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Testing the Role of Trade on Carbon Dioxide Emissions in Portugal

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Abstract: This article considers the relationship between trade intensity, energy consumption, income per capita, and carbon dioxide emissions from 1970–2016 for the Portuguese economy. Considering the arguments of monopolistic competition, the article tests the hypotheses of trade and energy consumption on climate change. We use the autoregressive distributed lag-ARDL model, quantile regression, and cointegration models such as fully modified ordinary least squares (FMOLS), canonical cointegration regression, and dynamic ordinary least squares (DOLS) as an econometric strategy. The econometric results have support with the literature review. The variables used in this research are integrated with the first differences, as indicated by the unit root test. The empirical study proves that trade intensity contributes to environmental improvements. However, energy consumption presents a positive impact on CO_2 emissions. The econometric results also demonstrated that a sustainable environmental system exists in the long run.

Keywords: Portugal; ARDL model; quantile regressions; cointegration models; trade; carbon dioxide emissions

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1. Introduction

The World of Heath Organization reports, the Intergovernmental Panel on Climate Change (IPCC-2013), the United Nations Framework Convention on Climate Change (United Nations Framework Convention on Climate Change (UNFCCC) (1992)), Kyoto Protocol (Kyoto Protocol to the United Nations Framework Convention on Climate Change 1997), and Paris Agreement (2015) showed that it should be necessary to change the paradigm of economic growth. The growth of economic activities is associated with energy consumption and efficiency. Non-renewable energy consumption is responsible for pollution and environmental damage.

Climate change, greenhouse gas, precipitation, and air temperature stimulated a change in the world economics mentality. The countries introduced environmental rules to reduce the externalities and control the intensity of pollution. However, the environmental rules and environmental taxation cause higher costs of adjustment in economies, namely in international trade. In this line, the empirical studies demonstrated that trade liberalization and trade intensity aimed to decrease pollution, showing that carbon dioxide emissions decrease.

The new theories of trade with an emphasis on monopolistic competition allowed to explain the intra-industry trade and trade intensity. Thus, it appears that the intra-industry trade is a type of trade associated with product differentiation, innovation, and economies of scale, where exports and imports of the same product or the same sector coexist. On the other hand, inter-industry trade is explained by comparative advantages theories.

Since the 1990s, economists have tried to explain products with the same quality and differentiation in the products' characteristics or attributes, with prices being relatively close, which is called the horizontal intra-industry trade. However, products can have different types of quality (high or low) and can be explained by different types of income and various types of demand, referred to in the literature as vertical intra-industry trade (Greenaway et al. 1995; Fontagné and Freudenberg 1997; Blanes and Martín 2000).

When we survey the investigation, we observed that the empirical studies of the intra-industry trade have concentrated on the determinants of the characteristics of countries, industries, adjustment issues, and the labor market or the fragmentation of production.

Other types of studies in the literature assess intra-industry trade's impact on environmental issues, emphasizing carbon dioxide emissions, with a more significant proliferation of theoretical than empirical studies.

Subsequently, the Kyoto Protocol (Kyoto Protocol to the United Nations Framework Convention on Climate Change 1997) and Paris Agreement (2015) promoted scientific research in the most diverse knowledge areas.

The issue of economic growth, energy consumption, and carbon emissions were investigated by Tong et al. (2020). The authors applied an autoregressive distributed Lag–ARDL model for Brazil, India, Indonesia, Mexico, China, Russia, and Turkey. In the long run, the authors proved that there is cointegration between income per capita, energy consumption, and carbon emissions for the following countries: Brazil, India, and Russia. Therefore, the study also showed causality between energy consumption and CO_2 emissions. In this context, using a panel cointegration, the empirical work of Zhang et al. (2019) validated the hypotheses of the environmental Kuznets curve (EKC) based on the relationship between income per capita and carbon dioxide emissions. The econometric results also demonstrated a negative correlation between international trade and emissions and a positive effect of energy consumption on CO_2 emissions.

Another issue is to assess the relationship between the intensity of trade and the environment. Some empirical studies consider the link between international trade and climate change (Leitão and Balogh 2020; Roy 2017; Dasgupta and Mukhopadhyay 2018; Chin et al. 2018; Yazdani and Pirpour 2020). As a rule, studies use panel data (OLS, fixed effects, random effects, or GMM-System) to assess the association between international trade and climate change. However, a few studies use time series (ARDL model—autoregressive distributed lag, VEC—vector error correction model, or Granger causality). Thus, there is a consensus in the literature that trade intensity reduces pollution.

Previous studies on the Portuguese economy (Fuinhas and Marques 2012; Shahbaz et al. 2016; Balsalobre-Lorente et al. 2021) focus on studying economic growth and the environmental Kuznets curve. However, the recent study by Balsalobre-Lorente et al. (2021) that introduces the effect of renewable energies continues to use the assumptions of the environmental Kuznets curve.

This study assesses the Portuguese economy, emphasizing structural adjustment issues, the relationship between trade intensity and environmental issues associated with innovation factors, and the relationship between economic growth, energy consumption, and climate change. In this context, the present study examines if the Portuguese economy has been applying sustainability measures to the environment.

As a methodological strategy, we use time series with particular emphasis on the ARDL model—autoregressive distributed lag and quantile regressions applied to the Portuguese economy for the period 1970–2016, where we assess the impact of trade intensity, energy consumption, and economic growth on carbon dioxide emissions.

This article is organized as follows. The second section presents the literature review. Section 3 considers the material and method applied in this research. The empirical results are produced in Section 4, and the conclusion is presented in Section 5.

2. Literature Review

This section presents the most relevant theoretical and empirical studies to consider the relationship between trade and the environment. The correlation between economic growth and energy consumption is also considered in this study.

There are several studies on the evaluation of the Portuguese economy and environmental issues, in which Fuinhas and Marques (2012), Leitão (2014), Shahbaz et al. (2016), or more recently Balsalobre-Lorente et al. (2021) assess the relationship between economic growth and carbon emissions.

2.1. Trade and Environment

Balogh and Jámbor (2020) showed that the association between trade impact on the environment is ambiguous. In this context, we need to revisit some theoretical models to understand trade intensity's effect on the environment's quality or climate change.

The theoretical models that consider the relationship between trade and climate change are explained in the monopolistic competition context. In this perspective, we selected the works of Copeland and Taylor (1994), Gürtzgen and Rauscher (2000), Haupt (2006), and Echazu and Heintzelman (2018), and Mehra and Kohli (2018). The selection of theoretical models is related to the fact that they formulate a set of conceptual assumptions that operate between two countries (home and host) with a structure of monopolistic competition according to oligopoly logic in which decision-making obeys a sequential game between countries regarding the use or not of environmental regulation. The theoretical models seek to demonstrate that the most restrictive environmental measures can affect international trade between countries.

Copeland and Taylor (1994) consider two countries (North and South) with different types of pollution intensity and one-factor endowment (labour). In both countries, the consumers have the same utility function. According to the Copeland and Taylor model prepositions, the economies with higher income use cleaner environmental rules and practices. The international trade between North and South countries increases climate change, which the authors called "world pollution." In this context, when the North increases their production, the pollution increases too. However, the growth of the South's production also increases, but decreases pollution. The introduction of international trade allows transferring pollution to the South. In this context, we observe that world pollution decreases.

Gürtzgen and Rauscher (2000) investigate the relationship between environmental policy and its restrictions between the two countries. The authors use Dixit–Stiglitz type modeling, where the market structure is based on monopolistic competition. The introduction of international trade expands production and increases negative externalities (gas emissions) in the host country. However, countries that have a more restrictive environmental policy cause less environmental damage.

Haupt (2006) assesses, as the other models previously presented, the link between the environment and trade, based on the assumptions of the externalities of taxes on production. The model is based on two countries, their governments, household consumption, and enterprises. The model is structured from a monopolistic competition perspective and in a sequential game. In the first phase, governments decide to encourage measures that ensure the environmental process. In the second phase, companies decide to introduce product differentiation and finally reach the free market. With the introduction of the competitive market and the liberalization of the market, households' utility function decreases, considering a reduction in imported varieties. The author also concludes that the impact of international trade on the environment is ambiguous. Moreover, free trade makes it possible to increase yields and promote ecological goals. However, market liberalization generates higher costs in terms of opportunity costs, and that discourages anti-pollution measures.

Echazu and Heintzelman (2018) use a monopolistic competition structure to reflect intra-industry trade and environmental regulation. The authors refer that the decision of countries on their emissions is associated with their strategies. In closed economies, these can function as strategic substitutes in a Nash equilibrium. However, when markets are liberalized, countries can opt for more rigid or more flexible environmental regulations depending on their products' preferences.

The model of Mehra and Kohli (2018) assesses the interdependence relationships between trade and environmental pollution. The authors use the assumptions of Krugman's model. The model makes it possible to verify that an exogenous increase in an environmental tax influence decreases production. Thus, if the home country is a net exporter, an increase in environmental rules has a negative impact on exports, which the authors call the "negative scale effect", that is, the demand for imports increases.

The empirical studies use panel data more frequently for testing the impact of trade intensity or the intra-industry trade on the environment. There are some studies such as Leitão and Lorente (2020), Roy (2017), and Leitão and Balogh (2020) that consider that liberalization of trade encourages a reduction in environmental damage. These studies found a negative impact of trade intensity or the intra-industry trade on carbon dioxide emissions. However, the studies of Dasgupta and Mukhopadhyay (2018), Chin et al. (2018), and Yazdani and Pirpour (2020) have a different perspective, showing that intra-industry trade is positively correlated with CO_2 emissions. The outsourcing or fragmentation of production considers the relationship between parts and components and the final product involving an increase in world pollution. Chin et al. (2018) used an autoregressive distributed lag (ARDL model) to consider the determinants of Malaysia's carbon dioxide emissions. In the long run, the empirical results found a positive impact of foreign direct investment, income per capita, and vertical intra-industry trade on CO_2 emissions.

2.2. Economic Growth and Environment

The link between economic growth and the environmental Kuznets curve (EKC) was introduced by Grossman and Krueger (1995) and Holtz-Eakin and Selden (1995), who demonstrated that economic growth is directly correlated with climate change and greenhouse gas emissions (Leitão and Lorente 2020; Ike et al. 2020; Sarkodie and Ozturk 2020; Koengkan et al. 2020). In the short run, the empirical research considers a positive correlation between economic growth and carbon dioxide emissions, showing that economic activities encourage environmental damage. However, in the long run, the countries and governments are preoccupied with environmental protection and their quality (Koengkan et al. 2020), and pollution intensity decreases.

We observe that the empirical studies as Gessesse and He (2020), Sarkodie and Ozturk (2020), Shahbaz et al. (2021), Burakov (2019), and Özokcu and Özdemir (2017) use time series (autoregressive distributed lag—ARDL model, vector error correction model—VECM, and Granger causality). Moreover, there exist other studies such as Leitão and Lorente (2020), Ike et al. (2020), and Koengkan et al. (2020) that applied panel data (fixed effects—FE, random effects—RE, FMOLS—fully modified ordinary least squares, DOLS—dynamic ordinary least squares, GMM—system estimator, and method of moments quantile regression).

Pata and Caglar (2021) considered the EKC curve arguments that globalization, trade intensity, and income stimulated climate changes using an ARDL model to China for the period 1980–2016. The study also concluded that human capital reduces ecological problems.

The association between energy consumption and carbon dioxide emissions is popularized in energy economics studies. In general, the empirical studies of Ike et al. (2020), Khan et al. (2020), and Salazar-Núñez et al. (2020) found a positive correlation between energy consumption and CO_2 emissions, showing that environmental damage increases. Additionally, Salazar-Núñez et al. (2020) studied the relationship between energy consumption, carbon dioxide emissions, and economic growth in 79 countries with a different type of development. Granger causality results prove a bidirectional causality between energy consumption and carbon dioxide emissions for the countries with high, upper-middle, and lower-middle income per capita countries.

Kwakwa et al. (2018) researched the impact of trade, urbanization, industrial energy, and energy efficiency on energy consumption. The authors used a time series cointegration (FMOLS, DOLS, and CCR) from 1975–2015 in Ghana, South Africa, and Kenya. The econometric results demonstrated that income and urbanization are positively correlated with energy consumption for all countries. Additionally, the authors referred that trade aims to decrease energy consumption in Kenya and South Africa.

The empirical study of Ike et al. (2020) applied a panel data cointegration of FMOLS, DOLS, and the method of moments quantile regression. The authors consider the impacts of economic growth, democracy, energy consumption, oil production, and trade intensity on carbon dioxide emissions.

Using the FMOLS estimator, the econometric results validate the assumptions of EKC. The variables of democracy, oil production, and electric consumption present a positive effect on CO_2 emissions. The results also showed that trade intensity is negatively correlated with carbon dioxide emissions.

The Pakistan experience was investigated by Khan et al. (2020) using a time series (ARDL model) for the period 1965–2015. The authors found that economic growth is positively associated with CO_2 emissions in the short- and long-run energy consumption. In this context, Sarkodie and Ozturk (2020) tested EKC in Kenya using an ARDL model, considering the period 1971–2013. The authors proved that there exists an inverted curve between income per capita and carbon dioxide emissions. Further, energy consumption encourages climate change in the long run, and income per capita and household consumption expenditure is directly correlated with energy consumption. In this context, the evidence of African OPEC countries was investigated by Moutinho and Madaleno (2020), who considered an ARDL model for 1973–2017. In the long run, the authors proved that trade intensity negatively impacts Algeria's economic growth. However, the variable is positively correlated with economic growth for Equatorial Guinea and Angola. The coefficient of energy consumption presents a positive effect on economic growth for Gabon and Angola. The variable of oil price positively affects Algeria, Equatorial Guinea, and Gabon's economic growth. Finally, the urban population positively affects Libya and Angola's economic growth and negatively affects Equatorial Guinea and Gabon.

Abdollahi's (2020) research evaluates a spatial panel with random effects for the period 1998–2011. The author formulates three equations: economic growth, energy consumption, and carbon dioxide emissions, considering the arguments of the environmental Kuznets curve. The equation for carbon dioxide emissions determinants shows that energy consumption, income per capita, and trade intensity positively impact CO_2 emissions.

Odugbesan and Rjoub (2020) considered the relationship between economic growth, carbon emissions, urbanization, and energy use. The authors applied the ARDL bound test to Mexico, Indonesia, Nigeria, and Turkey. They found a long-run effect between economic growth, energy use, carbon emissions, and urbanization.

The Republic of Kazakhstan was considered by Akbota and Baek (2018) to evaluate the environmental Kuznets curve for the period 1991–2014 using the ARDL model. The empirical results showed that income per capita and squared income per capita are positively and negatively correlated with carbon dioxide emissions. Additionally, energy consumption presents a positive impact on CO_2 emissions.

The relationship between carbon emissions, financial development, foreign direct investment, economic growth, and China's energy consumption was considered by Kong (2021). The author applied the ARDL model, and the results confirm that energy and income per capita have a positive effect on carbon emissions in the long run. Additionally, the author argues that foreign direct investment aims to improve the environment.

The linkage of CO_2 emissions between energy use, economic growth, and financial development applied to CEEC countries for 2000–2017 was investigated by Manta et al. (2020) using FMOLS, VECM, and Pairwise Granger causality test. The results demonstrated that there exists bidirectional causality between income per capita and financial system development. The authors also proved that financial proxies cause carbon emissions and energy use.

The study of Shahbaz et al. (2021) tested the SDGs—sustainable development goals—in India from 1980 to 2019. The econometric results confirm that economic growth does not use sustainable practices, as the authors demonstrated the economic growth is associated with energy consumption and crude oil.

Considering 93 countries with different development, the empirical study of Wawrzyniak and Doryń (2020) applied dynamic panel data (GMM-System) from 1995 to 2014. The authors proved EKC arguments; moreover, energy consumption positively affects carbon dioxide emissions, and the lagged variable of carbon dioxide emissions has a positive effect.

The correlation between economic growth, energy consumption, and carbon dioxide emission to Thailand's case for 1971–2018 was considered by Adebayo and Akinsola (2021). The authors used an econometric strategy Wavelet Coherence, Granger causality, and Toda—Yamamoto causality, and they prove that there is bidirectional causality between carbon emissions and energy consumption. Relatively, for the causality between economic growth and CO_2 emissions, the authors found unilateral causality.

3. Methodology and Data

The effects of trade intensity, energy consumption, and economic growth on carbon dioxide emissions are considered in this study for Portugal. This research uses a time series approach (autoregressive distributed lag—ARDL model), quantile regressions, and cointegration models of FMOLS, CCR, and DOLS for the period 1970–2016. The database covers a relatively long period, 47 years, which allows us to have a wide range over Portugal. The democratization process in Portugal began in 1974, accession to the European Union took place in 1986, at the time known as the European Economic Community—EEC. In 1995, the World Trade Organization (WTO) was created, which allowed regulating international trade and consequently impacted Portugal. It is also possible to argue that the period makes it possible to assess the globalization process and the Portuguese economy's structural adjustment issues.

Therefore, this research considers, in the first moment, the unit root test proposed by the augmented Dickey–Fuller test (e.g., Dickey and Fuller 1979) to test the stationarity, and sequentially we apply the econometric models.

Considering the empirical studies of Chin et al. (2018), Leitão and Balogh (2020), Pata and Caglar (2021), and Sarkodie and Ozturk (2020), the ARDL model assumes the following expression:

$$\Delta LogCO_2 = \alpha_0 + \alpha_1 \Delta LogCO_{2t-1} + \alpha_2 \Delta LogEC_{t-1} + \alpha_3 Log\Delta TRADE_{t-1} + \alpha_4 \Delta LogGDP_{t-1} + \Sigma^n_{t=1} \alpha_1 \Delta LogCO_{2t-1} + \Sigma^n_{t=0}\, \alpha_2 \Delta\, LogEC_{t-1} + \Sigma^n_{t=0}\, \alpha_3 \Delta\, LogTRADE_{t-1} + \Sigma^n_{t=0}\, \alpha_4 \Delta LogGDP_{t-1} + \gamma ECM_{t-1} + e \quad (1)$$

In Equation (1), the operator's change is represented by Δ; ECM_{t-1} represents the error correction term; γ signifies the adjustment of a short and long run.

Following the empirical studies of Pesaran et al. (2001), Matthew et al. (2018), and Leitão and Balogh (2020), two conditions with ARDL methodology should be considered:

H0: $\alpha 0 = \alpha 1 = \alpha 2 = \alpha 3 = \alpha 4$, represents no relationship in the long run.

H1: $\alpha 0 \neq \alpha 1 \neq \alpha 2 \neq \alpha 3 \neq \alpha 4$, represents the relationship in the long run.

The ARDL bound test is used to evaluate the test of cointegration and stationarity in the long run. Therefore, Stata software estimated the long run cointegration (proposed by (Kripfganz and Schneider 2016, 2018).

The dependent variable is the logarithm of carbon dioxide emissions (CO_2) in Kilotons, from the World Bank Indicators (2020). All variables are expressed in logarithmic form.

The independent variables used are the following:

The energy consumption (LogEC)—Logarithm of energy use by kg of oil equivalent per capita. The source of this variable from the World Bank Indicators (2020).

The trade intensity is represented by the following representation:

$$\mathrm{TRADE} = \frac{(\mathrm{X} + \mathrm{M})}{\mathrm{GDP}} \quad (2)$$

The total exports are represented by X; M—means the total imports, and GDP—gross domestic product.

The income per capita (LogGDP)—Logarithm of gross domestic product in constant prices 2010 US dollars.

Table 1 exhibits the sources, the definition of the variables, and the expected signs.

Table 1. Definitions of variables and expected signs.

Dependent Variable		Source
$LogCO_2$—Logarithm of carbon dioxide emissions		World Bank–World Development Indicators (2020)
Independent Variables	**Expected signs**	**Source**
LogEC—Logarithm of energy use per capita	[+]	World Bank–World Development Indicators (2020)
LogTRADE—Logarithm of trade intensity	[−]	World Bank–World Development Indicators (2020)
LogGDP—Logarithm of income per capita based on purchasing power parity (PPP)	[+; −]	World Bank–World Development Indicators (2020)

Source: Author elaboration.

Considering the literature review, we formulate the following hypotheses:

Hypothesis 1 (H1). *Energy consumption causes an increase in pollution intensity.*

Energy consumption (non-renewable) is associated with economic growth practices without considering the concept of sustainable development. Previous studies show that energy consumption stimulates climate change (Shahbaz et al. 2016; Zhang et al. 2019).

Thus, in recent studies, Kong (2021), Tong et al. (2020), Ike et al. (2020), Khan et al. (2020), and Salazar-Núñez et al. (2020) found a positive impact of energy consumption in CO_2 emissions ($EC > 0$), demonstrating that use of energy consumption encourages environmental damage and greenhouse gas.

Hypothesis 2 (H2). *Trade intensity encourages environmental structure.*

There exists abundant literature that considers a negative relationship between trade intensity and carbon emissions. The authors defend that trade liberalization is based on trade agreements and environmental rules to decrease greenhouse gas emissions. The previous studies of Leitão and Lorente (2020), Zhang et al. (2019), Roy (2017), and Leitão and Balogh (2020) found a negative correlation between trade intensity and carbon dioxide emissions ($TRADE < 0$); according to the literature, trade intensity promotes sustainability development.

Regarding hypothesis 3 and based on the literature review, it is possible to formulate two ideas as an alternative, i.e., considering the short- and long-term impact.

Hypothesis 3 (H3). *(a) In the short run, there exists a positive impact of economic growth on climate change; (b) in the long run, economic growth promotes the environment.*

The linkage between economic growth and the environmental Kuznets curve (EKC) proves that the countries and their governments aim for sustainable development in the long run. In this case, we observe improvements in environmental quality and pollution. According to the recent literature of Balsalobre-Lorente et al. (2021), Pata and Caglar (2021), Leitão and Lorente (2020), Ike et al. (2020), and Koengkan et al. (2020), in the short run, there is a positive impact of income per capita on CO_2 emissions ($GDP > 0$); however, we expect a negative effect of income per capita (*GDP* < 0) on carbon dioxide emissions in the long run.

4. Results

This section shows the impacts of trade intensity, energy consumption, and economic growth on carbon dioxide emissions. In the first moment, we consider general statistics and the unit root test, based on the Augmented Dickey–Fuller test (1979), to test the stationarity. We present the empirical results considering the ARDL model, as well as the test proposed by Pesaran et al. (2001), (Kripfganz and Schneider 2016, 2018) to verify long-run cointegration between variables (ARDL model bounds test) and their diagnostics. In this research, we also use the econometric results using quantile regressions for nine quantiles to compare the differences between the regressors and the cointegration models (FMOLS, CCR, and DOLS).

Table 2 reports the correlations between variables utilized in this empirical study. Considering the relationship between the independent variables and carbon dioxide emissions (dependent variable), we observe that energy consumption (LogEC) and income per capita are positively correlated with CO_2 emissions. Moreover, the variable of trade intensity (LogTRADE) is negatively associated with carbon dioxide emissions.

Table 2. Correlations between the variables.

Variables	Observations	LogCO_2	LogEC	LogTRADE	LogGDP
LogCO_2	47	1.000			
LogEC	47	0.996	1.000		
LogTRADE	47	−0.251	−0.169	1.000	
LogGDP	47	0.933	0.980	−0.339	1.000

Source: Author elaboration based on Word Bank Indicators, WDI data.

Table 3 presents the unit root tests, considering the augmented Dickey–Fuller (ADF). The test's null hypothesis indicates if the variables have a unit root, or in the alternative, the variables are stationary. According to Table 3, we observe that the variables (carbon dioxide emissions—LogCO_2, energy consumption—LogEC, trade intensity—LogTRADE, and economic growth—LogGDP) are integrated into the first differences.

Table 3. Unit root with ADF (augmented Dickey–Fuller test).

Variables	Level	1st Difference
LogCO_2	2.532 (0.996)	−2.244 ** (0.025)
LogEC	3.3009 (0.999)	−2.069 ** (0.038)
LogTRADE	−2.597 ** (0.010)	−3.246 *** (0.002)
LogGDP	−2.187 (0.992)	−3.1512 ** (0.002)

Source: Author elaboration based on Word Bank Indicators, WDI data. Represents statistically significant at 1% (***), and 5% level (**).

The ARDL is reported in Table 4. The adjustment coefficient or error correction coefficient (ADJLogCO_2(−1)) proves a long relationship between variables.

Table 4. Trade and environment with autoregressive and distributed lag (ARDL).

Variables	Coef.
ADJLogCO_2(−1)	−0.781 *** (0.000)
Long Run (LR)	
LogEC	1.464 *** (0.000)
LogTRADE	−0.195 *** (0.004)
LogGDP	−0.393 ** (0.036)
Short Run (SR)	
LogGDP D1	0.215 (0.238)
LD	0.399 ** (0.013)
C	3.316 ** (0.013)
Adj. R2	0.818

Source: Author elaboration based on Word Bank Indicators, WDI data. Represents statistically significant at 1% (***), and 5% level (**).

The lagged variable of carbon dioxide emissions is statistically significant at a 1% level with a negative effect. In the long run, we observe that CO_2 emissions tend to decrease, i.e., climate change reduces, and environmental quality improves. The empirical studies of Chin et al. (2018), Leitão and Balogh (2020), and Sun et al. (2019) also found a negative sign for the lagged variable of carbon dioxide emissions.

In the long run, the coefficient of energy consumption (LogEC) positively impacts carbon dioxide emissions. Furthermore, the result is according to previous models as Kong (2021), Ike et al. (2020), Khan et al. (2020), and Salazar-Núñez et al. (2020). Thus, the results also validate that trade intensity and income per capita have a negative effect on CO_2. ECK's theoretical and empirical models demonstrate that trade liberalization and the development of countries promote sustainable development.

Moreover, in the short run, it is possible to infer that economic growth (LogGDP) presents a positive impact on emissions; the environmental Kuznets curve also expects this result.

The integration of the variables used in this research is considered in Table 5. Based on the ARDL bounds test and the Kripfganz and Schneider methodology (2016, 2018), the results prove a long-run relationship between variables.

Table 5. Trade and environment with ARDL and bound test.

Pesaran et al. (2001) Bounds Test								
F = 31.896				T = −10.906			Case 3	
sample (3 variables, 43 observations, 2 short-run coefficients)								
Kripfganz and Schneider (2018) Critical Values and Approximate *p*-Values								
	10%		**5%**		**1%**		***p*-value**	
	I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
F	2.885	4.030	3.506	4.790	4.960	6.547	0.000	0.000
T	−2.560	−3.449	−2.901	−3.832	−3.588	−4.594	0.000	0.000

Source: Author elaboration based on Word Bank Indicators, WDI data.

Table 6 reports the diagnostic of the ARDL model. Based on the statistics, we can infer that the model is stable, i.e., no serial correlation based on the statistics of the Durbin–Watson (1.551) and Breusch–Godfrey Lagrange Multiplayer (LM) test (0.110). The White test assumes that the value of 0.150 demonstrates that the homoscedasticity can be accepted.

Table 6. Diagnostic of ARDL model.

Durbin–Watson d-Statistic	Breusch–Godfrey LM Test for Autocorrelation	White's Test
(7.43) = 1.551	Prob > chi2 = 0.110	Prob > chi2 = 0.150

Source: Author elaboration based on Word Bank Indicators, WDI data.

In the next step, we test the cointegration (see Tables 7 and 8) for the variables used in this study (carbon dioxide emissions—LogCO_2, energy consumption—LogEC, trade intensity—LogTRADE, and economic growth—LogGDP). Considering the trace test and maximum eigenvalue, we observe one cointegration at the 0.05 level.

Table 7. Trade and environment with unrestricted cointegration rank test (Trace).

Hypothesized No of CE (s)	Eigenvalue	Trace Statistic	0.05 Critical Value	*p*-Value
None	0.527	58.413	47.856	0.003
At most 1	0.340	24.763	29.7970	0.170
At most 2	0.077	6.006	15.494	0.695
At most 3	0.051	2.385	15.495	0.695

Source: Author elaboration based on Word Bank Indicators, WDI data.

Table 8. Trade and environment with unrestricted cointegration rank test (maximum eigenvalue).

Hypothesized No of CE (s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	*p*-Value
None	0.527	33.650	27.584	0.007
At most 1	0.341	18.756	21.132	0.104
At most 2	0.077	3.620	14.264	0.897
At most 3	0.052	2.385	3.841	0.122

Source: Author elaboration based on Word Bank Indicators, WDI data.

Table 9 reports the econometric results using different quantiles regression.

Table 9. Trade and environment with quantiles regression.

Quantiles	LogEC	LogTRADE	LogGDP
0.1	1.411 *** (0.000)	−0.460 *** (0.000)	−0.008 (0.855)
0.2	1.294 *** (0.000)	−0.353 *** (0.000)	0.029 (0.160)
0.3	1.285 *** (0.000)	−0.348 *** (0.000)	0.031 (0.167)
0.4	1.249 *** (0.000)	−0.329 *** (0.000)	0.043 ** (0.026)
0.5	1.186 *** (0.000)	−0.262 *** (0.000)	0.063 *** (0.000)
0.6	1.194 *** (0.000)	−0.281 *** (0.000)	0.062 *** (0.002)
0.7	1.165 *** (0.000)	−0.279 *** (0.000)	0.069 *** (0.000)
0.8	1.163 *** (0.000)	−0.278 *** (0.000)	0.070 *** (0.000)
0.9	1.107 *** (0.000)	−0.229 *** (0.000)	0.088 *** (0.000)

Source: Author elaboration based on Word Bank Indicators, WDI data. Represents statistically significant at 1% (***), and 5% level (**).

As expected, the variable of energy consumption (LogEC) is positively correlated with carbon dioxide emissions across all quantiles. Energy consumption, i.e., non-renewable energy, is directly associated with climate change and the environment's damage. The empirical studies of Ike et al. (2020), Khan et al. (2020), and Koengkan et al. (2020) support our result.

The coefficient of trade intensity (LogTRADE) confirms a negative effect on emissions by all quantiles with statistically significant at 1% level. This result shows that liberalization promotes a decrease in climate change. The studies of Leitão and Lorente (2020), Ike et al. (2020), and Sun et al. (2019) found a negative impact of trade intensity on carbon dioxide emissions. Moreover, the studies by AlZgool et al. (2020), Dogan et al. (2019), and Hasanov et al. (2018) also support our result, demonstrating that international trade promotes environmental improvements, explaining that trade intensity and marginal exports or imports reduce climate change and global warming.

The variable of income per capita (LogGDP) indicates a positive effect on CO_2 emissions from quartile 4 to quartile 9. This result is according to the EKC assumption (Balsalobre-Lorente et al. 2021; Leitão and Lorente 2020; Ike et al. 2020; Koengkan et al. 2020).

Table 10 presents the econometric results considering the cointegration models to test the long-run impacts of energy consumption, trade intensity, and income per capita on carbon emissions. We observe that the results are according to the expected signs.

Table 10. Trade and Environmental with FMOLS, CCR, and DOLS.

Variables	FMOLS	CCR	DOLS
LogEC	1.387 *** (0.000)	1.393 *** (0.000)	1.511 *** (0.000)
LogTRADE	−0.265 *** (0.000)	−0.265 *** (0.000)	−0.232 *** (0.000)
LogGDP	−0205 * (0.094)	−0.212 * (0.061)	−0.421 ** (0.039)
C	2.370 ** (0.039)	2.424 ** (0.019)	4.396 ** (0.018)

Source: Author elaboration based on Word Bank Indicators, WDI data. Represents statistically significant at 1% (***), 5% level (**), and 10 (*) % level.

The econometric results also show that the variable of trade intensity (LogTRADE) presents a negative impact on carbon dioxide emissions, which reveals that in the long run, the trade intensity allows reducing climate change, contributing to decarbonization, and reducing the footprint of carbon. This result aligns with the trade agreements and regulations promoted by the World Trade Organization—WTO and the European Union's policies. The studies by Sun et al. (2020), Li et al. (2020), and Zhang et al. (2019) also find a negative association with international trade and carbon dioxide emissions.

Additionally, we can infer that the estimated coefficients of FMOLS and CCR are similar. Furthermore, considering the DOLS estimator's results, it is observed that income per capita presents a negative impact on CO_2 emissions, demonstrating that economic growth seems to promote sustainable development practices in the long run. This result is supported in the literature (Leitão and Lorente 2020; Ike et al. 2020; Koengkan et al. 2020). In this context, the empirical study of Sun et al. (2019) considered Belt and Road regions for the period 1991–2014, and they proved that income per capita is negatively correlated with carbon emissions to these regions. The high income per capita and middle-income per capita regions also found the same tendency. The authors also show that energy consumption positively affects carbon dioxide emissions using different estimators (panel cointegration—FMOLS and panel VECM—vector error correction model).

5. Conclusions

This paper evaluates the theoretical and empirical studies on the effects of trade on carbon dioxide emissions. The theoretical arguments of monopolistic competition models and the relationship between trade intensity and pollution emissions are evaluated, allowing justifying this empirical study's results. The econometric results show that trade intensity contributes to improving the environment, both in the short and long term, justifying the importance of environmental regulation.

The article tests the novelty of the trade and environmental impacts, namely the level of pollution in Portugal for the period 1970 to 2016, using time series (autoregressive distributed lag—ARDL model), quantile regressions, and cointegration models of FMOLS, CCR, and DOLS. Additionally, the link between energy consumption and economic growth are also considered. In this context, this research applied a unit root test proposed by arguments of the augmented Dickey–Fuller test (1979). The results revealed that the variables used in this study are integrated with the first differences.

The econometric results are similar with different estimators. We found that energy consumption positively affects climate change; this result is according to previous studies (Ike et al. 2020; Salazar-Núñez et al. 2020; Khan et al. 2020).

In the long run, with an ARDL model, we observe that CO_2 emissions decrease in Portugal. According to the Kyoto Protocol (Kyoto Protocol to the United Nations Framework Convention on Climate Change 1997) and Paris Agreement (2015), this result shows improvements in the environment. The empirical studies of Chin et al. (2018), Leitão and Balogh (2020), and Shaari et al. (2020) also found a negative sign for the lagged variable of carbon dioxide emissions.

Consequently, economic growth negatively affects carbon dioxide emissions, showing that economic growth contributes to the environmental system in the long run when we apply the DOLS. In this context, we can refer that Portugal uses sustainability practices. Classical studies by Grossman and Krueger (1995) and Holtz-Eakin and Selden (1995) demonstrate that countries go through different phases concerning environmental issues, revealing that there are different attitudes in developing or developed countries. It appears that as a country reaches a stage of industrial expansion, it begins to worry about improving the environment and reducing pollution, thus contributing to the environmental systems to promote the environmental system. According to classic studies, our results are showing that in the long run, economic growth contributes to improving the environment. The results also prove that carbon dioxide emissions tend to decrease in the long run, contributing to reducing climate change, global warming, and gas emissions.

The present study also makes it possible to complete some recommendations in terms of economic policy. In this context, the Portuguese government should continue to promote the cleanest energy. We think that the use of cleaner energy allows a smooth adjustment. On the other hand, the Portuguese government should reward the sectors that use renewable energies, since the adjustment costs will certainly be smoother. In this context, the promotion of an effective energy policy should be based on the principles of Directive 2009/28/EC (THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 2009), the Paris Agreements (2015), and the European Commission's proposal for Horizon Europe (European Commission 2018) for sustainable development.

Additionally, we must look at the results obtained in this study for trade intensity. These indicate that the Portuguese economy has used and respected international rules based on the principle of sustainable development, since commercial transactions are negatively correlated with pollution emissions. Thus, the government should invest in the Portuguese economy's traditional sectors by implementing innovation and product differentiation.

In terms of future research, the introduction of some independent variables such as changes in employment, productivity, economies of scale, and renewables consumption will be essential to understanding the impact of these on structural adjustment issues in the Portuguese economy.

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