

Comércio Internacional de Bens Ambientais: Efeitos na Inovação em Energias Renováveis

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Resumo: A Declaração Ministerial de Doha de 2001 (DMD) estabeleceu uma importante conexão entre comércio e meio ambiente. Para incentivar a disseminação de bens e tecnologias ambientais, a declaração prevê a redução ou eliminação de barreiras tarifárias e não tarifárias para bens e serviços ambientais. No entanto, há um impasse no processo de negociação, tanto devido à dificuldade de definir bens ambientais quanto à falta de consenso entre países desenvolvidos e em desenvolvimento. Este artigo teve como objetivo avaliar a hipótese de que a imposição de tarifas sobre a importação de bens ambientais entre 2005 e 2015 exerceu efeitos negativos na geração de inovações ambientais em energias renováveis durante esse período. Com base em um modelo econométrico de dados em painel aplicado e com base em informações disponíveis da Organização para a Cooperação e Desenvolvimento Econômico (OCDE) e do Banco Mundial, concluiu-se que as tarifas sobre a importação de bens ambientais exercem um impacto negativo na geração de inovações em energia renovável.

Palavras-chave: Energia renovável; Bens ambientais; Eco-inovação; Comércio internacional; Tarifas de importação; Sistemas Nacionais de Inovação.

Código JEL: F18, Q42, Q56

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International trade in environmental goods: The effects on renewable energy innovation

Abstract: The 2001 Doha Ministerial Declaration (DMD) established an important link between trade and the environment. To encourage the dissemination of environmental goods and technology, the declaration provides for the reduction or elimination of tariff and non-tariff barriers for environmental goods and services. However, there is an impasse in the negotiating process, both because of the difficulty defining environmental goods and due to lack of consensus between developed and developing countries. This paper aimed at evaluating the hypothesis that the imposition of tariffs on the import of environmental goods between 2005 and 2015 exerted negative effects on the generation of environmental innovations in renewable energies during this period. According to an applied econometric model of panel data and based on information available from the Organization for Economic Cooperation and Development (OECD) and the World Bank, it was concluded that tariffs on the import of environmental goods exert a negative impact on the generation of renewable energy innovations.

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Keywords: Renewable energy; Environmental goods; Eco-innovation; International trade; Import tariffs; National Innovation Systems.

1 INTRODUCTION

Since the second half of the 20th century, the discussion on environmental risks associated with economic growth has gained significant prominence (KOELLER et al., 2019). However, a dichotomy emerged: while some innovation scholars see economic growth as an obstacle to the adoption of sustainable strategies, others believe in the catalytic role of international trade for the transition to a greener economy. This latter perspective was endorsed by the Doha Round, which emerged as an effort to eliminate barriers in the trade of environmental goods and services (EGSs) and was dubbed the Round for "Developing Countries and Environmental Protection" (STEENBLIK, 2005).

Central to this debate are complex concepts involving technology, innovation and the environment. Despite widespread agreement on the crucial role of environmental goods in promoting sustainable development, a stalemate continues due to technical barriers and economic complexities (SOILITA, 2019). The challenges are vast, and the need for information, analysis and policy proposals is imperative. The intersection between trade and the environment is changing, and the question of how trade negotiations impact sustainable development is crucial. The promotion of trade liberalization regarding these goods and services is oftentimes seen as beneficial for everyone. By opening national markets, the transfer of advanced technologies becomes more accessible, reducing costs and democratizing access. In this context, making environmental goods more accessible, such as wind turbines, is crucial to addressing the global climate crisis (IPCC, 2014). The ecological transformation of the economy, enhanced by trade, can culminate in sustainable competitive advantages (SCHOT; GEELS, 2008).

Therefore, this article aims at investigating the effects of import tariffs related to environmental goods on promoting innovations in renewable energies, using data from the OECD and World Bank databases, standing out in the current literature by addressing the effects of trade liberalization in environmental goods on innovations in renewable energies. While most previous research primarily focuses on the political and theoretical implications of this liberalization (CHAKRABORTY; CHATTERJEE, 2015), the current paper delves into an empirical analysis, using the panel data methodology, the Two-Stage Least Squares (MQ2E) method, and the Instrumental Variables (VI) method.

Consequently, our research offers a new perspective on how import tariffs and international trade in environmental goods directly influence sustainable technological development. This aligns with studies like the one by Soilita (2018), which reveal complex and differentiated effects of environmental goods' trade on different environmental aspects, such as water and air pollution. However, this paper goes further by connecting these effects with specific innovations in the field of renewable energies, an aspect scarcely explored in the existing literature. In summary, this article not only contributes to the academic debate on trade and the environment but also offers important insights for policymakers and stakeholders involved in the transition to greener and more sustainable economies.

The article acknowledges that the incentives for international trade and technological progress in various sectors of the economy are diverse (KALIRAJAN, 2016). For example, the export of solar and wind energy technologies has grown considerably in the last decade, both among developing and developed countries (WAN et al., 2018). In this context, the major challenge related to the standards of environmental technologies and their commercialization would be the creation of appropriate incentives for the economic system to facilitate and foster the development and commercialization of clean and sustainable technologies (MAVROIDIS; NEVEN, 2019).

In addition to this introduction, the article is organized into 4 further sections. Section 2 presents the discussion around the definition of environmental goods and the issue involved in liberalizing them, including current considerations and trends in the global market for environmental goods. Section 3 describes the database used in the empirical model and the treatment performed. Section 4 details the methodology used in the paper and the procedures employed for the methodological application. Section

5 presents the discussion of the results found from the model data. The conclusions are formulated in Section 6, which also includes the study limitations and suggestions for future research.

2 ECO-INNOVATION AND ENVIRONMENTAL GOODS: CHARACTERISTICS AND CHALLENGES

International trade is pivotal in spreading technologies for climate change mitigation, pollution reduction, and biodiversity conservation, evolving from the concept of "sustainable development" (Patriota, 2013). The 2001 Doha Ministerial Declaration (WTO, 2001) emphasized trade's role in environmental sustainability, promoting the reduction of barriers for environmental goods and services. Despite no precise WTO definition, OECD countries view these goods as ones that manage environmental damage (EUROSTAT, 2009). The Doha Round negotiations, however, have been stalled due to disagreements over definitions and classifications of environmental goods and the differing roles of developed and developing countries in their market (WTO, 2001; Patriota, 2013; EUROSTAT, 2009).

Over twenty classification proposals, mainly from OECD and APEC, have emerged (Neto, Rios & Velloso, 2006), leading the OECD to develop the "CLEG" (Combined List of Environmental Goods), comprising 248 products categorized by environmental themes (Sauvage, 2013). This list forms the basis of the subsequent analysis in this article.

The liberalization of environmental goods and services offers a unique chance for the multilateral trading system to enhance trade-environment synergy (WTO, 2001). However, the uncertain negotiation outcomes necessitate examining trade's impact on greenhouse gas emissions and the promotion of environmental goods (OECD, 1999). Trade liberalization affects the environment through scale, composition, and technology effects, with the latter being crucial for environmental goods (ECORYS, 2023). Open trade facilitates access to eco-friendly goods and technologies, leading to cleaner practices (UNEP & WTO, 2009), and is vital for countries lacking domestic production of such goods (Albrizio et al., 2014).

Nevertheless, the environmental impact of trade liberalization is dual-sided. While it can lead to pollution-intensive activities in countries with lenient environmental policies (the pollution haven hypothesis, Tamini & Sorgho, 2017), it also spurs economic growth, enabling better environmental management and encouraging the adoption of stricter environmental standards due to global market integration (World Bank, 2012; Esty & Geradin, 2000).

2.1 IMPACT OF REGULATORY POLICIES AND INCENTIVES FOR RENEWABLE AND SUSTAINABLE TECHNOLOGIES

The trade of environmental goods and services (EGSs) is influenced by both supply and demand factors. Supply-side factors include tariffs and trade-related restrictions, which impact the availability and price of EGSs (WTO, 2010; Dee, 2005). Other influential policies include development cooperation, export credits, and innovation and intellectual property regimes (UNEP & WTO, 2009). On the demand side, domestic environmental regulations, consumer pressure for 'green consumption', and community advocacy are crucial. Governments play a vital role in creating demand for EGSs through favorable regulatory environments (OECD, 2020). Industry trends are shifting from end-of-pipe solutions to integrated process technologies focusing on energy and material efficiency, which also depend on collaboration with research institutes and investment in R&D (Horbach, 2008; Triguero, Moreno-Mondéjar & Davia, 2013; Horbach & Rennings, 2013).

Empirical studies, such as those by JWPTE (Sauvage, 2014) and Jaffe et al. (1995), demonstrate that stringent environmental regulations correlate with higher exports of EGSs. Aichele and Felbeymayr (2015), as discussed by De Melo & Solleder (2018), found that environmental commitments like the Kyoto Protocol significantly impact trade patterns (De Melo & Braga, 1991; Copeland & Taylor, 2007). This underscores the role of well-designed environmental regulations in market creation (Johnstone et al., 2010). Given the complex interplay between trade, climate change, and environmental goods, further empirical research is needed for a deeper understanding of these dynamics (Antweiler et al., 2001). This

article aims to analyze how reducing import tariffs on environmental goods can foster innovation in renewable energies, as reflected in an increase in patent registrations.

2.2 CURRENT TRENDS AND THE IMPORTANCE OF LIBERALIZING THE TRADE OF ENVIRONMENTAL GOODS

Global trade in environmental goods significantly grew between 2003 and 2016, with a notable rise in renewable energy plants and related technologies (Garsous, 2019). This trend is part of the larger shift towards renewable energy, especially in electric power generation. In 2016, renewable energy plants comprised a significant portion of all exported environmental goods, with other important categories being wastewater management, drinking water treatment, and waste management systems (ICTSD, 2008). While developed countries are the main exporters, developing countries, except China, are emerging as significant importers with high growth potential, reflecting the varying maturity levels of these markets (Abdi, 2012; Nascimento & Almeida, 2016; Tamini & Sorgho, 2017).

Tariff trends show a general decrease, especially in OECD countries, facilitating the trade of environmental goods (Garsous, 2019; Dee, 2005). The role of environmental goods in achieving sustainable development goals set by the United Nations is crucial (World Bank, 2007). The removal of trade barriers is essential for the diffusion of technologies necessary for environmental protection (Eurostat, 2009). In the context of slow trade liberalization negotiations, there's an urgency to focus on environmental services, considering not only goods explicitly classified as 'environmental' but also those serving clear environmental objectives (Droege et al., 2017; Stern, 2007; UNEP & WTO, 2009). This article investigates how tariff reduction can promote innovation in environmental technologies, contributing new insights into the potential impact of tariff policies on sustainable technological advancement.

3 DATABASE

To specify the model used in this article, information was collected from OECD and World Bank data. Databases related to environmental innovations in renewable energy generation were extracted from the OECD platform, along with the database containing information on import tariffs for renewable energy-related goods. Additionally, data related to the volume of CO_2 emissions, *per capita* electric consumption, renewable energy generation and production of scientific articles were extracted from the World Bank data.

The final database covers an eleven-year time frame, with an annual data series from 2005 to 2015, containing a total of 62 developed and developing countries, selected based on data availability for the variables analyzed.

With the selection of the renewable energy category, the study specifically sought to analyze the impact of import tariffs on this category, thereby avoiding the manifestation of characteristics from other types of innovation when subcategories were aggregated.

The dependent variable used in the analysis represents the number of inventions related to the field of renewable energies (simple patent families) developed by inventors from each country, regardless of the jurisdictions where patent protection is sought (i.e., all known patent families worldwide are considered). This refers to the development of environmental innovations related to renewable energies, extracted from the OECD database.

Using patents as indicators for technological innovation has become a well-established practice in the economic and environmental literature. Popp (2002) highlights that innovations in energy technologies are largely induced by energy prices, with patent data acting as a vital thermometer to measure innovative activity.

The renewable energy category was chosen because it has the highest participation rate in the Combined List of Environmental Goods (CLEG)[1] and stands out in global imports of environmental goods, as shown in Chart 2 below:

Chart 2 – Distribution of environmental resources in the Combined List of Environmental Goods

Code	Environmental Theme or Medium	Average Participation in CLEG	Participation in World Imports of Environmental Goods (2005-2015)
APC	Air Pollution Control	5%	7%
CRE	Cleaner or More Resource-Efficient technologies and products	19%	6%
EPP	Environmentally Preferable Products based on end use or disposal characteristics	2%	<1%
HEM	Heat and Energy Management	10%	6%
MON	Monitoring, analysis and assessment equipment	15%	10%
NRP	Natural Resources Protection	<2%	<1%
NVA	Noise and Vibration Abatement	<2%	6%
REP	Renewable Energy Plant	22%	37%
SWM	Solid and hazardous waste management and recycling systems	10%	1%
SWR	Soil and Water Cleanup or Remediation	<2%	19%

[1] It should be noted that data on import tariffs for environmental goods are divided into categories as follows: APC = Air Pollution Control; CRE = Cleaner or Resource-Efficient technologies and products; EPP = Environmentally Preferable Products based on end use or disposal characteristics; HEM = Heat and Energy Management; MON = Environmental monitoring, analysis and assessment equipment; NRP = Natural Resources Protection; NVA = Noise and Vibration Abatement; REP = Renewable Energy Plant; SWM = Solid and hazardous waste management and recycling systems; SWR = Soil and water cleanup or remediation; and WAT = Wastewater management and drinking water treatment. Among them, the field of interest chosen was REP = Renewable Energy Plant.

WAT	Wastewater management and drinking water treatment	13%	9%

Source: Developed by the authors based on OECD data.

Furthermore, to include a control variable for the effects of the National Innovation System (NIS) on the development of environmental innovations, the number of scientific and engineering articles published by a country was used. The data extracted from the World Bank database consider the number of articles from a set of journals covered by the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI).

The NIS is a system constituted by a certain set of agents and their relationships, which determines its level of development and potentialities (LUNDVALL, 2007). In a well-developed innovation system, the NIS plays a fundamental role, as it is the companies and the agents who help promote innovation that must interact, establishing such information flows, sustaining proper alignment between scientific and technical knowledge (LUNDVALL, 2007). According to Griliches (1990), the production of scientific articles serves as a tangible indicator of a country's research and development (R&D) activity. Furthermore, the production of scientific articles is oftentimes used as a proxy for a nation's scientific and technological capacity (Lundvall, 1992).

The study focuses on import tariffs as the primary variable to assess their influence on environmental innovations related to renewable energy. These tariffs, sourced from the OECD database, represent the percentage points applied to renewable energy-related goods as defined in the Combined List of Environmental Goods (CLEG) for the period between 2005 and 2015. The research acknowledges that while renewable energy technologies are critical for addressing climate change and sustainable growth, economic and trade factors, such as import tariffs, play a significant role in their adoption and dissemination. Import tariffs can impact the cost, accessibility, investment, and innovation in the renewable energy sector. The study aligns with the OECD's recommendation that reducing tariffs on environmental goods can make renewable energy products more accessible and appealing, and it also considers the World Trade Organization's perspective that such tariff reductions enhance international competitiveness and encourage research and development investments. In summary, the study analyzes import tariffs as a key explanatory variable to understand their direct and indirect effects on generating environmental innovations within the renewable energy domain, considering relevant literature and international trade dynamics.

It should be noted that the data on import tariffs of environmental goods are divided into categories. Among them, the field of interest chosen was REP = Renewable Energy Plant. The information is presented in percentage points, representing the import tariff of a subcategory. Nevertheless, an arithmetic average of the tariffs of all 57 subcategories was calculated to obtain an overall average import tariff for goods related to renewable energy plants for each country. From the World Bank database, data regarding *per capita* electric consumption were collected as a control variable to represent the impacts of increased electric consumption on the development of innovations related to renewable energies.

Together, data related to CO_2 emissions (in Kilotons) were collected to control for the effects of atmospheric pollution on the generation of innovations in alternative and less polluting energies – renewable energies.

It is known that the increase in access to and use of electricity, as well as in the *per capita* electric consumption, have been frequently associated with economic development and technological progress (Stern, 1993). As mentioned with the "logConsumption" instrument, the instrumentalization of this variable emphasizes the dynamic relationship between increasing electric energy consumption and the drive towards more sustainable energy sources (KHAN et al., 2020).

Nonetheless, the increase in emissions and their adverse effects on the environment have historically been catalysts for innovation and the adoption of environmental technologies. As shown by Acemoglu et al. (2012) in the American Economic Review, economies with high emissions and stringent

environmental regulations tend to direct technological innovation towards more environmentally friendly technologies.

Finally, a focused analysis in the renewable energy sector by Johnstone, Haščič and Popp (2010) published in Environmental and Resource Economics, used patent counts to identify a positive relationship between policies aimed at reducing emissions and innovation in clean technologies. These studies collectively suggest that, as emissions increase, there is an increasing incentive to develop and adopt new technologies that reduce the environmental impacts.

As an additional aspect of the study, we aim at assessing whether import tariffs on environmental goods used in renewable energy plants exert differentiated impacts on the development of environmental innovations for developed and developing countries. For this purpose, a dummy variable was introduced, which is assigned a value of 1 for countries categorized as developed and of 0 for developing countries.

The use of interaction terms to assess the differentiated impact of a variable under different conditions or contexts is a well-established approach in economic analyses. Jaccard, Turrisi and Wan (1990) extensively outline the relevance and application of interaction terms in multiple regressions to explore and interpret complex relationships.

Due to the different scales and distributions of the collected variables, both dependent and explanatory, a functional transformation was performed, representing the selected variables in logarithmic form. The Tariffs explanatory variable was kept in its original form, as it is presented in percentage points. An overview encompassing the variables used in the study is shown in Chart 3.

Chart 3 – Description and source of variables used

Code	Variable	Source
$logInnovations$	Development of environmental innovations related to renewable energies	OECD
$Tariffs$	Import tariffs on renewable energy-related goods	OECD
$logRenewable$	Electricity production from renewable sources (kWh)	World Bank
$logConsumption$	*Per capita* electric consumption	World Bank
$logEmissions$	CO_2 emissions (in Kilotons)	World Bank
$logArticles$	Production of scientific articles	World Bank
$Development$	Development dummy (1 for developed countries and 0 for developing ones)	-

Source: Developed by the authors, using OECD data.

4 METHODOLOGY

With the objective of investigating the effects of import tariffs on the development of environmental innovations, the panel data methodology has proven to be the most suitable, as it provides a more dynamic analysis of the countries in the sample.

The initial model (and considered the most restrictive) is the pooled data model, which disregards the time and spatial dimensions of the data and assumes all coefficients to be constant over time and across individuals, taking the form of stacked data. In this case, the usual method for parameter estimation is ordinary least squares (OLS), and the general formulation of the model with n observations in T periods and k variables is given by the following equation:

$$\log Innovation = \beta_0 + \beta_1 Tariffs + \beta_1 Tariffs * Develop + \beta_2 \log Renewable + \beta_3 \log Articles + \varepsilon \quad (1)$$

In the model presented, the dependent variable (logInnovation) refers to the development of Environmental Technologies related to renewable technologies. The independent variables consist of data regarding import tariffs on environmental goods related to renewable energy (Tariffs), a variable for renewable energy generation (logRenewable), a representation of the country's volume of scientific publications (logArticles), and an interaction term between a dummy variable - relating developed and developing countries - and the Tariffs variable. This interaction term seeks to analyze whether the average impact of import tariffs on renewable energy goods differs for developed and developing countries (WOOLDRIDGE, 2010).

Due to the heteroscedasticity issues in the model, it is essential that their presence be detected prior to specifying the final model, so that statistical devices can be used to circumvent it. Thus, to obtain consistent estimators and to mitigate the simultaneity bias, the OLS method is followed by the two-stage least squares method (2SLS) and the instrumental variables (IV) method, which are detailed below. The use of instrumental variables to address the heteroscedasticity arising from endogenous variables (correlated to error term ε) is widely used in regression analysis.

Furthermore, to use the methodology of instrumental variables, it is necessary to define the explanatory variable to be instrumented. The Park test – used in this paper – begins with a specific model of the heteroscedastic process. Specifically, it assumes that heteroscedasticity can be proportional to the dimension of some independent variable in the model. The test regresses the square of the residuals on the independent variables and, therefore, if the coefficient of any independent variable proves to be significant, then there will be strong evidence that this variable is endogenous (JIANG; DENG, 2021). Thus, through the Breusch–Pagan test (BREUSCH PAGAN, 1979), presence of heteroscedasticity in the original model was identified. The problem was corrected using the two-stage least squares estimator (2SLS).

5. RESULTS

As presented in the Methodology section, through the Breusch–Pagan test, heteroscedasticity was identified in the OLS model used. The descriptive statistics and the correlation matrix of the variables can be seen in Annexes 1 and 2. Thus, to identify the endogenous explanatory variable, the Park test was performed. The results of the test, which consists of a regression of the squared residuals extracted from the original OLS regression against the explanatory variables of the original model, showed that the logRenewable variable was statistically significant in explaining the residual term, demonstrating evidence of an endogenous variable. The test results are shown in Table 1.

Table 1 – Park test results

Variables	Park test
logRenewable	-0.0691*
	(-2.23)
Tariffs	-0.00225
	(-0.20)
logArticles	-0.0477

	(-1.40)
Constant	1.118***

Dependent variable = e^2 of the original regression
t statistic in parentheses
Source: Developed by the authors.

Thus, the next step was to instrument this variable through the 2SLS model (least squares in two stages). To instrument the logRenewable endogenous variable, it was decided to use the logEmissions and logConsumption variables. The use of the logEmissions variable derives from the empirical relationship observed between the increase in air pollutant emissions and the increase in the use of renewable energy (ALVAREZ-HERRANZ; BALSALOBRE-LORENTE; SHAHBAZ, 2017). Similarly, the logConsumption instrument represents the increased use of renewable energy sources resulting from the increased global electricity demand (KHAN et al., 2020).

By regressing these two instruments on the instrumented variable, it was possible to observe that both were statistically significant at the 1% level in explaining the instrumented variable, configuring themselves as good adjustments in terms of instruments (R^2=0.3814). Thus, the 2SLS model proceeded from Equation (1) with the logRenewable variable having been instrumentalized by the logEmissions and logConsumption variables. The beta coefficients resulting from the 2SLS regression are presented in Table 2, as well as the robust standard errors of the coefficients:

Table 2 – Regression results with 2SLS

Variables	2SLS
logRenewable	0.465***
	(0.12)
Tariffs	-0.051*
	(0.02)
logArticles	0.527***
	(0.11)
IntDevelopment	0.060
	(0.11)
Constant	2.949***
R^2 = 0.8709	

t statistics represented in parentheses: *p<0.05, **p<0.01, ***p<0.001
Source: Developed by the authors.

It is possible to state that all variables were significant at a level equal to or below 5%, except for the interaction term IntDevelopment, which represents the interaction between the Tariffs variable and the DevDev dummy (which indicates the country's development level). In this way, despite the discrepancy found in the protection of environmental goods, with higher import tariffs in developing countries than in developed ones (Nascimento and Almeida, 2016), for the sample collected from 60 nations for the years under study, the results indicate that it cannot be concluded that the average effect of import tariffs differ for developed and developing countries.

In addition, the joint significance of the selected variables reinforces the varied character of each of the factors that affect environmental innovations, with the results explaining the impact of different socioeconomic, energy, scientific and commercial factors in the process of developing environmental innovations. Furthermore, to validate the specification of the model and instruments, the Sargan test was performed, which tests the validity and exogeneity of the instruments used. Correct validity of the model is reflected in its null hypothesis; therefore, for a properly specified model, a p-value greater than 0.05 is expected (so that it is not possible to reject the null hypothesis). The test results were not statistically significant (x^2=4.59; DoF=6; p=0.59), indicating that the model was correctly specified and that the instruments are not correlated with the error term.

Analyzing the coefficient of the variable of interest (Tariffs), it can be seen that, due to the log-level functional form, for each 1-unit increase in Tariffs – which refers to an increase of 1 percentage point in tariffs for importing renewable energy goods – there is a 5.1% reduction in the generation of environmental innovations related to this field. In this way, it is observed that the negative coefficient is consistent with the literature (SOILITA, 2019; CZELUSNIAK et al., 2011), indicating that import tariffs on environmental goods (renewable energy in this case) negatively affect the development of environmental innovations. This result also reinforces the relationship between the innovative process and international trade, showing strong evidence of the use of imported goods to improve existing processes and materials, as well as the generation of new technologies and end-of-pipe innovations based on existing products (BALINEAU; MELO, 2013; MELO; SOLLEDER, 2020).

In addition to observing the effects of import tariffs on the development of environmental innovations, the statistical significance of the logArticles variable in the model reinforced the role of the National Innovation System (NIS) in the process of developing environmental innovations. In this way, the model illustrates the need for good technological and scientific infrastructure in the countries so that the gains arising from the facilitation of trade in environmental goods can be used and improved on for the generation of environmental technologies.

Thus, it is possible that easing trade in environmental goods, based on reduced or zero tariffs, reduces the cost of producing environmental technologies and encourages eco-innovation. This statement is in line with the paper by Soilita (2019), who, based on the regression of instrumental variables, finds an improvement in environmental effectiveness for net importers of environmental goods. Furthermore, Antweiler et al. (2001) estimated a model that highlights the interaction of factor endowments and income differences in determining the trade pattern, and from data on sulfur dioxide (SO_2) concentrations at 293 sites in 44 countries taken from the Environmental Monitoring Project Global over the 1971-1996 period; he found that, in his sample, openness to trade reduces sulfur dioxide concentrations on average.

It is worth noting that, to some extent, the results highlight the importance of international trade on environmental innovations. Easing international trade through reduced or eliminated tariffs and non-tariff barriers on environmental goods would lower the cost of environmental technologies, increase their usage and stimulate innovation and technology transfer. Secondly, developing countries would benefit in two ways from better market access to environmental goods and services (CZELUSNIAK et al., 2011).

Environmental goods producers would enjoy better access to large markets in high-income Europe, the United States and Asia, and it would be easier for developing countries to obtain high-quality environmental goods produced abroad. Among other environmental benefits, this access should increase energy efficiency and improve water and sanitation conditions in developing countries. Through technology transfer and reduced barriers to environmental services, improved technologies and better-performing environmental services would reduce emissions. Finally, at the global level, the environment would be better preserved, especially if a broad definition of environmental goods was adopted to include products and services with production, use or disposal characteristics that avoid environmental damage (e.g., the use of biodegradable materials or environmentally preferable products) (CZELUSNIAK et al., 2011).

Furthermore, according to Hoekman (1995), regulation also has the power to influence countries to generate innovation. In general, the development of the environmental goods and services sector has been driven by the needs created by environmental legislation, including compliance with the

environmental objectives of the European Union (EU) and other national legal requirements, such as water quality targets or renewable energy production targets (CHAKRABORTY; CHATTERJEE, 2015).

Additionally, public and private funding resources that enable investment in innovative projects have also increased significantly, supported by social pressures and greater awareness about combating environmental pollution and preserving natural resources (EUROSTAT, 2009).

Thus, this article has demonstrated the triple gain between trade, the environment and development (Czelusniak et al., 2011), even considering countries with different characteristics. Specifically, developed nations have more accelerated environmental innovation processes and also benefit from international trade to stimulate their productive capacity. Similarly, the transition to renewable energy generation and increased usage is more significant in developed countries (GARSOUS, 2019).

The fact is that developing countries, such as Brazil, still face constraints regarding their potential for international trade and its relationship with environmental innovation processes. In other words, tariff and non-tariff barriers stand out for representing significant burdens for agricultural goods (the main export item in Brazil) when compared to industrial goods (which have higher added value and investments in R&D). As a result, developing countries become more resistant to reducing their subsidies and barriers to agricultural products (OLIVA and MIRANDA, 2008).

Therefore, a reduction in the production cost of environmental technologies disseminates their use and stimulates environmental innovation and technology transfer. Transfer of this higher-performing technology benefits the environment globally. Some factors that strengthen industrial sectors can be exemplified, such as regulatory frameworks and investments in environmental goods sectors comprising products that avoid environmental damage (e.g., the use of biodegradable materials or environmentally preferable products), as well as subsidies to companies that innovate in the production of equipment and technologies necessary to reduce or prevent environmental damage.

6 CONCLUSION

Since the 1990s, international economic transactions, especially international trade, have increased considerably. The article highlights a growing concern about the impact of these movements on the environment, as the world faces the consequences of global warming and accelerated natural resource degradation. In summary, the article emphasizes the intricate relationship between import tariffs and the generation of environmental innovations. By adopting a methodological approach based on OECD and World Bank data, it became evident that high tariffs on renewable energy goods can inhibit innovation in the energy sector, precisely at a time when the urgency of sustainable practices is more evident than ever. This finding serves as a warning sign for policymakers worldwide, emphasizing the need for a more balanced approach that favors both economic development and sustainability.

As addressed in the article, environmental problems have an inherently international nature. Hence the urgent need to establish a new global context with paradigms focused on sustainability, involving the dissemination of clean technologies and the creation of incentive policies for sustainable technologies and practices. This transformation is not only desirable but vital to ensure the quality of life of future generations.

The intrinsic relationship between scientific production and technological innovation is also emphasized. Furthermore, as highlighted in the article, the crucial role of renewable energy cannot be underestimated. The positive interaction between renewable energy production and the advancement of environmental technologies is a testament to the potential of clean energy to serve as a catalyst for environmental innovation.

The approach to topics such as the liberalization of trade in environmental goods and services has brought a new dimension to the discussion. While such liberalization has the potential to contribute economic and environmental benefits, it is essential that it is accompanied by complementary policies, ensuring equitable benefits and sustainability. Trade in environmental goods is a powerful instrument for promoting economic and environmental justice, as it is a means of reducing technological costs and diffusing innovation. Moreover, enhanced capabilities in various key sectors are required for the benefits

of environmental products to be realized. In summary, the article emphasizes that when addressing trade and innovation in environmental goods and services, it is vital to consider the complex interaction of economic, technological and social factors.

All the results observed in the article contribute to the literature and enable advances in terms of the countries' degree and characteristics, their dynamics and their potential for the development of international trade. These results justify some of the concerns expressed by developing countries, while also suggest that, due to higher tariffs for this group of countries, welfare gains will be affected. From a political perspective, EGS trade would benefit from greater regulatory convergence, provided that negotiations benefit a large number of participants.

Finally, this manuscript contributes to the literature basically in two aspects. The first one is that we considered multidimensional factors related to the characteristics of the countries. Indicators such as emissions, production of scientific articles and environmental innovations related to renewable energies has not yet been analyzed together by the empirical economic literature in terms of association with international trade. The second aspect is the results obtained, in which it cannot be concluded that the average effect of import tariffs differs for developed and developing countries. The results of our paper are different from what is found in the literature and, from them, the relationship between the innovative process and international trade is also reinforced, showing strong evidence of the use of imported goods to promote environmental technologies.

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ANNEX 1 - Descriptive statistics of the variables

Variables	Obs	Mean	Std.Dev	Min	Max
Innovations	682	120.3283	388.7866	0	3306.92
Tariffs	682	2.813237	3.591621	0	20.04939
Renewable	682	121.6389	376.9795	0	2590.87
Articles	682	22147.72	55645.44	75.15	433192.3
Emissions	682	6.689302	4.404535	.1005114	25.34315
Consumption	682	5442.341	4414.668	77.065	25083.21

Source: Elaborated by the authors based on OECD data

ANNEX 2 - Variable correlation matrix

	logInnovations	Tariffs	logConsumption	logRenewable	logArticles	logEmissions
loginnovations	1.0000					
Tariffs	-0.4273	1.0000				

logconsumption	0.5421	-0.5988	1.0000			
logrenewable	0.9201	-0.4527	0.5787	1.0000		
logarticles	0.8423	-0.2176	0.4744	0.8101	1.0000	
logemissions	0.4226	-0.5226	0.8888	0.4410	0.3724	1.0000

Source: Elaborated by the authors based on OECD data