possible relationship in Portugal better. For this reason, the present research aims to fill the abovementioned gaps by analysing the impact of IIT between Portugal and Spain on Portuguese CO_2 emissions. It also considers investigating the effects of FDI on CO_2 emissions, pondering the arguments of the pollution haven hypothesis and the halo hypothesis.

Therefore, this investigation seeks to answer these questions: What is the impact of IIT between Portugal and Spain, FDI, and renewable energy on Portuguese CO_2 emissions? What is their directional relationship?

Thus, to fill these gaps and the main questions mentioned above, this investigation will conduct a macroeconomic analysis using a panel with data from Portugal from 2000 to 2018. A pooled mean group (PMG) of an autoregressive distributed lag (ARDL) model and panel quantile regression (PQR), as well as the Pairwise Dumitrescu–Hurlin panel causality test, will be used to carry out this empirical investigation.

This investigation is innovative for the literature by investigating the influence of the IIT between Portugal and Spain, FDI, and renewable energy on Portuguese CO_2 emissions. As mentioned above, the literature has not so far approached this topic. Moreover, ARDL, PQR models, and the Pairwise Dumitrescu–Hurlin panel causality test were used to carry out this empirical investigation.

Additionally, this study contributes to the literature in three ways. First, the relationship between IIT and climate change, air quality and the impact of IIT on CO_2 emissions are analysed both in theoretical and empirical terms of CO_2 emissions, which, as a rule, empirical studies tend to attribute a negative correlation, demonstrating that they allow a reduction in greenhouse effects and global warming. Second, we assess the relationship between FDI and polluting emissions. In this relationship, there are two different perspectives. On the one hand, empirical studies demonstrate that FDI positively impacts CO_2

emissions, which is explained by the pollution haven hypothesis. In other words, countries use FDI to circumvent stringent domestic environmental standards. This results in moving polluting activities to less environmentally regulated countries.

On the other hand, empirical studies indicate that FDI is associated with innovation factors, reducing greenhouse effects, and consequently improving climate change. In this case, it is explained by the pollution halo hypothesis, i.e., transnational enterprises transfer green technology via FDI to host countries. Therefore, we observe that the crucial objective of this research is to evaluate the effect of IIT and FDI on pollution and the environment. Moreover, this article considers the association of renewable energy with CO_2 emissions. Usually, empirical studies argue that renewable energy aims to decrease climate change and global warming (e.g., Usman et al. [24]; and Yu et al. [25]).

Finally, this investigation is important because its experimental findings contribute to the development of the existing literature and have significant implications for the policies of complex economies with diversified export products to reduce environmental degradation. Moreover, the results and explanations of this study will support policymakers and governments in developing consistent policies and initiatives that promote clean energy, reduce energy consumption, and achieve sustainable development.

The literature review and the empirical studies will emerge in the next section; Section 3 presents information on data collection, the hypotheses to be tested, and the economic model to apply. Subsequently, the empirical results appear in Section 4, and finally, we present the conclusions of this investigation in Section 5.

2. Literature Review and Empirical Studies

This part discusses the relevant empirical studies and theoretical models to study the linkages between IIT and pollution emissions and the nexus between FDI, renewable energy and CO_2 emissions.

2.1. Theoretical Framework

In the first stage, we present some preliminary issues to do with IIT. Understanding this type of trade in the world economy and its relationship with the environment is essential. In the second stage, we present two perspectives on the effects of FDI on CO_2 emissions (pollution haven hypothesis versus pollution halo hypothesis). Finally, we examine the link between renewable energy and pollution emissions.

In this context, IIT is explained by economies of scale, industrial concentration, and the differentiation in products. This type of trade predominates in the same sector or the same branch; see, for instance, Grubel and Lloyd [26] and Greenaway and Milner [27].

The theoretical models of the IIT (e.g., Krugman [1]; Lancaster [2]; Falvey and Kierzkowski [3]; and Shaked and Sutton [4]) are based on the assumptions of monopolistic competition, where geographical proximity, similarities or different factor endowments, and the respective consumer preferences are usually the explanatory variables. Therefore, this investigation will also refer to the connection between the IIT and environmental issues explained by monopolistic competition. However, before introducing the relationship between IIT and ecological issues, it is also important to mention that there is a set of empirical studies that assess the determinants of the IIT through the gravity model, i.e., using the characteristics of the countries or through the characteristics of the industries (e.g., Hasim et al. [28]; Vidya and Prabheesh [29]; and Jošić and Žmuk [30]).

2.2. The Relationship between IIT and Air Pollution

When a literature review is carried out on the relationship between IIT and climate change, it is observed that there are more theoretical than empirical models on this link. Thus, it can be inferred that empirical studies should emerge in the literature. Indeed, this type of research makes it possible to assess whether a given country or a set of sectors of a given economy is associated with the theory of comparative advantages, where inter-industry trade predominates. Consequently, higher pollution levels are expected. On the contrary, innovation and using more sustainable practices translate into IIT, where it is possible to improve the environment. However, there seems to be a convergence between theoretical models and empirical studies. Indeed, most studies conclude that the IIT allows for an improvement in the environment.

There is a set of theoretical and empirical models (e.g., Roy [13]; Leitão and Balogh [14]; Leitão [15]; Kazemzadeh et al. [16]; Copeland and Taylor [31]; Gürtzgen and Rauscher [32]; Echazu and Heintzelman [33]; Gallucci et al., [34]; and Shapiro [35]) demonstrating that IIT, and exports quality and trade intensity improve the quality of the air and environment.

Subsequently, this investigation will present some conclusions and more details about empirical studies of IIT and the environment, namely the articles of Roy [13], Leitão and Balogh [14], Leitão [15], Kazemzadeh et al. [16], and Gallucci et al. [34]. In this context, the empirical study of Roy [13] analysed the determinants of IIT, considering the arguments of the gravity model. The author tested the effect of IIT, marginal IIT, and trade intensity on air quality and pollution emissions using panel data. The regressions showed that IIT aims to decrease the climate change generated by environmental improvements. In this line, Gallucci et al. [34] concluded that IIT could be considered an indicator of innovation, and this type of trade positively influences the environment with cleaner technologies.

Considering the European countries' experience, the work of Leitão and Balogh [14] used the fixed effects and generalized method of moments estimators. The authors concluded that IIT is negatively correlated with CO_2 emissions. On the other hand, Leitão and Balogh [14], based on a fixed effects model, concluded that renewable energy aims to decrease pollution emissions, and CO_2 emissions positively impact income per capita and agricultural land productivity. The extensive empirical study of Leitão [15], for the Portuguese case, using the autoregressive distributed lag (ARDL) model with a time series, demonstrated that trade intensity decreases CO_2 emissions. Nevertheless, the variables in energy consumption and income per capita increase pollution emissions, namely CO_2 emissions. In this line, the empirical study of Kazemzadeh et al. [16] considered the effects of economic complexity and export quality on pollution emissions in 98 countries between 1990 and 2014, using PQRs. The authors found that trade openness and export quality improve environmental and pollution emissions. Moreover, income per capita, population, and non-renewable energy are positively associated with climate change and ecological damage. However, when Kazemzadeh et al. [16] applied panel cointegration regressions, the results demonstrated that urban population and economic complexity are always negatively correlated with CO_2 emissions.

Another contribution applied to India developed by Aggarwal et al. [36] demonstrated that India IIT is characterised by the low quality of products because there exists a difference in environmental rules. The authors suggest that India should develop trade agreements with European Union countries and the United Kingdom to improve this issue.

Khan et al. [37] evaluated the link between international trade, renewable energy, and CO_2 emissions in the Group of Seven (G7) economies. They found that imports and income per capita increased pollution emissions in the long run. Nevertheless, exports, environmental innovations, and renewable energy decrease CO_2 emissions.

From the empirical studies referred to above, there appears to be a gap in the literature because the studies assess a set of countries or a country's total trade. Moreover, few studies seem to test the bilateral relationship between Portugal and Spain, namely the impact of IIT on Portuguese CO_2 emissions.

2.3. The Link between FDI and CO_2 Emissions

The literature review argues that two different opinions exist regarding the effect of FDI on CO_2 emissions. For instance, according to the pollution haven hypothesis proposed by Cole et al. [21], Kisswani and Zaitouni [23], Usman et al. [24], Zhu et al. [38], Teng et al. [39], and Zmami and Ben-Salha [40], there was a positive effect of FDI on CO_2 emissions. In contrast, the empirical studies of Demena and Afesorgbor [41] and Marques and Caetano [42] argue that FDI encourages an improvement in the environment (pollution halo hypothesis), explaining this effect to be based on innovation factors due to FDI.

Following this, this investigation will present some conclusions from the empirical work of Agyeman et al. [43], Lin et al. [44], and Huang et al. [45]. Using the cointegration panel for a set of 27 African countries, the study by Agyeman et al. [43] demonstrated that government policies allowed a reduction in CO_2 emissions, evaluating the environmental Kuznets curve (EKC) hypothesis. Furthermore, the dynamic ordinary least squares (DOLS) model shows that tourism and FDI positively correlate with CO_2 emissions.

The investigation of local, regional, and countrywide experiences in China by Lin et al. [44] showed that FDI reduces pollution emissions at the national level. Besides, the empirical study of Lin et al. [44] revealed that EKC hypotheses are valid at all levels, and energy consumption increases CO_2 emissions in local regions. A different position can be found in the studies of Usman et al. [24] and Huang et al. [45], which demonstrate that FDI accentuates climate change, explained by the pollution haven hypothesis.

A panel analysis of data for India, Pakistan, Sri Lanka, and Bangladesh was carried out by Mehmood [46], and the long-term effects through the ARDL estimator showed that economic growth and FDI accentuate CO_2 emissions. However, the interaction variables of renewable energy and FDI and the interaction of renewable energy and economic growth promote environmental improvements. Furthermore, the empirical study shows that government effectiveness and renewable energies stimulate a reduction in pollution levels.

The links between financial inclusion, globalisation, renewable energy, and CO_2 emissions were investigated by Qin et al. [47], where the study used panel data (PQRs and cointegration panel tests) and concluded that the EKC hypotheses are valid for the emerging seven economies (e.g., China, India, Brazil, Turkey, and Russia). Furthermore, the authors demonstrate that financial inclusion, globalization, and renewable energy electricity make it possible to reduce CO_2 emissions.

2.4. The Correlation between Renewable Energy and CO_2 Emissions

Several articles in energy economics (e.g., Shaari et al. [48]; Razzaq et al. [49]; Muço et al. [50]; and Balsalobre-Lorente et al. [51]) showed that renewable energy consumption mitigated the damage to the environment, showing with different econometric techniques that there is a negative impact of renewable energy on CO_2 emissions. The studies argue that renewable energy and clean technologies aim to decrease climate change. In this context, Muço et al. [50] applied a panel vector autoregression model to new European countries from 1990 to 2018. Considering the CO_2 emissions as a dependent variable, the authors found a negative effect of lagged renewable energy on CO_2 emissions, and that the lagged variable in income per capita is positively correlated with CO_2 emissions. Moreover, the lagged variable in energy use presents a positive effect on CO_2 emissions. However, the authors found a negative impact of lagged CO_2 emissions, showing that CO_2 decreases in the long run.

In the recent article of Mehmood [47] applied to four South Asian countries from 1990 to 2017, with the ARDL model, the author found that globalisation and financial inclusion are positively correlated with CO_2 emissions in the long run. Furthermore, the model also validates the hypothesis of the Kuznets curve. Finally, the variables in renewable energy decreased pollution emissions.

Shaari et al. [48] considered different economies from 1990 to 2017 in their research, using a panel ARDL model. Considering a PMG estimator, Shaari et al. [48] found that CO_2 emissions negatively impact renewable energy, and income per capita and population positively correlate with pollution in the long run.

The Middle East/North Africa countries were investigated by Omri and Saidi [52] using a panel data fully modified ordinary least squares (FMOLS) estimator, and they found that the EKC hypotheses are valid. The coefficients of trade, financial development and non-renewable energy positively affect climate change. However, the variable in renewable energy aims to decrease CO_2 emissions.

The case of Africa was investigated by Usman et al. [24], and the authors considered the impacts of corruption control, economic growth, renewable energy, and FDI on CO_2 emissions using the panel method of moments quantile estimators. The econometric models revealed that the variables in corruption control and economic growth are positively correlated with CO_2 emissions. Besides, the effect of FDI on CO_2 emissions is explained by pollution haven hypotheses, reflecting that FDI increases pollution emissions. However, renewable energy aims to decrease pollution emissions and improve the environment.

The empirical work of Pata [53] tested the United States of America's CO_2 emissions and ecological footprint. The results showed that economic complexity and the squared economic complexity index are according to the assumptions of EKC. Moreover, renewable and non-renewable energy are negatively and positively associated with CO_2 emissions.

The relationship between financial development, renewable energy, and CO_2 emissions in 11 economies was investigated by Wang et al. [54]. According to Goldman Sachs's criteria, the authors selected 11 economies and found that economic growth positively correlates with CO_2 emissions and financial development. Besides, renewable energy, globalisation and the interaction of financial development and renewable energy decrease the pollution effects, namely the CO_2 emissions.

The experience of South Africa was investigated by Ekwueme et al. [55] to evaluate the impacts of renewable energy, fiscal development, and FDI on CO_2 emissions. Considering the vector error correction model and ARDL (autoregressive distributed lag model), the authors found that in the long run, renewable energy, economic growth, and financial development are positively impacted by CO_2 emissions.

Adebayo and Kirikkaleli [56] considered the nexus between renewable energy, globalization, innovation, and CO_2 emissions in Japan using wavelet analysis. According to [56], economic growth and innovation stimulate climate change, but renewable energy decreases CO_2 emissions in the short and medium run.

In the context of the Environmental Kuznets curve, the empirical study by Safar [57] tests the relationship between income inequality and pollution emissions in France. The ARDL model shows that inequality can affect CO_2 emissions differently, i.e., it depends on the indicator the author used (Gini index or Atkinson). Furthermore, the work of Safar [57] demonstrates that net inequality improves the environment.

In the following section, the methodology and econometric model are going to be presented in this article.

3. Methodology and Econometric Model

The effects of IIT between Portugal and Spain and renewable energy on Portuguese CO_2 emissions from 2000 to 2018 are considered in this investigation. Moreover, this research also introduces the impact of FDI on Portuguese CO_2 emissions to test the pollution haven hypothesis versus innovation and product differentiation (pollution halo hypothesis). Following this, the last variable allows us to observe if FDI is associated with pollution emissions or decreases CO_2 emissions.

The index of IIT was calculated from Organisation for Economic Co-operation and Development (OECD) statistics and bilateral trade in goods by industry from the International Standard Industrial Classification. The dataset is organised in panel data, and this study used the PMG of an ARDL model and the PQR model. In the first phase, this investigation will focus on the coefficients obtained through the panel ARDL model; these were determined using the Akaike information criterion (AIC), and the specification is fixed. This strategy serves as an analysis tool to later analyse the heterogeneity of the variables under study through the PQR. In the first step, cointegration tests were considered (e.g., Kao et al. [58], Kao and Chiang [59], and Johansen [60]) to assess if there is a long-run relationship between the variables under study. Besides, this investigation will verify the panel unit roots, multicollinearity, and cross-sectional dependence tests.

The index of intra-industry trade (e.g., Grubel and Lloyd [26]) can be represented by:

$$IIT_{ij} = 1 - \frac{\left| \sum_{k=1}^{K} X_{ijk} - \sum_{k=1}^{K} M_{ijk} \right|}{\left(\sum_{k=1}^{K} X_{ijk} + \sum_{k}^{K} M_{ijk} \right)} \quad (1)$$

The index varies between 0 and 1. When IIT_{ij} = 1, all trade is intra-industry trade, but when IIT_{ij} = 0, the trade is inter-industry trade.

In our study, the selected sectors were total trade, intermediate goods, household consumption, capital goods, mixed end-use (personal computers, passenger cars, personal phones), precious goods, packed medicines, and miscellaneous. Based on the empirical studies (e.g., Roy [13]; Leitão and Balogh [14]; Balsalobre-Lorente et al. [51]; Zafar et al. [61]; and Dogan and Ozturk [62]), this investigation formulates the following model:

$$\begin{aligned}\Delta LogCO_{2it} = {} & \alpha_{0it} + \alpha_{1it}LogCO_{2i(t-1)} + \alpha_{2it}LogIIT_{i(t-1)} + \alpha_{3it}LogRE_{i(t-1)} + \alpha_{4it}LogRESP_{i(t-1)} + \alpha_{5it}LogFDI_{i(t-1)} \\ & + \sum\nolimits^{P}{}_{j=0}\gamma_1 LogCO_{2i(t-j)} + \sum\nolimits^{P}{}_{j=0}\gamma_2 LogIIT_{i(t-j)} + \sum\nolimits^{P}{}_{j=0}\gamma_3 LogRE_{i\,(t-j)} + \\ & \sum\nolimits^{P}{}_{j=0}\gamma_4 LogRESP_{i(t-j)} \sum\nolimits^{P}{}_{j=0}\gamma_4 LogFDI_{i(t-j)} + \psi ECT_{i(i-t)} + \mu_{it}\end{aligned} \quad (2)$$

As seen in Equation (2), all variables are in natural logarithms. The components of white noise are represented by μit, the differences by Δ, and finally, ψECT represents error correction. As can be observed, the dependent variable is CO_2 emissions per capita. The explanatory variables are the index of IIT (LogIIT), Portuguese and Spanish renewable energy consumption (LogRE and LogRESP), and Portuguese FDI (LogFDI). All variables are collected from the World Bank Open Data [63].

The equation takes the following form in PQR:

$$Q\tau\ (LogCO_{2it}) = (La)\tau + \beta_1\tau LogIIT_{it} + \beta_2\tau LogRE_{it} + \beta_3\tau LogRESP_{it} + \beta_4\tau\ LogFDI_{it} + \mu_{it} \quad (3)$$

where the model's parameters are βxτ (IIT, Portuguese renewable energy, Spanish renewable energy, and FDI); the model's constant is represented by (La)τ.

Next, this investigation will present the hypotheses, considering the literature that justifies the econometric model.

Hypothesis 1a (H1a). *Intra-industry trade is negatively correlated with CO_2 emissions.*

Hypothesis 1b (H1b). *Intra-industry trade is linked with environmental damage.*

Based on the literature of Roy [13], Leitão and Balogh [14], Leitão [15], Copeland and Taylor [31], Gürtzgen and Rauscher [32], Echazu and Heintzelman [33], Gallucci et al. [34], and Shapiro [35], IIT aims to improve the environment and to decrease pollution emissions. In this context, Khan et al. [37] showed that exports and innovation encourage improvements in the environment. However, the alternative hypothesis considers that bilateral trade can be explained by the pollution haven hypothesis (PHH) since it can stimulate polluting emissions.

Hypothesis 2. *Renewable energy consumption encourages air quality and decreases CO_2 emissions.*

The empirical studies of Shaari et al. [48], Razzaq et al. [49], Muço et al. [50], and Balsalobre-Lorente et al. [51] give support to our hypothesis. Furthermore, the studies demonstrate that renewable energy is negatively associated with CO_2 emissions.

Hypothesis 3a (H3a). *FDI is directly associated with CO_2 emissions and is explained by the pollution haven hypothesis (PHH).*

Hypothesis 3b (H3b). *FDI is described by innovation and product differentiation and aims to decrease pollution emissions.*

The empirical studies of Cole et al. [21], Singhania and Saini [22], Zhu et al. [38], Teng et al. [39], Demena and Afesorgbor [41], Marques and Caetano [42] and Qin et al. [47] described the hypotheses formulated. FDI—Portuguese FDI, net inflows (% of gross domestic product (GDP)). Table 1 below summarises the description of the variables used in the investigation and the expected signs.

Table 1. Explanation of variables.

Nomenclature (Variables)	Description	Expected Sign	Source	QR Codes
	Dependent variable			
$LogCO_2$	Portuguese carbon dioxide emissions per capita: dependent variable	n.a.	World Bank Open Data [63]	
	Independent variables			
$\alpha_1 = LogCO_{2t-1}$	A lagged variable of Portuguese carbon dioxide emissions per capita	+; −	World Bank Open Data [63]	
$\alpha_2 = LogIIT$	Index of intra-industry trade between Portugal and Spain	−; +	OECD [64]	
$\alpha_3 = LogRE$	Portuguese renewable energy consumption as a percentage of total energy consumption	−	World Bank Open Data [63]	
$\alpha_4 = LogRESP$	Spanish renewable energy consumption as a percentage of total energy consumption	−	World Bank Open Data [58]	
$\alpha_5 = LogFDI$	Portuguese foreign direct investment, net inflows (%of GDP)	+; −	World Bank Open Data [64]	

Notes: All variables are expressed in logarithm form; n.a. denotes not available.

After presenting the econometric model and variables used in this empirical investigation, it is necessary to show the methodology strategy that this investigation will use. Figure 1 below shows the methodology strategy this investigation will follow.

Subsequently presenting the methodology and econometric model, it is necessary to show the empirical results of this investigation. Section 4 below shows the empirical results found through the econometric approach.

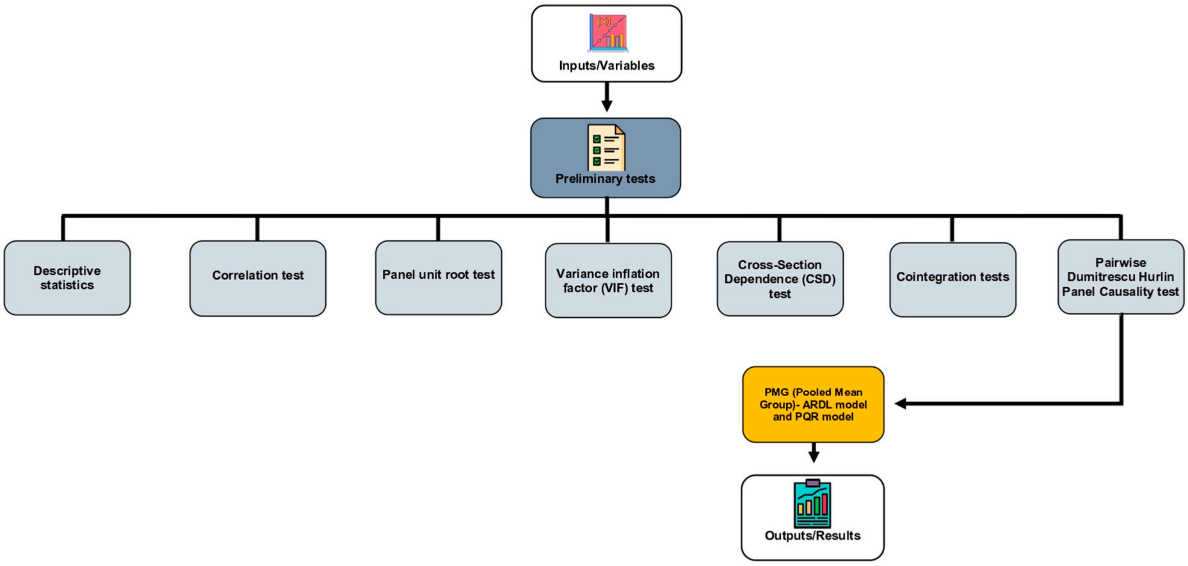

Figure 1. Methodology strategy. The authors created this figure.

4. Empirical Results

In this section, the investigation starts with the analysis of the variables, namely the descriptive statistics and the test of the properties of the variables (unit root test, cross-sectional dependence and cointegration tests). Finally, this study will present the estimates obtained through the PMG estimator and PQR. The descriptive statistics are discussed in Table 2 below.

Table 2. Descriptive statistics.

Statistics	$LogCO_2$	LogIIT	LogRE	LogRESP	LogFDI
Mean	4.740	−0.448	1.380	1.066	0.514
Median	4.751	−0.353	1.387	1.087	0.576
Maximum	4.817	−0.000	1.484	1.2403	0.995
Minimum	4.662	−1.762	1.257	0.863	−0.358
Std. Dev.	0.050	0.347	0.069	0.143	0.336
Skewness	−0.003	−1.242	−0.231	−0.069	−1.134
Kurtosis	1.569	4.410	1.932	1.275	3.739
Probability	0.000	0.000	0.005	0.000	0.000
Observations	189	189	189	189	189

Notes: All variables are expressed in logarithm form.

The variables in CO_2 emissions ($LogCO_2$), Portuguese renewable energy use (LogRE), and Spanish renewable energy use (LogRESP) present higher values of maximums. Therefore, considering the skewness, it can be observed that all variables exhibit a negative skewness. On the other hand, the Kurtosis statistic demonstrates that the variables used in this research show a positive kurtosis, and the IIT (LogIIT) and FDI (LogFDI) are the variables with higher values of kurtosis statistics.

Table 3 below presents the correlations between the variables under study. All explanatory variables (IIT, Portuguese renewable energy use, Spanish renewable energy use, and Portuguese FDI) present a negative correlation with the dependent variable ($LogCO_2$). These signs are according to the previous studies and the hypotheses formulated.

Table 3. Group of statistics studied: Correlations.

Statistics	$LogCO_2$	LogIIT	LogRE	LogRESP	LogFDI
$LogCO_2$	1.000				
LogIIT	−0.019	1.000			
LogRE	−0.794	0.019	1.000		
LogRESP	−0.801	0.014	0.937	1.000	
LogFDI	−0.014	−0.095	1.000	−0.059	1.000

Notes: All variables are expressed in logarithm form.

Table 4 below presents the stationarity of the variables used in this research, considering the Levin Lin, the Chu, ADF-Fisher Chi-square, Phillips–Perron, and Im–Pesaran–Shin tests; see, for instance, Maddala and Wu [65], Choi [66], Levin et al. [67], and Im et al. [68].

Table 4. Panel Unit Root Test.

Variables (Levels)	Levin, Lin & Chu t		Im, Pesaran and Shin W-Stat		ADF-Fisher Chi-Square		PP-Fisher Chi-Square	
	Statistic	*p*-Value	Statistic	*p*-Value	Statistic	*p*-Value	Statistic	*p*-Value
$LogCO_2$	0.195	(0.574)	2.054	(0.980)	5.154	(0.999)	5.682	(0.999)
LogIIT	−3.274 ***	(0.000)	−2.648 ***	(0.004)	39.213 ***	(0.006)	53.557 ***	(0.000)
LogRE	0.488	(0.687)	1.223	(0.889)	7.725	(0.994)	20.796	(0.409)
LogRESP	2.989	(0.999)	3.328	(0.999)	2.676	(1.000)	15.467	(0.749)
LogFDI	−6.578 ***	(0.000)	−5.172 ***	(0.000)	62.644 ***	(0.000)	121.062 ***	(0.000)
Variable (First Differences)	**Statistic**	***p*-Value**	**Statistic**	***p*-Value**	**Statistic**	***p*-Value**	**Statistic**	***p*-Value**
$\Delta LogCO_2$	−3.972 ***	(0.000)	−3.649 ***	(0.000)	45.501 ***	(0.000)	133.773 ***	(0.000)
ΔLogIIT	−7.193 ***	(0.000)	−6.754 ***	(0.000)	81.545 ***	(0.000)	204.244 ***	(0.000)
ΔLogRE	−4.895 ***	(0.000)	−7.391 ***	(0.000)	88.588 ***	(0.000)	220.650 ***	(0.000)
ΔLogRESP	7.290 ***	(0.000)	−3.625 ***	(0.000)	45.265 ***	(0.000)	288.5111 ***	(0.000)
ΔLogFDI	−9.139 ***	(0.000)	−9.259 ***	(0.000)	111.012 ***	(0.000)	2038.40 ***	(0.000)

Notes: *** denotes statistical significance at a (1%) level; all variables are in logarithm form.

As shown in Table 4 above, the variables under investigation are integrated into the first difference. Nevertheless, the variables in IIT (LogIIT) and FDI are simultaneously stationary in levels and the first differences. The multicollinearity and cross-sectional dependence are presented in Table 5 below.

Table 5. Multicollinearity (VIF) and Cross-sectional dependence (CSD) tests.

VIF test			CSD Test		
Variables	VIF	1/VIF	Test	Statistic	*p*-Value
LogIIT	1.01	0.990	Breusch-Pagan LM	542.635 ***	(0.000)
LogRE	8.34	0.119	Pesaran scaled LM	52.455 ***	(0.000)
LogRESP	8.36	0.119	Pesaran CD	20.550 **	(0.000)
LogFDI	1.02	0.990	Breusch-Pagan LM	542.635 ***	(0.000)
Mean VIF	4.68				

Notes: ***, ** denote statistical significance at (1%) and (5%) levels, respectively; all variables are in logarithm form.

Table 5 above demonstrates that Portuguese FDI (LogFDI) and IIT (LogIIT) have no multicollinearity problems (i.e., have a VIF inferior to five, as suggested by Leitão [15] and

Fuinhas et al. [69]). As expected, there is collinearity between the Portuguese and Spanish renewable energy consumption variables. The tests of cross-sectional dependence show that the variables considered in this research have cross-sectional dependence between them.

Table 6 below presents a complementary test for each variable using the Pesaran methodology. Once again, cross-sectional dependence is found for the selected variables.

Table 6. Diagnostic tests of Cross-sectional dependence: Pesaran (CD test).

Variables	Statistic	*p*-Value
$LogCO_2$	29.084 ***	(0.000)
LogIIT	0.997	(0.312)
LogRE	25.575 ***	(0.000)
LogRESP	26.852 ***	(0.000)
LogFDI	−1.891 *	(0.058)

Notes: ***, * denote statistical significance at (1%), and (10%) levels, respectively; all variables are in logarithm form.

Next, Table 7 below presents the unit root test (second generation) considering the test of Pesaran (CIPS test). Again, the results reveal stationarity in the variables under study through the Pesaran test (CIPS).

Table 7. Unit root test: Second generation (CIPS).

Variables	Lags	t-Statistic	*p*-Value
$LogCO_2$	0	−3.088 ***	(0.000)
LogIIT	1	−2.831 ***	(0.000)
LogRE	1	−4.177 ***	(0.000)
LogRESP	1	−2.515 **	(0.050)
LogFDI	1	−3.673 ***	(0.000)

Notes: ***, ** denote statistical significance at (1%) and (5%) levels, respectively; all variables are in logarithm form.

Indeed, the cointegration test by Kao et al. [58] and Johansen and Fischer are presented in Table 8 below.

Table 8. Cointegration tests.

Johansen Cointegration Test					Panel Cointegration Test		
Hypothesized	**Fisher Stat.**		**Fisher Stat.**		**Kao Cointegration Test**	**t-Statistic**	***p*-Value**
No. of CE(s)	(from trace test)	*p*-value	(from the Max−Eigen test)	*p*-value	ADF	−3.296 ***	(0.000)
None	356.3 ***	(0.000)	259.3 ***	(0.000)	Residual variance	0.000	
At most 1	160.0 ***	(0.000)	100.9 ***	(0.000)	HAC variance	0.000	
At most 2	77.76 ***	(0.000)	43.91 ***	(0.001)			
At most 3	54.46 ***	(0.000)	37.30 **	(0.018)			
At most 4	57.6 ***	(0.000)	57.67 ***	(0.000)			

Notes: ***, ** denote statistical significance at (1%) and (5%) levels, respectively.

The results from Table 8 above demonstrate that there is a long-run relationship between the variables in used CO_2 emissions ($LogCO_2$), IIT, Portuguese renewable energy use (LogRE), and Spanish renewable energy use (LogRESP) and FDI (LogFDI).

Subsequently, this investigation presents the Pedroni test [70] in Table 9 below, where it can be observed that there is a significance for the Phillips−Perron panel (Panel PP statistics) and the Phillips−Perron Group statistic (Group PP statistics), confirming the previous test.

Table 9. Panel cointegration Pedroni.

(WD)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	−1.746	(0.937)	−1.535	(0.937)
Panel rho-Statistic	−0.488	(0.373)	−0.324	(0.373)
Panel PP-Statistic	−7.418 ***	(0.000)	−6.584 ***	(0.000)
Panel ADF-Statistic	−2.529 ***	(0.005)	2.146	(0.984)
(BD)				
	Statistic	Prob.		
Group rho-Statistic	1.143	(0.874)		
Group PP-Statistic	−6.563 ***	(0.000)		
Group ADF-Statistic	3.425	(0.999)		

Notes: *** denotes statistical significance at (1%) level. WD–represents within dimensions; BD–represents between dimensions.

Moreover, Table 10 below reveals the causality between the variables used in this research, which is considered the recent technique of the pairwise Dumitrescu−Hurlin panel [71].

Table 10. Pairwise Dumitrescu−Hurlin panel causality test.

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LogIIT does not homogeneously cause $LogCO_2$	4.051 *	1.7642	(0.077)
$LogCO_2$ does not homogeneously cause LogIIT	5.453 ***	3.266	(0.001)
LogRE does not homogeneously cause $LogCO_2$	0.426 **	−2.119	(0.034)
$LogCO_2$ does not homogeneously cause LogRE	58.367 ***	59.946	(0.000)
$LogCO_2$ does not homogeneously cause LogRESP	29.964 ***	29.521	(0.000)
LogRE does not homogeneously cause LogIIT	6.095 ***	3.953	(0.000)
LogRESP does not homogeneously cause LogIIT	6.063 ***	3.9185	(0.000)
LogIIT does not homogeneously cause LogRESP	4.79625 **	2.56208	(0.010)

Notes: ***, **, * denote statistical significance at (1%), (5%), and (10%) levels, respectively; all variables are in logarithm form.

Table 10 above only presents the relationship between variables where a bidirectional and unidirectional causality exists. In this line, a bidirectional causality between IIT (LogIIT) and CO_2 emissions ($LogCO_2$) and Portuguese renewable energy use (LogRE) and CO_2 emissions ($LogCO_2$) can be observed. Moreover, bidirectional causality between Spanish (LogRESP) and IIT (LogIIT) also can be considered. The relationship between CO_2 emissions ($LogCO_2$) and Spanish renewable energy use (LogRESP) presents a unidirectional causality. Finally, we can also see a unidirectional causality between Portuguese renewable energy use (LogRE) and IIT (LogIIT). Figure 2 below summarises the causal relationship between the variables based on Table 10 above.

After presenting the results from the pairwise Dumitrescu−Hurlin panel causality test, it is necessary to observe the results from the PMG of the ARDL model and the PQR model. Therefore, Table 11 below shows the econometric results using the PMG model, which should be observed as a preliminary instrument that assesses the trend between the variables under study and their significance for later proceeding with the econometric interpretation via the PQR estimator. In addition, the Wald test (diagnostic test of coefficients) in Table 11 below demonstrates that all independent variables have statistical significance.

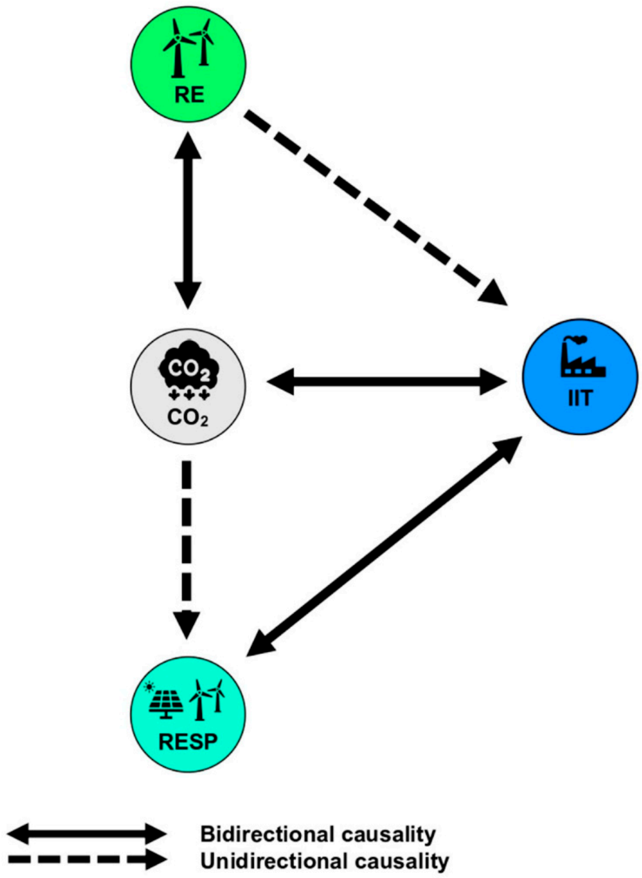

Figure 2. Summary of the causality relationship between the variables. The authors created this figure.

Table 11. Pooled mean group (PMG)—Autoregressive distributed lag (ARDL) model.

Independent Variables	**Coefficient**	**Std. Error**	**t-Statistic**	***p*-Value**
	Dependent Variable: LogCO$_2$			
Long Run Equation				
LogIIT	−0.0256 **	0.011	−2.323	(0.022)
LogRE	−0.417 ***	0.095	−4.403	(0.000)
LogRESP	−0.131 ***	0.045	−2.891	(0.004)
LogFDI	−0.032 ***	0.008	−4.021	(0.000)
Short Run Equation				
ECT	−0.470 ***	0.133	−3.541	(0.000)
Δ (LogIIT)	−0.028	0.025	−1.1085	(0.267)
Δ (LogRE)	0.2199 ***	0.050	4.371	(0.000)
Δ (LogRESP)	−0.092 ***	0.029	−3.153	(0.002)
Δ (LogFDI)	0.005	0.006	0.807	(0.421)
C	2.563 ***	0.725	3.536	(0.000)
Mean dependent var	−0.005	S.D. dependent var		0.024
S.E. of regression	0.022	Akaike info criteria		−4.407
Sum squared resid	0.062	Schwarz criteria		−3.309
Log-likelihood	480.501	Hannan−Quinn criteria		−3.9627
Wald test 279 (0.00) ***				

Notes: ***, ** denote statistical significance at (1%) and (5%) levels, respectively; all variables are in logarithm form.

The panel ARDL estimator has the advantage of considering short- and long-term effects. All independent variables are statistically significant in the long run, and the expected signs are according to the formulated hypotheses. Subsequently, this analysis considered the effects of the explanatory variables on CO_2 emissions in the long run and tested the hypotheses formulated in the methodology. The error correction adjustment (ECT) is negative and statistically significant at a (1%) level. The recent papers of Teng et al. [39] and Boufateh and Saadaoui [72] found a similar result.

The coefficient of the index of IIT (LogIIT) is statistically significant at a (5%) level. The result showed that intra-industry aims to decrease pollution emissions and improve the environment. The previous empirical studies of Roy [13], Leitão and Balogh [14], Leitão [15], Kazemzadeh et al. [16], and Khan et al. [37] support our result, showing that monopolistic competition assumptions validate the theory that two-way trade encourages and respects the rules of the environment.

Regarding Portuguese and Spanish renewable energy use (LogRE and LogRESP), it can be observed that the variables are negatively impacted by CO_2 emissions, showing that renewable energy aims decreased climate change. Furthermore, the studies of Leitão et al. [12], Balsalobre-Lorente et al. [51], Kirikkaleli [56], Zafar et al. [61], and Dogan and Ozturk [62] also found a similar relationship between renewable energy use and CO_2 emissions.

Finally, the coefficient of FDI (LogFDI) presents a negative effect on pollution emissions ($LogCO_2$), indicating that FDI can be associated with product differentiation and innovation and consequently seeks to decrease climate change and improve air quality (e.g., Teng et al. [39]; Demena and Afesorgbor [41]; and Marques and Caetano [42]). This result is according to the pollution halo hypothesis, i.e., multinational enterprises export cleaner technology to the host country and allow them to decrease the environmental damage (e.g., Kisswani and Zaitouni [23]). Figure 3 summarises the impact of independent variables on dependent ones. This figure is based on Table 11 above.

Based on the empirical studies by Khan et al. [73] and Alotaibi and Alajlan [74] in Table 12 below, the heterogeneity between the quantiles for the IIT (LogIIT), Portuguese and Spanish renewable energy (LogRE and LogRESP), FDI (LogFDI) and Portuguese CO_2 emissions ($LogCO_2$) can be assessed. The PQR was suggested by Koenker and Bassett [75]. The coefficients are considered for the quantile (e.g., 10th, 20th, 25th, 50th, 75th, 90th). The IIT coefficient (LogIIT) is statistically significant at (1%) for the 20th and 25th quantiles and (10%) and (5%) for the 50th and 75th quantiles. From the point of view of economic interpretation, the relationship between IIT and CO_2 emissions seems to be associated with an alternative hypothesis. That is, the pollution haven hypothesis explains IIT. It can be verified that only the 75th quantile presents a negative signal, demonstrating that the IIT contributes to environmental improvement (halo pollution hypothesis).

The coefficients of Portuguese (LogRE) and Spanish (LogRESP) renewable energy are always statistically significant across the quantiles. The Portuguese renewable energies (LogRE) present the signal advanced by the literature in the 50th, 75th and 90th quantiles. Regarding Spanish renewable energies (LogRESP), there is always a negative association between CO_2 emissions and statistical significance, validating the hypothesis formulated. As in the empirical study by Khan et al. [73], the result obtained for FDI is negative and insignificant. Figure 4 below shows the PQR results. Moreover, the shaded (95%) areas are confidence bands for the quantile regression estimates.

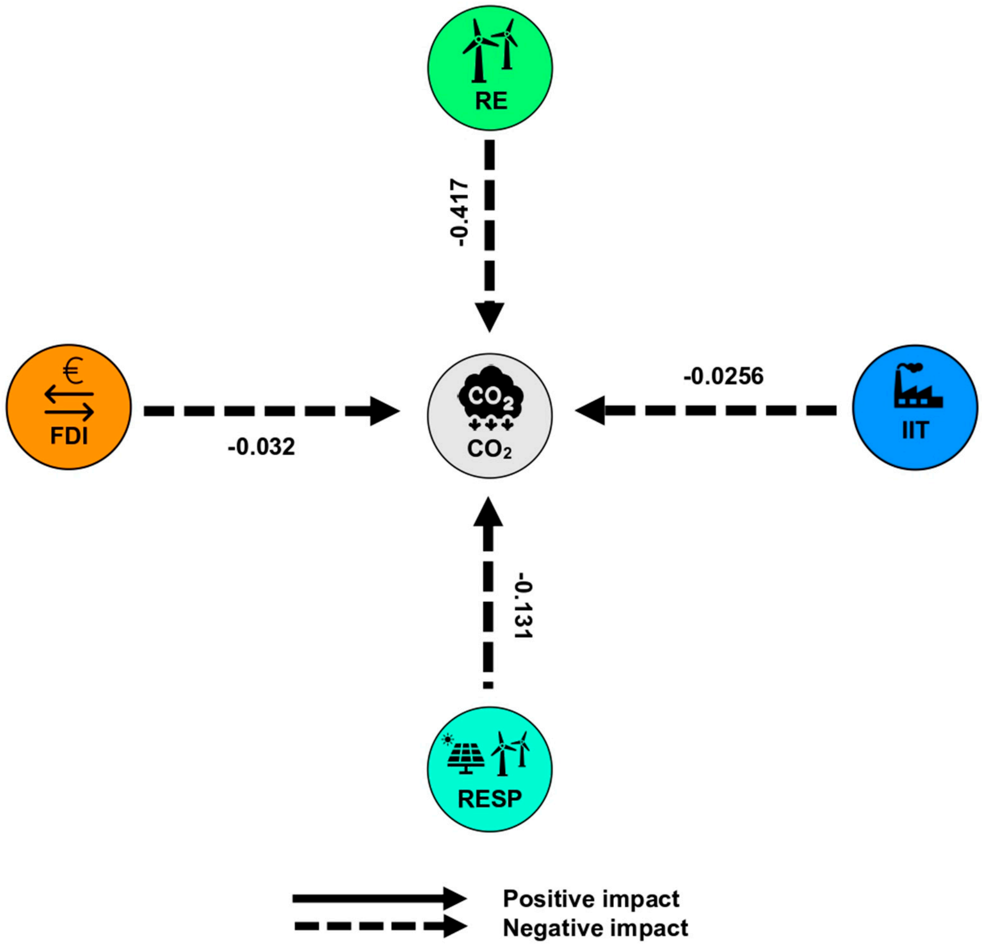

Figure 3. Summarises the impact of independent variables on dependent ones. The authors created this figure.

Table 12. Panel quantile regression.

Variables	10th	20th	25th	50th	75th	90th
LogIIT	-7.62×10^{-1}	0.002 ***	0.004 ***	0.005 *	−0.017 **	−0.001
LogRE	0.064 ***	0.063 **	0.072 *	−0.166 ***	−0.352 ***	−0.936 ***
LogRESP	−0.366 ***	−0.367 ***	−0.371 ***	−0.248 ***	−0.124 **	0.300 ***
LogFDI	-1.73×10^{-1}	0.0008	0.001	−0.005	−0.006	−0.013
C	5.017 ***	5.021 ***	5.016 ***	5.230 ***	5.371 ***	5.766 ***
Pseudo R^2	0.65	0.61	0.59	0.56	0.36	0.29

Notes: ***, **, * denote statistical significance at (1%), (5%), and (10%) levels, respectively; all variables are in logarithm form.

After presenting the empirical results, it is necessary to show the main conclusions of this investigation. Section 5 below shows this empirical investigation's main conclusions and policy implications.

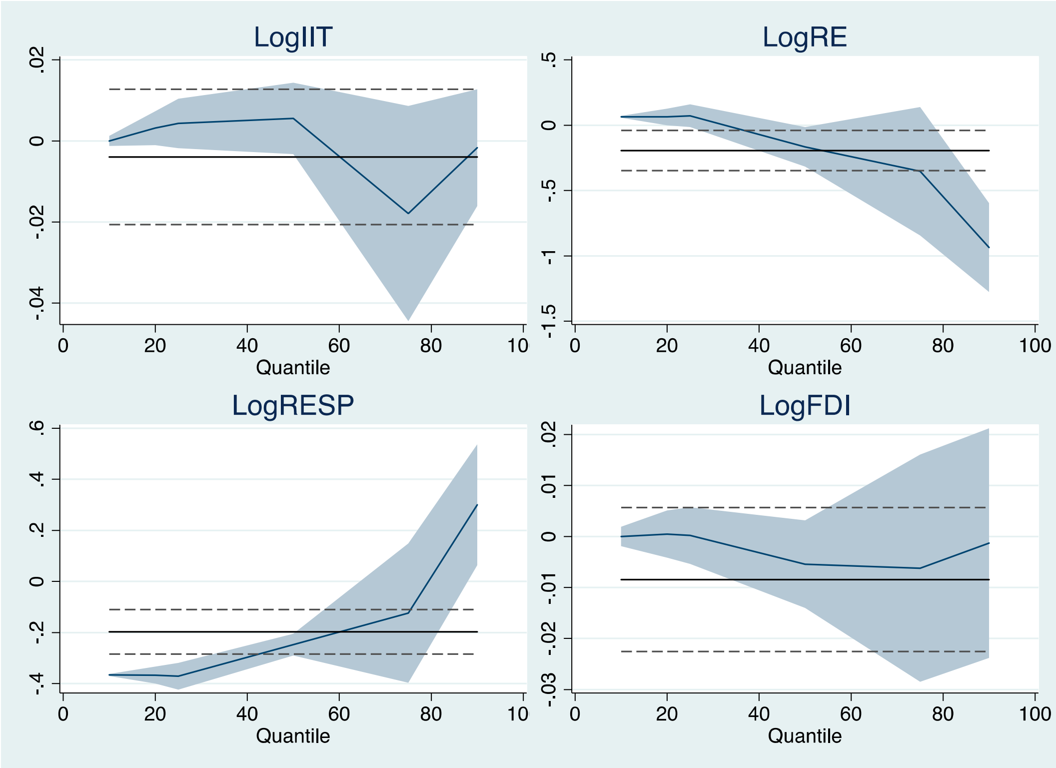

Figure 4. The quantile estimates.

5. Conclusions and Policy Implications

This paper investigated the role of IIT between Portugal and Spain, as well as of renewable energy, and FDI in Portuguese CO_2 emissions from 2000 to 2018. This investigation conducted a macroeconomic analysis using a panel with data from Portugal from 2000 to 2018. A PMG of an autoregressive distributed lag (ARDL) model and PQR, as well as the pairwise Dumitrescu−Hurlin panel causality test, were used to carry out this empirical investigation.

The results from the preliminary tests indicated that the variables in IIT and FDI are stationary at all levels. However, all variables considered in this research (CO_2 emissions, IIT, Portuguese and Spanish renewable energy use, and Portuguese FDI) are integrated at the first differences. We also used the second-generation unit roots (the Pesaran CIPS test), showing that the variables under study are stationary. Finally, the cointegration test showed that the variables used in this research are cointegrated in the long term.

Considering the methodology of Dumitrescu and Hurbin [71] to test the unidirectional and bidirectional causality with panel data, this investigation concluded that there is bidirectional causality between IIT and CO_2 emissions. Portuguese and Spanish renewable energy use also causes CO_2 emissions. In addition, the pairwise Dumitrescu−Hurlin panel demonstrated a bidirectional causality between Spanish renewable energy and IIT. Therefore, this investigation answered the main questions posed in the introduction section.

Regarding the empirical results, this investigation compared the econometric results between the panel ARDL model estimator and the PQR model, verifying heterogeneity between the coefficients obtained. Therefore, at first this investigation evaluated the panel ARDL as an analysis tool, and subsequently presented the main conclusions of this estimator.

Therefore, the results from thr PMG-ARDL model have indicated that the independent variables in natural logarithms, such as LogIIT, LogRE, LogRESP, and LogFDI, have a negative impact on the dependent variable $LogCO_2$ in the long run. In other words, the independent variables, such as LogIIT, had a negative impact of (−0.0256), while the variables, LogRE (−0.417), LogRESP (−0.131), and LogFDI (−0.032). Moreover, the independent variables in the first differences of natural logarithms, such as ΔLogRE, have a positive impact of (0.2199) on the dependent variable $\Delta LogCO_2$ in the short run, while the variable ΔLogRESP has a negative impact of (−0.092) on the dependent variable. However, the variables ΔLogIIT and ΔLogFDI are statistically insignificant.

Moreover, the PQR results indicated that independent variables in natural logarithms, such as LogIIT, positively impact the 20th, 25th, and 50th quantiles on the dependent variable $LogCO_2$ and have a negative impact on the 75th quantile. Therefore, the results obtained in the 75th quantile match those obtained in the main model in the long-run equation. The independent variable LogRE has a positive impact in the 10th, 20th, and 25th, quantiles on the dependent variable $LogCO_2$ and a negative impact in the 50th, 75th, and 90th quantiles. Therefore, the results obtained in the 10th, 20th, and 25th quantiles match those obtained in the main model in the short-run equation. Similarly, the results from the 50th, 75th, and 90th quantiles match those obtained in the main model in the long-run equation. The independent variable LogRESP negatively impacts all quantiles on the dependent variable $LogCO_2$. Therefore, the results obtained in all quantiles match the results obtained in the main model in the long- and short-run equation. However, the independent variable in natural logarithms, such as LogFDI, is statistically insignificant.

After this investigation presented the results above that were found in both the PMG-ARDL model and the PQR, the following question was elaborated —What are the possible explanations for the results that were found in this empirical investigation?

The negative correlation between IIT and climate change shows that cleaner trade based on innovation and product differentiation aims to decrease CO_2 emissions. This result is according to the previous studies (e.g., Roy [13]; Leitão and Balogh [14]; and Leitão [15]). Furthermore, based on the relationship between Portuguese and Spanish renewable energy and CO_2 emissions, this investigation obtained a negative expected sign, i.e., renewable energy consumption decreases global warming and promotes the improvement of the environment (e.g., Balsalobre-Lorente et al. [51]; Dogan and Ozturk [62]; Fuinhas et al. [69]; and Ebrahimi et al. [76]). Finally, the relationship between FDI and CO_2 emissions showed a negative correlation. This result allows us to conclude that FDI is associated with innovation, as in previous studies by Demena and Afesorgbor [41] and Marques and Caetano [42], and confirms the argument of the pollution halo hypothesis.

An important conclusion can be highlighted: the empirical results presented in this research are according to the goals of sustainable development foreseen in Agenda 2030 of the United Nations, namely climate action.

However, the results obtained through the PQR show a different conclusion with a particular focus on the IIT, which seems to be explained by the pollution haven hypothesis. Only the 75th quantile validates the negative signal, as the dominant theory pointed out by the literature, between IIT and CO_2 emissions.

Furthermore, as mentioned earlier in the literature review, there are few empirical studies on the impact of bilateral trade, i.e., IIT between Portugal and Spain, on Portuguese CO_2 emissions. In our understanding, this study has that advantage and can contribute to economic policymakers. Thus, IIT and renewable energies enable environmental improvements and reduce CO_2 emissions. In this context, Portuguese and Spanish economic policy should encourage support for industries that use differentiating factors and nascent industries that bet on cleaner energies and allow for sustainable development in both countries.

This investigation presented some lines for further investigation and policy recommendations considering our study's limitations. In this context, our research will be extended by European Union countries and Brazil, Russia, India, China, and South Africa (BRICS), applying the assumptions of the environmental Kuznets curve. Moreover, it should be necessary to test the impact of variables such as the globalisation index (KOF) and corruption or economic complexity. Concerning the effects of international trade, it is essential to test the structural adjustment, i.e., to understand the linkage between marginal IIT and labour markets and their adjustment in pollution emissions (e.g., Roy [13]), considering the assumptions of symmetric and asymmetric stock. In this line of investigation, it is interesting to assess the links between the economic complexity and corruption index and the effects of pollution emissions and bilateral trade between Portugal and Spain.

Based on the literature (e.g., Roy [13]), it is believed that marginal IIT, or trade intensity (e.g., Leitão [15]), allows adjustment and decreases pollution emissions once this type of trade increases productivity via innovation in the context of monopolistic competition. In addition, this methodology provides for considering dynamic indicators and lagged variables over time [12]. Furthermore, in this context of product differentiation and its association with consumer preferences for high- or low-quality products, it is essential to assess the impact of the horizontal IIT and vertical IIT on CO_2 emissions. In terms of disaggregation and separation of the horizontal IIT-HIIT and vertical IIT-VIIT see, for example, Greenaway et al. [5]; Faustino and Leitão [6]; Jambor and Leitão [8].

From theoretical models, it can be seen that labour-intensive products tend to use less sustainable or less clean energy. In contrast, capital-intensive products or sectors certainly use more sustainable measures. This analysis will be necessary for bilateral trade between Portugal and Spain to understand regional clusters' impact on climate change. Another question for future work concerns the effects of income inequality on economic growth and the environment, as well as the impact of the inflation rate and the increase in fuel consumption (e.g., Ullah et al. [77]; and Sreenu [78]).

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