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The impact of intra-industry trade on carbon dioxide emissions: The case of the European Union

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Abstract: The reductions of climate change and greenhouse gas emissions are an essential objective of the European Union (EU) to achieving the reduction target by 20% by 2020. Along with energy consumption and agriculture, trade has a diverse impact on climate change. International trade usually negatively affects the environment, while the influence of intra-industry trade is more favourable. The paper investigates the impact of energy use, agriculture, and intra-industry trade on environmental pollution in EU countries using panel data for the period 2000–2014. The research frames the theoretical hypothesis that describing the relationship between agricultural intra-industry trade and climate change. The assumptions are confirmed by panel fixed effects, and Generalized Method of Moment (GMM) estimations, and the panel cointegration test. The empirical results have supported by the literature, and all variables used in this study are stationary applying panel unit root test. Results show that agricultural intra-industry trade, renewable energy is negatively correlated with climate change, confirming the less pollutant hypothesis, while economic growth and agricultural productivity induce environmental problems. This study confirms the theoretical hypotheses explaining the effect of intra-industry trade for agricultural products as well as the impacts of renewable energy use, agricultural land productivity, and economic growth on CO_2 emissions.

Keywords: agriculture; climate change; economic growth; Europe; intra-industry trade; panel data; renewable energy

The European Union's (EU) policy aims to reduce greenhouse gases, to slow down the effect of climate change and to stop global warming.

According to the recent statistics (European Commission 2019), the greenhouse gas emissions in the EU-28 decreased by 22% compared with the levels of 1990, pushing the EU on the path to surpass its 2020 target (reduction of greenhouse gas emissions by 20% by 2020).

Conversely, Member States of the EU depict a different picture regarding its emissions. Across the Member States, greenhouse gas emissions were the highest in Germany (21% of the EU total), followed by the United Kingdom and France in 2017. The most significant decreases were reported for Lithuania (–57%), Latvia (–54%), and Romania (–48%) compared to 1990. On the other hand, the most significant increases were reported for Cyprus (+56%), Portugal (+23%), and Spain (+22%) compared to 1990.

The five main sources of greenhouse gas (GHG) emission by sectors includes energy (fuel combustion and fugitive emissions from fuels), transportation, industrial production, agriculture, land use, land-use

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change, forestry, and waste management (European Commission 2019). Out of the total GHG emissions, 10% was emitted by the agricultural sector in the EU in 2016. From 1990 to 2016, the EU farming sector managed to reduce its emissions by 21% compared with 1990 (European Commission 2019).

Besides, energy consumption and agriculture, trade has a different (positive or negative) effect on climate change. However, international trade usually affects the environment negatively; in turn, intra-industry trade may have favourable effects.

Europe is one of the more significant areas to analyse the intra-industry trade (IIT). Since EU-15 countries are similar in industrial structure, income, and economic growth, horizontal intra-industry trade is substantially large in within-EU countries trade. Deepening European economic integration has promoted the intra-EU IIT. Furthermore, European economic integration in past years has geographically expanded to include the economies of Eastern Europe, increasing vertical intra-industry trade (Ito and Okubo 2012).

The empirical works investigating the relation between intra-industry trade and environmental pollution proxied by greenhouse gases (carbon dioxide emissions – CO_2) are relatively new (Roy 2017; Chin et al. 2018).

Roy (2017) concludes that intra-industry trade (IIT) is beneficial for the environment and argue that international trade is to be less environmentally friendly than IIT.

Furthermore, IIT might stimulate innovation (Ruffin 1999) and also encourage energy efficiency (Melitz and Trefler 2012). Therefore, analysing the role of IIT in the environment is crucial from the European point of view.

This article explores the impact of IIT on environmental pollution (CO_2 emissions) in the EU-28 countries by using panel data between 2000 and 2014. The effects of energy use, agricultural productivity (conventional agriculture), and economic growth are also considered.

The contribution of the paper to the empirical literature is twofold. First, the impact of intra-industry trade on environmental pollution (climate change) is investigated and revisited. Second, the effects of agricultural production, renewable energy consumption, and economic growth on carbon dioxide emissions are also examined.

LITERATURE REVIEW

Theoretical and empirical evidence gives relevance to the relationship between intra-industry trade and environmental pollution or climate change issues. However, it is necessary to evaluate the link and the correlations between climate change and intra-industry trade, as well as a set of variables that influences positively and negatively the environment pollution, such as renewable energy, agricultural productivity, and economic dimension. In this context, we decided to organize this section, keeping in mind the theoretical framework and the empirical studies.

Theoretical framework. A rich literature deals with the theoretical models explaining the association between IIT and CO_2 emissions based on monopolistic competition criterion (Gürtzgen and Rauscher 2000; Haupt 2006; Echazu and Heintzelman 2018).

Following the theoretical models of monopolistic competition (Copeland and Taylor 1994; Gürtzgen and Rauscher 2000; Haupt 2006; Echazu and Heintzelman 2018), most of the researchers argue that intra-industry trade (IIT) allows reducing climate change.

The early pioneering studies of IIT (Grubel and Lloyd 1975; Balassa 1986; Greenaway et al. 1994) concludes that this type of trade is explained by innovation and product differentiation. Regarding these arguments, intra-industry trade enables to decrease greenhouse gases when we compared with inter-industry trade (explained by comparative advantage). Comprehensive empirical literature exists modelling the determinants of intra-industry trade and the adjustment costs in the labour market (Brülhart et al. 2006; Cabral and Silva 2006; Jámbor and Leitão 2016).

Antweiler et al. (2001), Cole and Elliot (2003), Copeland and Taylor (2004), Kahn and Yoshino (2004), Cole et al. (2010), Grether et al. (2010), and Roy (2017) found a negative impact of IIT on CO_2. These studies indicate that IIT is less polluting for the environment, showing that the progress of climate change shrinks with intra-industry trade.

Chin et al. (2018) analysed the relationship between carbon dioxide emissions, income per capita, and vertical intra-industry trade (different types of trade quality, explained by neoclassic trade theory (Jámbor and Leitão 2016) using Autoregressive Distributed Lag (ARDL) model. The empirical study shows that vertical intra-industry trade is positively correlated with CO_2 and illustrates that this type of trade is explained by the theory of comparative advantages.

Usually, the scholars used panel data to explain the link between climate change and intra-industry trade (Cole et al. 2010; Grether et al. 2010; Roy 2017).

Review of empirical studies. We consider the empirical studies that reveal the connection between environmental pollution/climate change and intra-industry

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trade (IIT), controlling for key factors sectors (energy use, agriculture and economic development) responsible for climate change.

Several empirical studies analysed the causality between economic growth and CO_2 emissions (Balogh and Jámbor 2017; Bilan et al. 2019), by testing the hypotheses of the Environmental Kuznets Curve (EKC). In this field, the latest articles (Bilan et al. 2019; Hasnisah et al. 2019; Jebli et al. 2019) are focused on the relationship between renewable energy consumption, economic growth, and climate change.

The recent empirical research (Omri and Kahouli 2014; Saidi and Hammami 2015; Amador et al. 2017; Antonakakis et al. 2017; Balogh and Jámbor 2017; Bashir et al. 2019; Bilan et al. 2019; Sukono et al. 2019) proved that it is causality between carbon dioxide emissions and economic growth.

Sukono et al. (2019) demonstrated that growth and population are directly correlated with CO_2 emissions in Indonesia. Bashir et al. (2019) examined the causality between human capital, energy, carbon dioxide emissions, and growth utilizing a Vector Error Correction Model (VECM) and Granger causality method in Indonesia. The authors showed that cointegration occurs between income per capita and CO_2 emissions in the short-run.

Antonakakis et al. (2017) analysed the cointegration between energy consumption (non-renewable and renewable energy) and the economic growth for the period 1971–2011, using a panel vector autoregression. The study explored a bidirectional causality between economic growth and non-renewable energy use. Moreover, they showed that there is a positive correlation between economic growth and CO_2 emissions. Similar conclusions were declared by Omri and Kahouli (2014), Saidi and Hammami (2015), Amador et al. (2017), Balogh and Jámbor (2017).

The effects of renewable energy on carbon dioxide emissions were investigated by Hasnisah et al. (2019) for the period 1980–2014, applying panel data (FMOLS – Fully Modified Ordinary Least Squares, DOLS – Dynamic Ordinary Least Squares Estimation) and unit root tests. Their results validate the arguments of Environmental Kuznets Curve (a positive correlation between per capita income and CO_2 as well as a negative impact of squared per capita income and carbon dioxide emissions) in long-run (Hasnisah et al. 2019).

The relationship between renewable energy, tourism, economic growth and CO_2 emissions was reflected by Jebli et al. (2019). The long-run estimation using FMOLS and DOLS confirmed that income per capita and trade had a positive effect on CO_2 emissions. Besides, the variables of renewable energy, tourism, and foreign direct investment are negatively correlated with carbon dioxide emissions.

Paweenawat and Plyngam (2017) researched the causality between renewable energy and carbon dioxide emissions for Thailand between 1986 and 2012. The results of ARDL model illustrated that income per capita and squared income per capita are in line with the assumptions of the Environmental Kuznets Curve. The study also concludes that causality exists between income per capita, carbon dioxide emissions, and energy consumption. On the other hand, renewable energy was not associated with CO_2 emissions as the authors demonstrated.

The empirical study of Bilan et al. (2019) explores the relationship between renewable energy, carbon dioxide emissions, and gross domestic product (GDP) for potential candidates of European Union between 1995 and 2015, employing FMOLS, DOLS and VECM. The empirical results suggest that there is a negative relationship between renewable energy and CO_2 emissions in short- and long-run estimating FMOLS and DOLS. By contrast, the income per capita had a positive effect on CO_2 emissions when FMOLS was applied.

The environmental effects of intra-industry trade were also investigated by Roy (2017) through a gravity model using panel data for the period 2000–2005. The econometric results proved that IIT helps to decrease the climate change supported by the explanatory variables of the model, showing IIT uses more environmentally friendly technology. In contrast, higher productivity and bigger size of economies encourage the level of pollution and climate change. A different perspective was presented by the empirical study of Dasgupta and Mukhopadhyay (2018). The authors applied Grubel and Lloyd (1975) index and concluded that IIT between India and USA along with EU-27 are pollution-intensive, depicting dirty industries.

The effects of agricultural productivity on climate change were studied by Asumadu-Sarkodie and Owusu (2017), and Ullah et al. (2018) . The authors used Granger causality and autoregressive vector models (Vector Autoregression – VAR, and Vector Error Correction Model – VECM), and Autoregressive and Distributed Lag (ARDL) as estimation methods. The studies indicated that agricultural productivity and energy consumption stimulate climate change. In contrast, Pant (2009), and Edoja et al. (2016) found a negative correlation between agricultural productivity and carbon dioxide emissions.

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Moreover, Balsalobre-Lorente et al. (2019), applied a panel cointegration (FMOLS, DOLS estimator) to BRICS (Brazil, Russia, India and China) countries to prove that agricultural production responsible for climate change and greenhouse gas emission. In this context, the empirical studies of Martínez-Zarzoso and Maruotti (2011), Leitão and Shahbaz (2013), and Balogh and Jámbor (2017) used a dynamic panel data (GMM – System estimator) to explain the environmental pollution effects.

A significant part of the empirical literature (Asumadu-Sarkodie and Owusu 2017; Paweenawat and Plyngam 2017; Ullah et al. 2018; Bilan et al. 2019; Hasnisah et al. 2019; Jebli et al. 2019) applies multivariate time series methods (VAR – Vector Autoregressive, Granger Causality, VECM – Vector Error Correction Model, and ARDL – Autoregressive Distributed Lag model) and dynamic panel estimations (Martínez-Zarzoso and Maruotti 2011; Leitão and Shahbaz 2013; Balogh and Jámbor 2017) to test the causality between carbon dioxide emissions and its explaining factors such as energy use, agricultural productivity and economic growth.

MATERIAL AND METHODS

Econometric strategy. The impacts of agricultural intra-industry trade, agricultural productivity, renewable energy, and income per capita (economic size) on environmental pollution are investigated in this study. Regarding the literature review, the following hypotheses are formulated:

H_1**:** Agricultural intra-industry trade that related to cleaner energies assist in reducing CO_2 emissions in the EU Member States.

The introduction of this hypothesis aims to explore whether the agricultural intra-industry trade allows reducing climate change and GHG effects in the EU. Analysing the agricultural intra-industry trade on carbon dioxide emissions is still relatively scarce in the empirical literature compared to theoretical models supported by monopolistic competition (Copeland and Taylor 1994; Gürtzgen and Rauscher 2000; Haupt 2006; Echazu and Heintzelman 2018). On the other hand, most empirical works assess only the relationship between trade openness and carbon dioxide emissions, showing that there is a positive association between freer trade and greenhouse gas emission (Wang and Ang 2018; Balsalobre-Lorente et al. 2019), based on the arguments of pollution-intensive production (Copeland and Taylor 2004). As we analysed in the literature review, the intra-industry trade is associated with factors of innovation and price differentiation. Therefore, intra-industry trade may be related to cleaner and less energy use in the case of European agriculture.

The studies of Haupt (2006), Cole et al. (2010), Grether et al. (2010), Roy (2017), and Echazu and Heintzelman (2018) support the idea that intra-industry trade (IIT) is less pollutant compared to other trade allowing to reduce climate change associated with product differentiation. These arguments are valid in the economic context of monopolistic competition (Krugman 1979; Krugman 1980). The intra-industry trade data are extracted from World Bank (2019b), and World Integrated Trade Solution (WITS), in the harmonised system aggregated category of agriculture trade flows, i.e. agricultural IIT within EU and EU trading partners.

H_2**:** Higher share of renewable energy use induces less air pollution and decreases the level of environmental burden in the EU Member States.

Empirical studies on environmental issues have more frequently used non-renewable energy consumption such as coal, oil, fossil fuels, and natural gas to demonstrate that this type of energy accentuates climate change and global warming. It follows that the use of alternative practices called renewable energy (solar energy, wind power, hydroelectricity, geothermal energy, and biomass) is associated with the benefits of cleaner energy. Recently, empirical studies aim to test the assumptions and conclusions set out in the Kyoto Protocol (1995), and the Paris Agreement (2015). This variable has been introduced to assess the extent to which renewable energy produced in the EU can reduce climate change and reduce greenhouse effects.

According to Paweenawat and Plyngam (2017), Bilan et al. (2019), Hasnisah et al. (2019), and Jebli et al. (2019), renewable energy is negatively correlated with CO_2 emissions. The use of renewable energies reduces GHG gases and climate change. Renewable energy (RE) is measured by a percentage of renewable energy in total final energy consumption. The source of this variable is the World Development Indicator (WDI) database (World Bank 2019a).

H_3**:** The higher level of agricultural land productivity stimulates greenhouse gas emissions and contributes to climate change.

The selection of this hypothesis is based on the recent studies (Asumadu-Sarkodie and Owusu 2017; Ullah et al. 2018; Balsalobre-Lorente et al. 2019) indicating that climate change caused by conventional agricultural practices associated with deforestation, agricultural and livestock production, as well as the intensive use of fertilizers. The reduction

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of these practices is on the EU agenda that highlights the relevance of the hypothesis analysed. Agricultural productivity and the use of fertilizers encourage climate change, CO_2 emissions, and global warming. This hypothesis has support in previous studies such as Asumadu-Sarkodie and Owusu (2017), and Ullah et al. (2018). Agricultural land productivity (*ARGLAND*) is the share of arable land area in per cent, including crops and pastures. The variable was coming from the World Bank (2019a) WDI database, and FAO (2019) Food and Agriculture Organization of United Nations, Statistics Data.

$\boldsymbol{H_4}$**:** Economic growth (income per capita) has a direct positive impact on global warming (CO_2 emissions per capita) in the EU.

Over the past decades, in energy and environmental economics have shown that economic growth involves environmental degeneration. The introduction of H_4 hypothesis aims to investigate whether the European economic growth entails climate change, based on the arguments of monopolistic competition.

Considering the arguments of Cole et al. (2010), Grether et al. (2010), and Tariq and Rahim (2016), income per capita is positively correlated with carbon dioxide emissions. The recent empirical studies of Amador et al. (2017), Antonakakis et al. (2017), Balogh and Jámbor (2017), Bashir et al. (2019), Bilan et al. (2019), and Sukono et al. (2019) supported this hypothesis. Gross domestic product per capita (GDP) captures economic growth expressed in current international US dollars, derived from World Bank (2019a) WDI database.

Methodology. The empirical literature indicates that there are two forms of panel data estimation (static and dynamic). Of the static panel methods (pooled ordinary last squared, fixed effects, and random effects), panel fixed effects can be employed (Yoshida et al. 2009; Rasekhi and Shojaee 2012) to estimating IIT.

As a rule, the static panel presents serial correlation and heteroscedasticity problems. Thus, as Arellano and Bover (1995) and Blundell and Bond (1998) demonstrate, the Generalized Method of Moment (GMM) can solve these econometric problems. Martínez-Zarzoso and Maruotti (2011), Leitão and Shahbaz (2013), Balogh and Jámbor (2017) applied GMM estimation in their climate change-related panel research. According to the literature the GMM estimator is valid when there is no serial correlation of second-order (AR2 statistics), and the instruments used are valid (Sargan test).

Moreover, before applying estimators, it is necessary to perform a set of econometric procedures, therefore, we applied the unit root tests [Levin et al. 2002; Im et al. 2003, Augmented Dickey-Fuller (ADF) Fisher Chi-Square, Phillips–Perron (PP) proposed by Maddala and Wu 1999, and Choi 2001] to evaluate the stationarity of the variables used and the proposed criteria by Pedroni (2001, 2004) to evaluate the cointegration in panel variables.

The dependent variable captured by carbon dioxide emissions (CO_2) expressed in metric tons per capita derived from World Bank (2019a) World Development Indicator (WDI) data. The applied explanatory variables are agricultural intra-industry trade, renewable energy, agricultural land productivity, and economic growth (income per capita) for the period 2000–2014. The intra-industry trade became more representative after the accession of New Member States to the EU in 2004. According to European Commission (2019), the changes of carbon dioxide emissions was illustrative in Old (Cyprus, Portugal, Spain, Germany, France and UK accounted for the biggest increase) and also in the New Member States (Lithuania, Latvia, Romania and Estonia reported the biggest decrees), therefore, the sample comprises all EU-28 countries. Moreover, to obtain stable, strongly balanced panel dataset we selected the period for 2000–2014. It should be noted that per capita CO_2 emission was only available until 2014 in World Bank (2019a) data.

The agricultural intra-industry trade (IIT) is calculated in help with the Grubel and Lloyd (1975) index:

$$IIT = \sum\left[\left(X_i + M_i\right) - \left|X_i - M_i\right|\right] \Big/ \sum\left(X_i + M_i\right) \tag{1}$$

where: X_i – total of agricultural exports; M_i – total of agricultural imports.

The index variates between zero and one. The values zero signify that all trade is inter-industry trade; however, if the values are one, all trade is intra-industry trade. The IIT (intra-industry trade) data are calculated for the bilateral agricultural trade flow (export and import expressed in U.S. dollar) of EU-28 Members States (EU intra trade), collected from World Bank (2019b) World Integrated Trade Solution (WITS), using the harmonised system (HS) data at the aggregated category of all agricultural products traded. Table 1 presents a description of the independent variables and their expected signs.

The following function estimates the statistical relationship between intra-industry trade in EU agriculture and environmental pollution:

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Table 1. Description of variables

Variable	Description	Source	Expected sign
Dependent			
LnCO_2pc	the logarithm of per capita carbon dioxide emissions expressed in the EU-28, including consumption of solid, liquid, gas fuels and gas flaring (metric tons)	World Bank (2019a) World Development Indicator (WDI)	
Independent			
LnCO_2pc_{t-1}	the logarithm of lagged per capita carbon dioxide emissions expressed in the EU-28 (metric tons)	World Bank (2019a) WDI	+
Ln*IIT*	the logarithm of Grubel and Lloyd index calculated for agricultural intra-industry trade of the EU-28	World Bank (2019b) World Integrated Trade Solution (WITS)	–
Ln*RE*	the logarithm of renewable energy in total final energy consumption (%)	World Bank (2019a) WDI	–
Ln*ARGLAND*	the logarithm of agricultural land productivity, the share of arable land, including crops and pastures (%)	World Bank (2019a) WDI, and FAO (2019) database	+
Ln*GDP*	the logarithm of per capita gross domestic product (current international US dollars)	World Bank (2019a) WDI	+

Source: Own composition

$$CO_2 = f\left(IIT,\ RE,\ ARGLAND,\ GDP\right) \tag{2}$$

where: *IIT* – intra-industry trade; *RE* – renewable energy; *ARGLAND* – agricultural land productivity; *GDP* – gross domestic product.

Based on the function, we formulated the static and dynamic panel model:

$$\begin{aligned}\text{Ln}CO_2pc = {} & \beta_0 + \beta_1\text{Ln}IIT + \beta_2\text{Ln}RE + \\ & + \beta_3\text{Ln}ARGLAND + \\ & + \beta_4\text{Ln}GDP + \delta_t + \eta_i + \varepsilon_{it}\end{aligned} \tag{3}$$

$$\begin{aligned}\text{Ln}CO_2pc = {} & \beta_0 + \beta_1\text{Ln}CO_2pc_{t-1} + \beta_2\text{Ln}IIT + \beta_3\text{Ln}RE + \\ & + \beta_4\text{Ln}ARGLAND + \beta_5\text{Ln}GDP + \delta_t + \eta_i + \varepsilon_{it}\end{aligned} \tag{4}$$

Because of the larger data availability, the stability of the model, and to obtain a strongly balanced panel, we selected the data for 2000–2014. All variables are expressed in logarithm forms. The constant term is β_0. The coefficients for each variable take β_x. The error term is expressed by ε_{it}, i.e. denotes random disturbance; δ signifies the common deterministic trend, and η_i represents the unobserved time.

EMPIRICAL RESULTS

Regarding the period of this study (2000–2014), it can be concluded that the total agricultural intra-industry trade in EU-28 member countries has an average value of 71%. A more detailed analysis (Figure 1) allows verifying that the higher values are concentrated in Germany, Czech Republic, Lithuania, Bulgaria, and Slovakia. However, as can be seen, as a rule, all EU-28 countries have IIT above 50% on average, except Slovenia (49%), Finland (46%), Cyprus (38%) and Malta (7%).

The correlations between all variables used in this research are presented in Table 2. The independent variables have a positive impact on per capita CO_2 emissions, excluding the variable of renewable energy that has a negative influence on emissions. The agricultural intra-industry trade (Ln*IIT*) is positively correlated with income per capita (Ln*GDP*), renewable energy (Ln*RE*), and agricultural land productivity (Ln*ARGLAND*).

Moreover, the sample data illustrates that we employed a strongly balanced panel with 418 observations for EU-28 countries. The variables of agricultural intra-industry trade (Ln*IIT*), agricultural land productivity (Ln*ARGLAND*), and income per capita (Ln*GDP*) are similar in their means and medians Table S1 [Table S1 in electronic supplementary material (ESM); for the supplementary material see the electronic version].

Table 3 presents the unit-roots test for the variables applied, using the methodology proposed by Levin et al. (2002), Im et al. (2003), ADF Fisher Chi-Square, and Phillips–Perron (Choi 2001). According to the unit-roots literature, the researchers need to test two hypotheses: H_0: the existence of unit root, and H_1: stationarity

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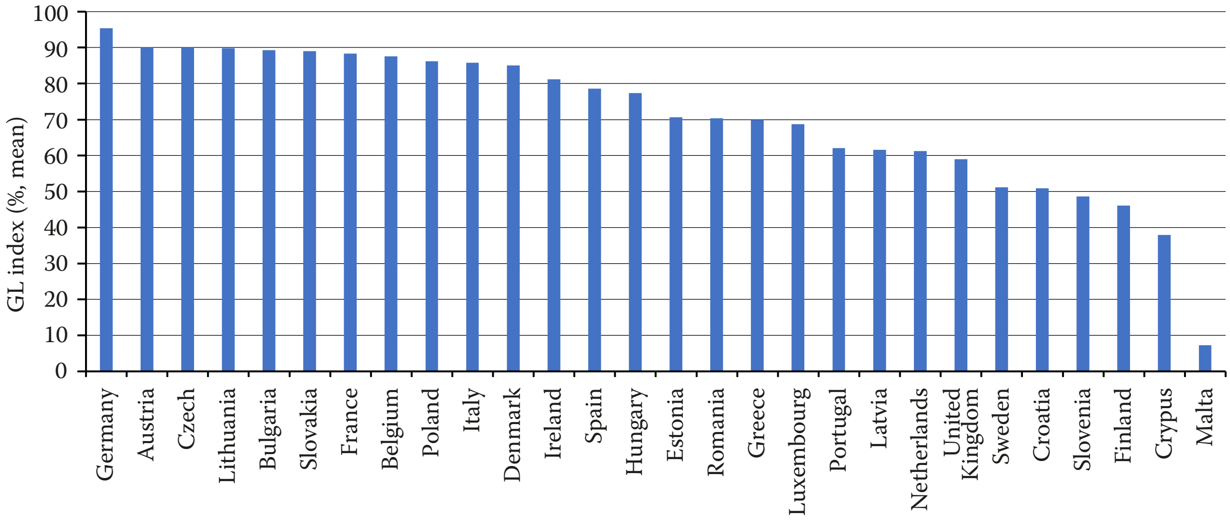

Figure 1. Agricultural intra-industry trade, 2000–2014, mean

GL – Grubel and Lloyd index calculated for agricultural products
Source: Own composition based on World Bank (2019b) WITS data

(no unit root). We consider all variables (carbon dioxide emissions, intra-industry trade, renewable energy, agricultural productivity, and income per capita). In Table 3, we can observe that all variables are stationary. Therefore, the rejection of the hypothesis of the unit root indicates that the panel data can be used in this study.

Table 2. Correlation between variables

Variables	LnCO_2pc	Ln*IIT*	Ln*RE*	Ln*ARGLAND*	Ln*GDP*
LnCO_2pc	1.000	–	–	–	–
Ln*IIT*	0.050	1.000	–	–	–
Ln*RE*	–0.386	0.212	1.000	–	–
Ln*ARGLAND*	0.074	0.433	–0.394	1.000	–
Ln*GDP*	0.534	0.007	–0.160	–0.028	1.000

LnCO_2pc – logarithm of per capita carbon dioxide emissions; Ln*IIT* – agricultural intra-industry trade; Ln*ARGLAND* – agricultural land productivity, Ln*GDP* – per capita gross domestic product, Ln*RE* – renewable energy
Source: Own composition based on World Bank (2019a) WDI and World Bank (2019b) WITS data

Table 3. Unit root test selection based on asymptotic *t*-statistic in level

Tests	LnCO_2pc	Ln*IIT*	Ln*RE*	Ln*ARGLAND*	Ln*GDP*
Levin, Lin and Chu (LLC) test	–5.719*** (0.000)	–5.425*** (0.000)	–6.223*** (0.000)	–11.958*** (0.000)	–6.031*** (0.000)
Im, Pesaran and Shin (IPS) *W*-statistics	–0.198 (0.421)	–2.183** (0.014)	–2.577*** (0.005)	0.851 (0.802)	0.541 (0.701)
Augmented Dickey-Fuller (ADF) – Fisher Chi-Square	96.314*** (0.000)	82.682** (0.011)	84.275*** (0.008)	140.384*** (0.000)	47.587 (0.780)
Phillips-Perron (PP) – Fisher Chi-Square	106.401*** (0.000)	79.276*** (0.002)	79.918** (0.029)	174.382*** (0.000)	70.295* (0.095)

Statistically significant at 1% (***), 5% (**), and 10% (*) level; *P*-values in parentheses; LnCO_2pc – logarithm of per capita carbon dioxide emissions; Ln*IIT* – agricultural intra-industry trade; Ln*ARGLAND* – agricultural land productivity, Ln*GDP* – per capita gross domestic product, Ln*RE* – renewable energy
Source: Own composition based on World Bank (2019a) WDI and World Bank (2019b) WITS data

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Table 4. Pedroni (2001, 2004) – panel cointegration test

	Statistic	Probability	Weighted	
			statistic	probability
Within-dimension				
Panel *V*-statistic	–0.314	0.623	–1.566	0.941
Panel rho-statistic	2.521	0.994	2.164	0.984
Panel PP-statistic	–5.235***	0.000	–6.522***	0.000
Panel ADF-statistic	–1.711*	0.043	–2.629***	0.004
Between-dimension				
Group rho-statistic	4.131	1.000	–	–
Group PP-statistic	–9.068***	0.000	–	–
Group ADF-statistic	–1.292*	0.098	–	–

Statistically significant at 1% (***), 5% (**), and 10% (*) level
Source: Own composition based on World Bank (2019a) WDI and World Bank (2019b) WITS data

The panel cointegration tests proposed by Pedroni (2001, 2004) are presented in Table 4. Based on the results, it is possible to infer that the variables used are cointegrated, complementing the information presented in Table 3.

The fixed effects (static panel) and dynamic (GMM) panel estimations are reported in Table 5. The sample covers 418 observations for fixed effects and 391 for GMM estimation.

The GMM estimation reveals that the results are similar for two steps. The econometric results suggest that there is no serial correlation based on the second-order AR2 statistics, and the instruments used are valid according to the Sargan test. The lagged variable of carbon dioxide emissions (LnCO_{2t-1}) is statistically significant in both steps, and the variable has a positive sign, showing that carbon dioxide emissions increase over the long-term.

Table 5. Environmental impacts and intra-industry trade with Generalized Method of Moment (GMM) estimation

Variables	Fixed effects	One-step GMM	Two-step GMM
LnCO_2pc_{t-1}	–	1.004*** (0.000)	1.005*** (0.000)
Ln*IIT*	–0.015* (0.050)	–0.022* (0.061)	–0.019* (0.062)
Ln*RE*	–0.370*** (0.000)	0.029 (0.598)	0.040 (0.383)
Ln*ARGLAND*	0.645*** (0.000)	0.054 (0.518)	0.029 (0.685)
Ln*GDP*	0.162*** (0.003)	–0.215*** (0.005)	–0.220** (0.017)
Constant	0.642*** (0.008)	0.843** (0.019)	0.887**
Observations	418	391	391
Adjusted *R*-squared	0.384	–	–
Arellano-Bond test AR2	–	–	0.2278
Sargan-Hansen test	–	–	0.4667

Statistically significant at 1% (***), 5% (**) and 10% (*) level; LnCO_2pc – logarithm of per capita carbon dioxide emissions; Ln*IIT* – agricultural intra-industry trade; Ln*ARGLAND* – agricultural land productivity, Ln*GDP* – per capita gross domestic product, Ln*RE* – renewable energy; number of country is 28 for all estimation models
Source: Own composition based on World Bank (2019a) WDI, World Bank (2019b) WITS data

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Considering the fixed effects, and GMM estimation in two-steps, we can infer that the coefficient of intra-industry trade (Ln*IIT)* is statistically significant at 10% level, and has a negative impact on CO_2 emissions, showing that agricultural intra-industry trade allows reducing climate change. This result confirms the H_1 hypothesis. Accordingly, the empirical studies of Cole et al. (2010), Grether et al. (2010), and Roy (2017) also found a negative impact of IIT on CO_2 emissions. Moreover, in line with the literature (Copeland and Taylor 1994; Gürtzgen and Rauscher 2000; Haupt 2006; Echazu and Heintzelman 2018), we observed that intra-industry trade permits to reduce the development of climate change, and environmental pollution.

The variable of renewable energy (Ln*RE*) is statistically significant at 1% level and has a negative effect on per capita carbon dioxide emissions in line with the literature (Jebli et al. 2019; Paweenawat and Plyngam 2017; and Bilan et al. 2019) when we applied the fixed effects estimation confirming the H_2 hypothesis. Finally, renewable energy induces less air pollution in the EU Member States.

According to Asumadu-Sarkodie and Owusu (2017), and Ullah et al. (2018) agricultural productivity stimulates climate change in line with our result. The variable of agricultural land productivity (Ln*ARGLAND*) has a positive impact on CO_2 emissions applying fixed effects, confirming that agricultural land productivity rouses greenhouse gas emission.

The coefficient of income per capita (Ln*GDP*) is statistically significant at 1% level in the fixed effects model, indicating that market size and economic growth boosts climate change and environmental pollution. The empirical studies of Amador et al. (2017), Antonakakis et al. (2017), Balogh and Jámbor (2017), Bashir et al. (2019), and Sukono et al. (2019) also supported our result.

CONCLUSION

The article revisits the empirical studies assessing the impact of intra-industry trade on climate change. The paper analysed the role of agricultural IIT (of the EU Member States in the EU common market) on environmental pollution (per capita CO_2 emissions) in the EU-28 countries by using balanced panel data between 2000 and 2014. Furthermore, the effects of renewable energy use, agricultural productivity, and economic growth are also investigated. We applied unit root test (Levin et al. 2002; Im et al. 2003; ADF Fisher Chi-Square, and Phillips–Perron tests), Pedroni (2001, 2004) cointegration test, Fixed effects and dynamic panel (GMM –System suggested by Blundell and Bond 1998) as methodology.

The unit root tests confirmed that the variables are stationary, and all variables used in this panel are integrated. Besides, the Pedroni panel cointegration tests induce that the variables are cointegrated.

The results of Fixed effects and GMM estimation allow inferring that intra-industry trade in agriculture reduces carbon dioxide emissions since product differentiation and innovation factors characterize this type of trade. Therefore, the findings demonstrate that cleaner firms are operating in the case of EU agricultural trade (compared to industrial production), i.e. this type of trade encourages the reduction of GHG. More specifically, econometric results reveal that agricultural intra-industry trade in the EU-28 associated with cleaner energies, promoting competitiveness through product differentiation and innovation, satisfying the principles of EU sustainable agricultural policy.

Moreover, the estimation results also show that the use of renewable energy reduces carbon dioxide emissions, environmental pollution and validating the principles established in the Kyoto Protocol (1997), and Paris Agreement (2015).

The economic growth and agricultural productivity accentuate carbon dioxide emissions and greenhouse effects; consequently, climate change. Our econometric results are supported by the previous studies of Cole et al. (2010), Grether et al. (2010), and Roy (2017), confirming that intra-industry trade is more sustainable than classical international trade. These findings are in line with the EU objectives, the targets of the Paris Agreement (2015) and analysis of the European Commission (2019).

In terms of policy recommendations, our results suggest, that the European policymakers should support agricultural IIT (instead of standard agricultural trade) between the EU Member States to reduce CO_2 emission more significantly and provide more sustainable development of the EU.

In contrast, the results indicate that agricultural productivity and economic growth significantly stimulate greenhouse emissions in the EU. Consequently, we suggest that the EU trade policy should make a compromise between sustainability and competitiveness by betting on renewable energy, product differentiation, and innovation, taking into account the commitments set out in the Paris Agreement (2015) regarding energy efficiency and the reduction of CO_2 emissions. To achieve more sustainable practices, the use of renewable energy sources, encouraging Short Food Sup-

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ply Chain, producer markets, and Climate-Smart Agriculture is needed.

The contribution of the paper to the literature is diverse. The majority of empirical studies evaluating the relationship between intra-industry trade and environmental pollution employing country characteristics as explanatory variables (Roy 2017; Dasgupta and Mukhopadhyay 2018) while we analysed the role of IIT, economic growth, renewable energy and agricultural land productivity on carbon emission. Our study applied static and dynamic methods focusing on the IIT of the agricultural sector in the EU.

Regarding directions for future research, we consider that it will be interesting in testing the impact of marginal intra-industry trade and trade intensity on environmental pollution.

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