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Environmental requirements for imported products: environmental concerns or disguised protectionism?

Requisitos ambientais para bens importados: preocupações ambientais ou protecionismo disfarçado?

Michelle Marcia Viana MARTINS[1,*], Maria Rita Anastácio RODRIGUES[1]

[1] Universidade Federal de Viçosa (UFV), Viçosa, MG, Brasil.

[*] Contact e-mail: michellemartinsufv@gmail.com

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ABSTRACT: This study examines trade-related environmental measures adopted by World Trade Organization members and assesses their outcomes using Organization for Economic Co-operation and Development (OECD) indicators. It draws on notifications from the WTO Environmental Database for 2009–2021 and on OECD-Stat metrics for 2012–2019. Each notification is classified by measure type, sector and environmental objective, tracing trends among major issuers such as the United States, the European Union, Australia, China and Canada. Results show that the agricultural and manufacturing sectors account for the largest share of measures, while technical regulations and subsidies are the most prevalent instruments. Evaluations of $PM_{2.5}$ exposure, greenhouse gas emissions, renewable energy share and environmental policy stringency reveal that countries issuing numerous environmental notifications generally achieve better environmental performance, although variations arise according to development status and policy design. Nations with stricter requirements have demonstrated improvements in their indicators, implying that import regulations form part of a comprehensive green policy rather than solely protectionist intent. China is notable for advancing its indicators despite persistent pollution and emission challenges.

Keywords: green protectionism; environmental indicators; international trade; regulatory analysis.

RESUMO: Este estudo examina as medidas ambientais relacionadas ao comércio adotadas pelos membros da Organização Mundial do Comércio e avalia seus resultados por meio de indicadores da Organização para a Cooperação e Desenvolvimento Econômico (OCDE). A análise baseia-se em notificações do Banco de Dados Ambiental da

OMC referentes ao período de 2009–2021 e em métricas da OCDE-Stat para 2012–2019. Cada notificação foi classificada segundo o tipo de medida, setor e objetivo ambiental, identificando tendências entre os principais emissores, como Estados Unidos, União Europeia, Austrália, China e Canadá. Os resultados mostram que os setores agrícola e de manufatura concentram a maior parte das medidas, enquanto regulamentos técnicos e subsídios são os instrumentos mais frequentes. A avaliação da exposição a $PM_{2,5}$, das emissões de gases de efeito estufa, da participação de energia renovável e do rigor das políticas ambientais evidencia que países que emitem numerosas notificações ambientais geralmente apresentam melhor desempenho ambiental, embora ocorram variações conforme o nível de desenvolvimento e o desenho das políticas. Nações com requisitos ambientais mais rígidos registraram avanços em seus indicadores, o que indica que as normas de importação fazem parte de uma política verde abrangente, e não têm apenas caráter protecionista. A China destaca-se por melhorar seus indicadores, mesmo diante de persistentes desafios de poluição e emissões.

Palavras-chave: protecionismo verde; indicadores ambientais; comércio internacional; análise regulatória.

1. Introduction

Since the World Trade Organization (WTO) was established in 1995, the relationship between international trade and the environment has become increasingly important. Historically, trade discussions focused on balancing trade flows, reducing barriers, and encouraging foreign direct investment. The creation of the WTO and its Committee on Trade and Environment have broadened these discussions to include environmental and sustainability concerns under international trade law (WTO, 2022).

The WTO's environmental mandate rests on several international agreements that define the multilateral trading system's legal framework. The General Agreement on Tariffs and Trade (GATT), which underpins the WTO, includes Article XX, permitting exceptions to trade rules to protect human, animal or plant health and to conserve exhaustible natural resources. The Agreement on Technical Barriers to Trade (TBT) and the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) establish specific procedures for technical regulations and protective measures that may serve environmental objectives (Thorstensen, Mota & Corrêa, 2018).

The WTO Committee on Trade and Environment (CTE), created in 1995, provides a forum for discussing trade-related environmental measures and for promoting sustainable development without imposing unnecessary obstacles on trade. Environmental notifications submitted by WTO members are reviewed and classified in the WTO's Environmental Database, which enhances transparency and monitoring of measures affecting trade (WTO, 2024a).

Multilateral Environmental Agreements (MEAs) also interact with WTO rules. More than 200 MEAs are currently in force, approximately 20 of which include trade-related provisions. The interface between these treaties and WTO obligations can be complex and sometimes contentious, especially when trade restrictions are adopted for environmental reasons. In such cases, the WTO Dispute Settlement Body interprets trade agreements in line with public international law, including environmental treaties, pursuant to the Vienna Convention on the Law of Treaties (Morosini & Niencheski, 2014).

Despite these developments, the relationship between trade and the environment remains unclear. Trade may worsen environmental pressures by encouraging overexploitation of natural resources and raising greenhouse gas emissions associated with economic activity (Wang & Zhang, 2021). Conversely, it can support the diffusion of green technologies and sustainable practices, promoting more efficient resource use through international environmental standards embedded in trade policies. The principal challenge is reconciling global environmental goals with WTO rules and the sovereign actions of member states (Thorstensen, Mota & Corrêa, 2022; WTO, 2022). To address this, the WTO convenes the Trade and Environmental Sustainability Structured Discussions, which include 51 countries and cover topics such as environmental goods and services, fossil fuel subsidies, carbon border adjustment mechanisms, climate change, sustainable supply chains, and assistance for developing nations.

The Organisation for Economic Co-operation and Development (OECD) is also key to understanding trade-related environmental policy. The OECD's Joint Working Party on Trade and Environment (JWPTE) has, since 1999, identified and classified environmental goods and services to reduce trade barriers and foster the exchange of products that advance environmental objectives, such as renewable energy generation equipment (OECD, 2021a; 2021b).

In 2001, OECD environmental ministers, alongside representatives of business, labor unions, and non-governmental organizations, endorsed the Environmental Strategy for the First Decade of the 21st Century (OECD, 2001). That strategy aimed to promote sustainability via economic instruments, regulations, voluntary agreements, and enhanced information access. Its objectives included preserving ecosystems, decoupling environmental impact from economic growth, improving decision-making information, integrating social and environmental considerations, and strengthening global cooperation on environmental issues (OECD, 2025).

A follow-up meeting was held in 2004 to review the progress of the Environmental Strategy, emphasizing the importance of international cooperation and subsidy reform. Since 2008, climate change and biodiversity loss have become leading concerns within the OECD, prompting initiatives to gather data and recommend policies that support sustainable development. As part of this effort, the JWPTE began disseminating and analyzing environmental indicators to track national progress (OECD, 2021b, 2023).

Using resources provided by the WTO and OECD, this study examines the characteristics of trade-related environmental measures adopted by various countries, the scope of these measures, the affected sectors, and the targeted environmental domains. It then evaluates the environmental profiles of countries with extensive environmental regulations to determine whether they have improved their internal environmental indicators or are using trade measures for protectionist purposes, illustrating instances of green protectionism.

2. Effect of environmental measures on international trade

A key question regarding trade-related environmental measures is their actual effects: "What are the environmental and economic outcomes for the countries subject to these rules?"; "Do such regulations spur the development of green technologies?"; and "Have environmental pressures linked to economic activity declined following the adoption of these measures?" This section reviews findings from several studies that address these questions.

Environmental notifications in the context of international trade are formal submissions that WTO members must file when they enact trade measures with environmental implications. These notifications underpin the transparency and predictability of the multilateral trading system, allowing other members to assess potential impacts on their exports and to request clarifications or challenge measures deemed unjustified. Notifications are classified by measure type (technical regulations, subsidies, quantity restrictions, etc.), affected sector (agriculture, manufacturing, energy, etc.) and environmental objective (conservation, renewable energy, waste management, etc.). The WTO's Environmental Database (EDB) (WTO, 2024b) compiles and categorizes these notifications, offering a comprehensive overview of global environmental regulatory trends in trade (Monteiro & Trachtman, 2020).

Environmental indicators are quantitative metrics developed by international organizations, most notably the OECD, to evaluate national environmental performance across multiple dimensions. The OECD's Environmental Policy Stringency Index, for example, rates countries on a 0 to 6 scale by combining market-based instruments (taxes, emissions-trading schemes) and direct regulations (emission standards, pollution limits). Other widely used indicators include greenhouse gas emissions, energy intensity, air and water quality, waste management and biodiversity measures. These metrics enable cross-country comparisons and time-series analyses of environmental performance, thus providing empirical evidence on the effectiveness of environmental policies and their relationship with economic development (OECD, 2023).

The intersection between WTO environmental notifications and OECD indicators represents an important nexus of trade and environmental governance. Notifications reflect the regulatory steps countries take to meet environmental goals, while indicators measure the real-world outcomes of those policies. This relationship can be examined from several perspectives: first, as a check on policy coherence, assessing whether countries with a high volume of environmental notifications also demonstrate improvements in their indicators; second, as a tool to distinguish between disguised protectionism and genuine environmental concern, since countries imposing strict import requirements but showing little domestic environmental progress may be using non-tariff measures for protectionist ends; and third, as a way to gauge the effectiveness of trade measures in advancing sustainable development (Yamaguchi, 2021).

Empirical analyses reveal notable patterns.

Lim, Mathur & Suk (2020) drew on the WTO EDB to trace how the trade-environment interface has evolved in the Organization's Trade Policy Reviews (TPRs). They sorted each TPR entry by policy instrument, measure and sector. Between 2009 and 2018 they identified 2,839 environment-related trade policies, ranging from import quotas and product regulations to nationwide conservation plans. The range of sectors widened over the period, and by 2018 the count had risen to 3,166 measures; energy, agriculture, fisheries and services together accounted for more than three-quarters of the total (Lim, Mathur & Suk, 2020).

Steinfatt (2020) moved the discussion forward by examining how WTO members are weaving circular-economy (CE) objectives into their trade regimes. Using the EDB, he catalogued more than 370 CE-related trade measures adopted by 65 members between 2009 and 2017, most of them aimed at recycling and materials recovery. Yet the study also revealed trade constraints, such as restrictions on scrap-metal flows or second-hand goods, that can impede CE progress.

Vavrova (2020) showed that well-designed environmental charges and tariffs can reshape producer and consumer choices in the European Union (EU): higher duties on polluting inputs raise demand for cleaner substitutes, while the revenue can finance domestic environmental programs. By explicitly tying trade and fiscal tools to national green objectives, such measures help governments align economic expansion with environmental priorities. Testing the Porter Hypothesis[1] with panel data for OECD manufacturing, Wang, Sun & Guo (2019) found that tighter environmental rules lifted green productivity as long as policy stringency remained below a threshold (index value ≈ 3.08). Beyond that point, compliance costs outweighed innovation gains and productivity fell.

Bellelli & Xu (2022) combined natural-language processing and econometric analysis to measure how environmental measures reported to the EDB affect trade in, and patents for, environmental goods. Regulatory instruments that mandate performance standards or provide research and development (R&D) incentives spurred both imports and exports of green products; the effect grew when subsidy schemes were introduced alongside the regulations. Ahmed (2020) linked the OECD Environmental Policy Stringency Index with innovation metrics for 20 member economies. In the long run, stricter policies reduced greenhouse-gas emissions and encouraged green patenting, although the study found no stable link between aggregate trade flows and environmental innovation. Exports contributed to short-term emission cuts, whereas imports were associated with greater embedded emissions.

Extending the analysis to 179 countries, Ma & Wang (2021) reported that trade participation lowered carbon-intensity but had little effect on sulfur-dioxide intensity; the improvement stemmed more from domestic enforcement than from technology transfer. The authors argued that lower-income economies, which are still absorbing cleaner technologies, can benefit the most

[1] The Porter Hypothesis posits that stringent but well-designed environmental regulations can stimulate firms to innovate, improving resource efficiency and competitiveness so as to at least partially offset compliance costs (Porter & van der Linde, 1995).

from open trade coupled with robust regulation.

At the macro level, Xu *et al.* (2020) showed that trade improves nine environment-related Sustainable Development Goal (SDG) targets globally, but the gains are uneven: 65 % of high-income countries improved their SDG scores, whereas more than 60 % of low-income countries saw their scores decline, often because pollutive activities migrate to jurisdictions with laxer enforcement (Xu *et al.*, 2020).

Taken together, these studies highlight three drivers that shape the outcomes of trade-related environmental measures:

(i) policy stringency and design,

(ii) countries' development levels and absorptive capacity, and

(iii) the choice of indicators used to track results.

Regulations by themselves do not always stimulate green technology (Ma & Wang, 2021); they do so more reliably when paired with complementary tools such as targeted subsidies (Bellelli & Xu, 2022). Environmental tariffs can reinforce sustainable behavior and supply revenue for protection programs (Vavrova, 2020), yet trade barriers, especially where circular-economy goods are concerned, can also stall progress (Steinfatt, 2020).

3. Methodology

This investigation adopts an exploratory, descriptive design and compiles both quantitative and qualitative evidence. Environmental indicators were retrieved from the OECD-Stat platform, whereas environmental measures were collected from the WTO EDB.

The EDB platform contains environmental notifications submitted by WTO members. The documents have been available since 2009, hence the analysis focused on the period from 2009 to 2021, which includes complete information on environmental policies up to the last year for which information is available (WTO, 2024b).

Data were obtained through document analysis, which included information on the affected industries, the environmental objectives of the policies, and the countries issuing the measures. One example of an analyzed document is shown in Figure 1: a notification submitted by Brazil in 2021 concerning effluent discharge limits in the sugarcane ethanol sector. From this notification, the study extracted key information, including the issuing country (Brazil), the year (2021), the type of measure (technical regulation on effluent limits), the sectors affected (biofuel production and wastewater management), and the environmental objectives (protection of water quality and reduction of industrial pollutant loads) (WTO, 2024b).

A single measure can cover several sectors, keywords, and objectives. Consequently, a search may retrieve 100 documents yet yield, for example, 110 sectoral observations once all sector links are tallied, because one notification may be classified in more than one sector. The same principle applies to data on objectives and issuing countries: a single measure can influence multiple sectors and address various goals, which produces distinct analytical totals for each

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Committee on Technical Barriers to Trade

Original: English

NOTIFICATION

The following notification is being circulated in accordance with Article 10.6

1.	**Notifying Member:** BRAZIL **If applicable, name of local government involved (Article 3.2 and 7.2):**	
2.	**Agency responsible:** Ministry of the Environment - National Council for the Environment (CONAMA) **Name and address (including telephone and fax numbers, email and website addresses, if available) of agency or authority designated to handle comments regarding the notification shall be indicated if different from above:** Institute of Metrology, Quality and Technology-INMETRO Telephone: +(55) 21 2145.3817 Email: barreirastecnicas@inmetro.gov.br Website: http://www.inmetro.gov.br/barreirastecnicas	
3.	**Notified under Article 2.9.2 [X], 2.10.1 [ ], 5.6.2 [ ], 5.7.1 [ ], other:**	
4.	**Products covered (HS or CCCN where applicable, otherwise national tariff heading. ICS numbers may be provided in addition, where applicable):** Fixed electrical energy generating systems (atmospheric emissions)	
5.	**Title, number of pages and language(s) of the notified document:** Ordinance 382, 26 December 2006 (41 page(s), in Portuguese)	
6.	**Description of content:** CONAMA Ordinance establishes maximum limits for air pollutants for fixed sources.	
7.	**Objective and rationale, including the nature of urgent problems where applicable:** Considering the growing industrialization, with the consequent increase in atmospheric pollution levels already reached, mainly in metropolitan regions, and the negative effects on health, the environment, the economy and the degradation of air quality, the Ordinance aims to minimize the impacts on air quality and, thus, protect the health and well-being of the population. The Ordinance also considers that determining national atmospheric emission limits must also take into account its costs and impact on regional economies.; Protection of human health or safety; Quality requirements	
8.	**Relevant documents:** (1) Brazilian Official Journal (Diário Oficial da União) 01, 02 January 2007, section 1, page 131-137; Ordinance 05, 15 June 1989 https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=02/01/2007&jornal=1&pagina=131&totalArquivos=140 http://conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=81	
9.	**Proposed date of adoption:** Not applicable **Proposed date of entry into force:** Not applicable	
10.	**Final date for comments:** Not applicable	
11.	**Texts available from: National enquiry point [ ] or address, telephone and fax numbers and email and website addresses, if available, of other body:** http://www.carvaomineral.com.br/abcm/meioambiente/legislacoes/bd_carboniferas/ar/resolucoes_conama_382-2006.pdf	

FIGURE 1

SOURCE: WTO (2021a).

classification criterion.

OECD indicator series display uneven temporal coverage (OECD, 2023). To include as many indicators as possible and secure a broader empirical pool, the analysis concentrates on 2012–2019. This choice imposes a limitation, since missing values beyond 2019 prevent a longer panel, and observations before 2012 are not uniformly available across indices. The starting year also aligns with the first EDB observations that overlap with the OECD indicator window. Indicator selection was guided by cross-country coverage. While most OECD metrics refer only to member economies, a subset encompasses a wider group of countries.

All findings were presented in graphical form to facilitate mapping and visualization. The interpretations concerning the interaction between environmental concerns and international trade draw upon a triangulation of bibliographic sources, primary documents, and regulatory texts.

4. Results

The analysis of the most frequently used keywords in WTO environmental measures facilitates identifying, characterizing, and delineating their regulatory scope. Figure 2 shows the main regulatory trends. In total, 31 keywords were identified, and twelve of these account for more than 1,000 mentions, representing 71.5% of all entries. The remaining twenty keywords are grouped under "other." The keyword environment appears most often, with 8,328 mentions (23.38% of the total), but it is a broad term that gains precision only when paired with other

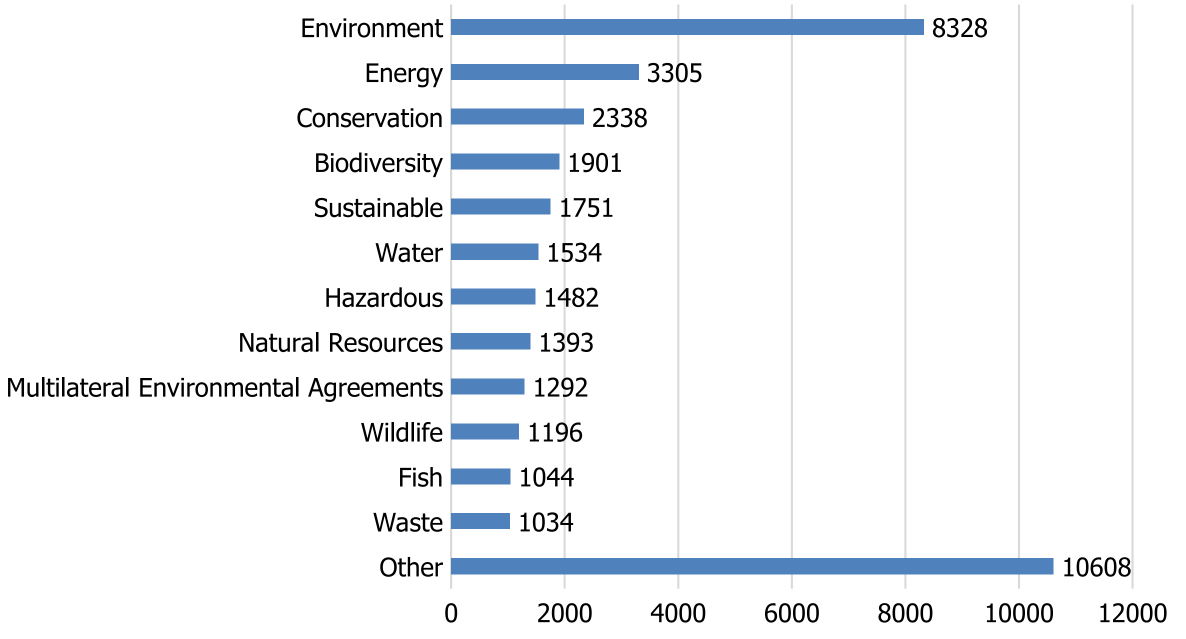

FIGURE 2 – Most mentioned keywords in WTO environmental notifications (2009–2021).
SOURCE: Author's elaboration using data from WTO (2024b).

keywords. The second most common keyword is energy, which appears in 3,305 measures (8.88%). This high frequency reflects efforts by many countries to promote an energy transition and to reduce the environmental and public-health impacts of energy production by adopting cleaner technologies and diminishing dependence on fossil fuels. As a result, there is a growing emphasis on clean energy alternatives, especially in the transport and power-generation sectors.

Conservation is the third most frequent keyword, appearing 2,338 times, which corresponds to 6.28% of all mentions. These measures focus on preserving both animal and plant biodiversity. Biodiversity itself ranks fourth, with 1,901 mentions (5.11%). According to the WTO (2023), environmental trade measures addressing biodiversity have steadily increased; since 2009, roughly 114 WTO members have notified one or more biodiversity-related measures, spanning countries in every region and at every level of development.

Figure 3 shows that, out of 21,260 recorded measures by industry, 5,481 (25.78%) apply to agriculture, making it the most affected sector. Manufacturing follows with 4,251 measures (19.99%), and the chemical industry accounts for 2,874 measures (13.52%). The energy sector is next, with 1,919 measures (9.03%). Together, the services (1,467), fishing (1,030), forestry (872) and mining (249) sectors sum to 3,618 measures, or 17.02% of the total. When the "other" category

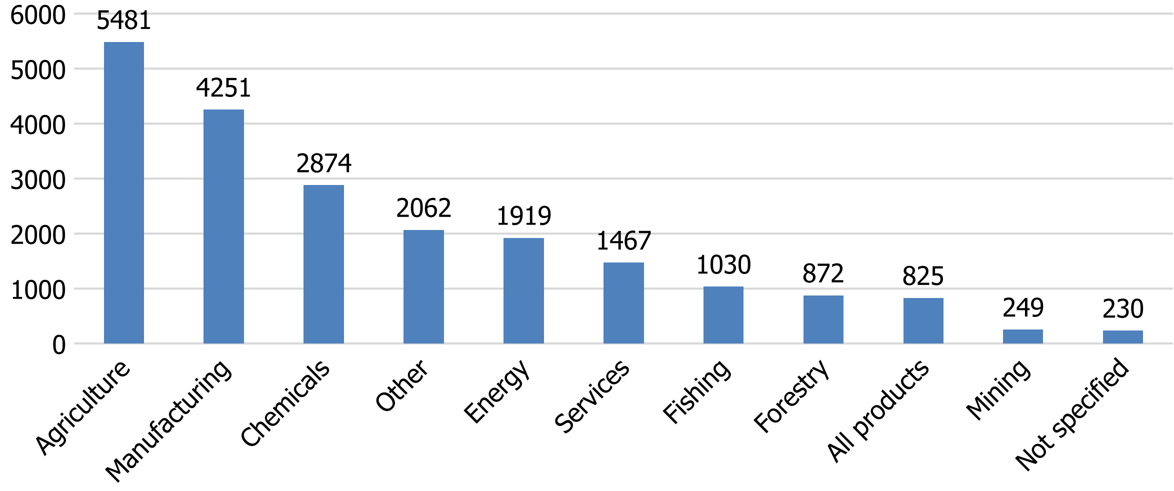

FIGURE 3 – Sectors most affected by environmental measures (2009-2021).
SOURCE: Author's elaboration using data from WTO (2024b).

(2,062 measures), "all products" (825) and "not specified" (230) are combined, they represent 3,117 measures, or 14.66% of all notifications.

Examining the annual distribution of measures from 2009 through 2021 confirms that agriculture consistently received the highest number of notifications each year. The only exception occurred in 2019, when manufacturing led with 23.2% of notifications, while agriculture still accounted for 20.6%. Sambuichi *et al.* (2012) explain that agriculture's environmental impacts stem mainly from deforestation, burning, conversion of natural ecosystems into cropland, suboptimal cultivation practices and pollution from pesticide and fertilizer use. This pattern is reflected in the agricultural sector's most common keywords, environment, followed by conservation, water, soil, natural resources and biodiversity, which underscore the principal concerns driving regulatory action in this field.

In the manufacturing sector, Pereira &Horn (2009) note that rising global consumption has spurred mass production, creating environmental challenges related to energy use, raw material extraction and waste generation. As a result, the most prevalent keywords in manufacturing-related measures are environment, energy, emissions, conservation and labeling, reflecting efforts to mitigate pollution, improve resource efficiency and enhance transparency in supply chains.

An analysis of the primary environmental objectives of the notifications (Figure 4) shows that 10.75% of all measures (3,056 mentions) address the management of chemical, toxic and hazardous substances, this objective is most prevalent in the chemical products sector. The next most common objective is conservation and energy efficiency, at 7.76% and 2,208 notifications, which appears predominantly in

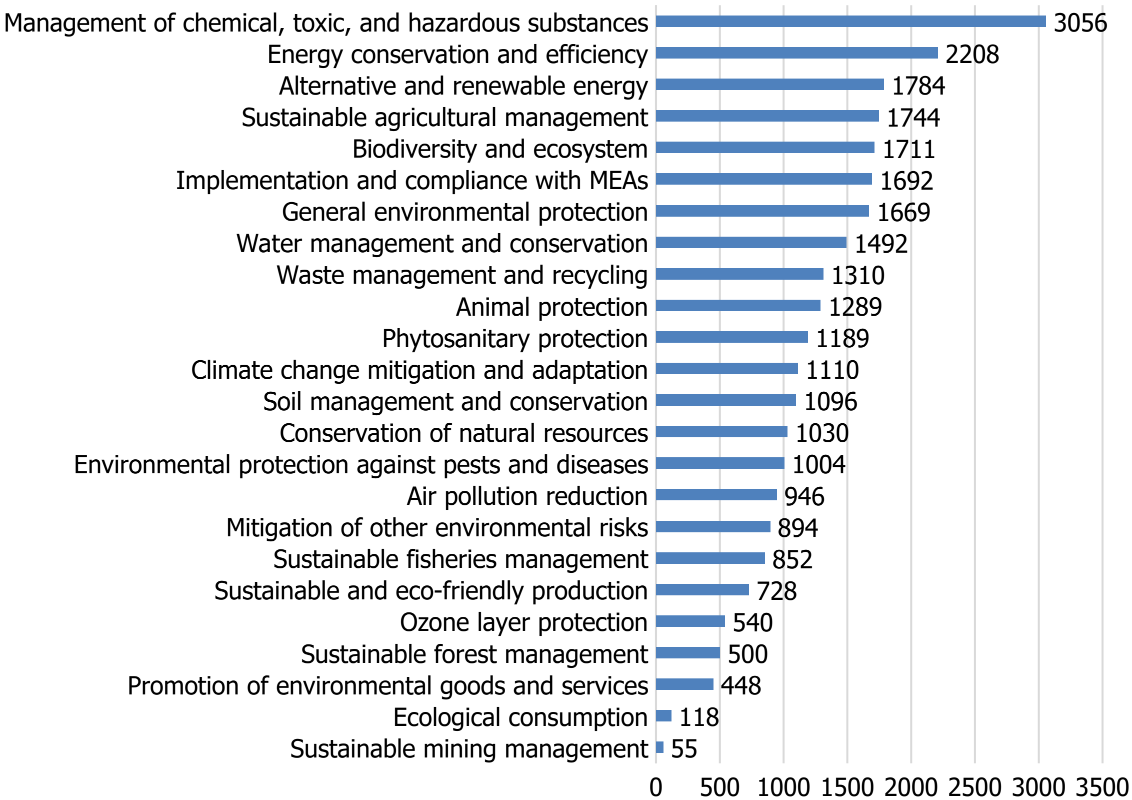

FIGURE 4 – Objectives of environmental notifications (2009–2021).
SOURCE: Author's elaboration using data from WTO (2024b).

manufacturing. Measures promoting alternative and renewable energy account for 6.27% (1.784) of notifications, aligning with initiatives in the energy sector. Sustainable agricultural management follows at 6.13% (1,744), and biodiversity and ecosystem protection represent 6.11% (1,711), both objectives are particularly concentrated in the agricultural industry.

Figure 5 shows that 26.4% (5.627 mentions) of all trade policies associated with environmental regulations are classified as rules or technical specifications. These documents establish requirements for a product's attributes, performance, composition or dimensions, as well as for the procedures and methods used in its production (UNCTAD, 2019). For example, a measure of EU, concerns a draft regulation of the European Parliament and Council on the prevention and management of invasive alien species (WTO, 2013). That legislation defines technical specifications to mitigate the social and economic harm caused by such species, with a particular focus on preventing their introduction and spread within the territory of the EU.

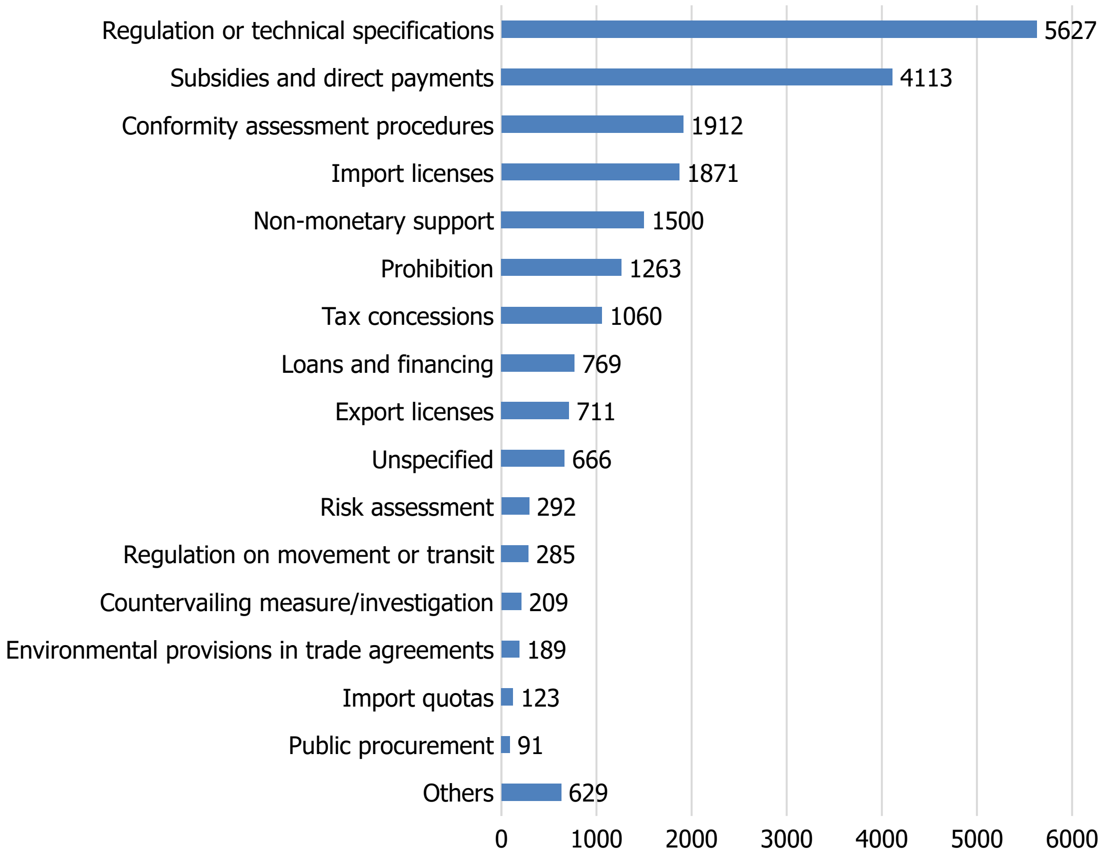

FIGURE 5 – Notifications type by trade policies (2009-2021).
SOURCE: Author's elaboration using data from WTO (2024b).

Subsidies and direct payments are the second most common category of notifications, representing 19.3% of the total, 4,113 measures. These mentions provide financial aid to reduce consumer prices or production costs (UNCTAD, 2019). Subsidies may take the form of grants, preferential loans and guarantees that offer direct financial support, improve profit margins and give advantages to recipient companies. Such measures aim to promote sustainable development and encourage the adoption of green technologies. However, they can distort international trade by giving unfair competitive advantages to subsidized firms and may trigger trade disputes in forums such as the WTO. For example, measure issued by Australia, illustrates environmental subsidies: the Smarter Business Solutions program provides free technical support and financial incentives for local businesses to adopt efficient, innovative technologies and best practices, thereby reducing expenditures on energy, water, waste and materials (WTO, 2021b).

Conformity assessment procedures and import licenses represent 6.97% (1,912) and 8.78% (1,871) of notifications, respectively. Conformity assessment refers to any procedure, direct or indirect, used to verify compliance with relevant technical regulations or standards. An import license is a document that authorises a company or individual to import goods after confirming they meet all legal and administrative requirements. The “other” category, which includes fourteen miscellaneous types of notifications, accounts for 2.68% of the total.

Figure 6 shows that the United States (U.S.) leads with 2,562 notifications, 14.94% of the

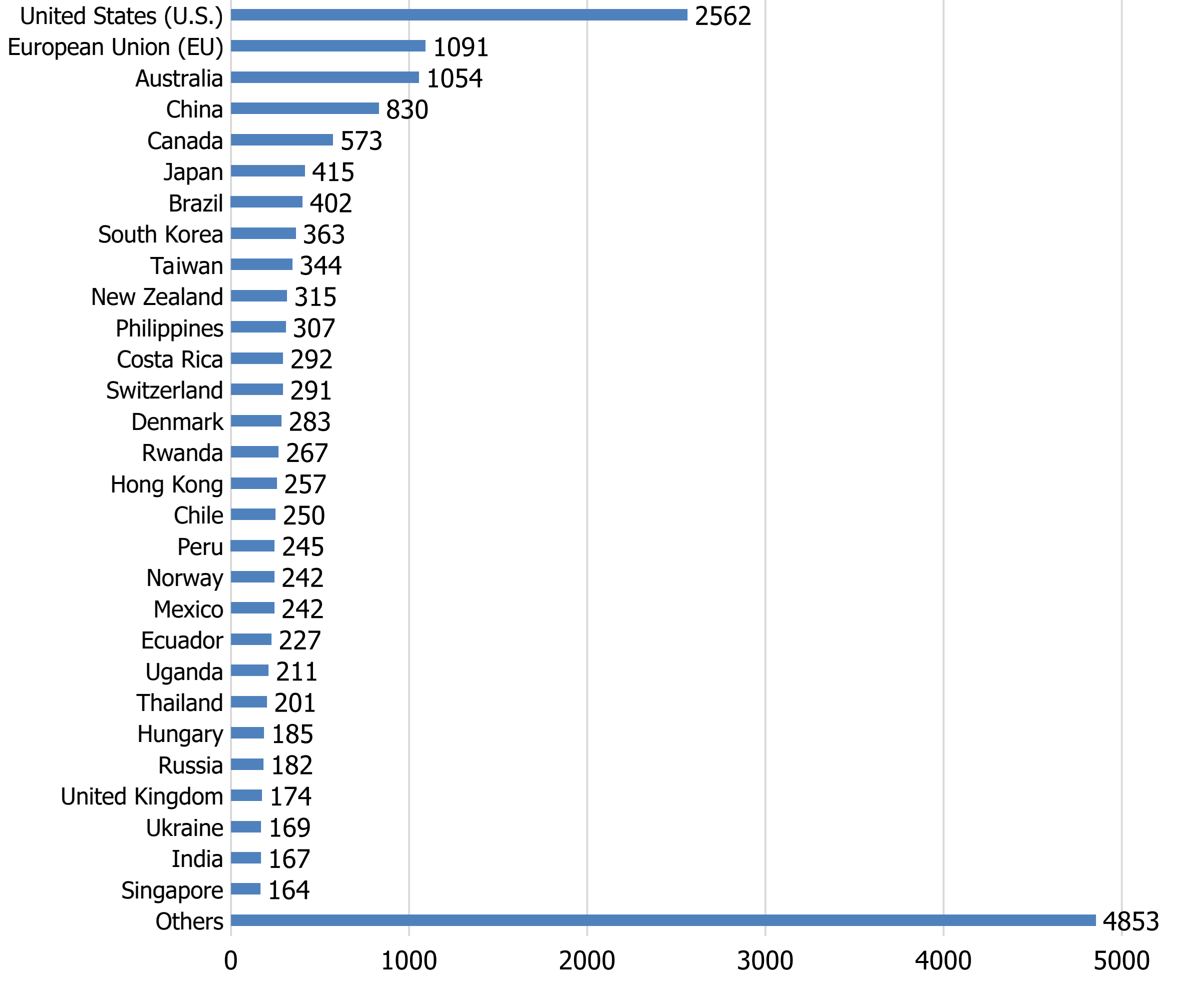

FIGURE 6 – Number of environmental notifications per member (2009-2021).

SOURCE: Author’s elaboration using data from WTO (2024b).

overall total, followed by the EU with 1,091 notifications (6.36%), Australia with 1,054 (6.15%), China with 830 (4.84%) and Canada with 573 (3.30%). Together, these five actors account for more than one-third of all environmental regulations (35.60%). Meanwhile, 141 other countries issued fewer than 1% of notifications, but collectively they represent 29.30% of the total, with 4,853 measures.

An examination of the leading issuers of environmental notifications shows a clear pattern: the U.S., the EU and Australia are all developed regions. China, however, breaks this pattern as a developing country that ranks among the world's largest polluters. Ferreira & Barbi (2012) attribute China's prominence to its rapid economic and industrial expansion in recent decades, combined with a sharp rise in urban population since 1990. As a result, China has experienced surges in energy consumption, atmospheric pollutant emissions, water scarcity and deforestation, exacerbating global challenges such as air pollution, acid rain and climate change.

A twelve-year review of notification volumes from these principal issuers (Figure 7) reveals an upward trajectory, though not a perfectly linear one. This pattern reflects a growing awareness of environmental issues among those countries over time. Mendonça (2019) highlights that global warming, deforestation and pollution have reached catastrophic levels, affecting both current and future generations. As understanding of resource overexploitation and climate-change impacts deepens, especially in developed nations, this upward trend in notifications is likely to continue. Consequently, countries must reassess existing production and consumption patterns and their environmental impacts, while exploring measures that safeguard ecosystems without hindering economic progress.

It is important to emphasize that a decrease in the number of notifications issued each year

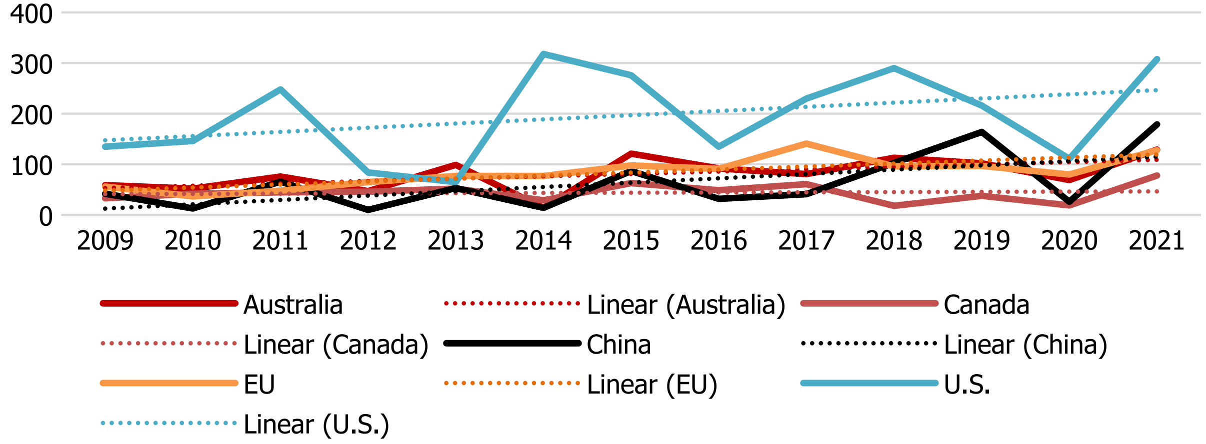

FIGURE 7 – Number of environmental notifications by the U.S, EU, Australia and China (2009-2021).

SOURCE: Author's elaboration using data from WTO (2024b).

NOTE: The dotted line represents the trend for each country.

does not necessarily indicate a weakening of environmental regulations. Previously established measures remain in force; the only difference is that fewer new notifications were submitted during that year compared to earlier periods.

Looking at the primary sectors covered by notifications from each country, 44.38% of Australia's notifications and 36.5% of Canada's notifications pertain to agriculture, whereas 36.51% of China's measures focus on the manufacturing sector. The EU distributes its measures across three main sectors: 32.67% address chemicals, 26.4% target agriculture, and 17.2% cover manufacturing. In the U.S., 25.93% of notifications fall under the energy sector; nonetheless, significant shares also relate to manufacturing (20.1%) and agriculture (21.5%).

Applying the same analysis to policy objectives reveals that, in Australia, the most common targets are water management and conservation (11.2%) and environmental protection against pests and diseases (11.1%). Canada's notifications are more evenly distributed among objectives, with environmental protection (8.3%) and water management and conservation (7.9%) ranking highest. In China, 16.7% of measures focus on energy conservation and efficiency. European notifications concentrate heavily on the management of hazardous chemical substances, accounting for 24.4% of the total. In the U.S., 21.2% of notifications are devoted to alternative and renewable energy.

After identifying the countries that submitted the most environmental notifications under the WTO framework, is evaluated whether those nations are meeting their own environmental targets and achieving positive outcomes. To this end, the study analyzes relevant OECD environmental indicators.

One such indicator measures the share of the population exposed to fine particulate matter ($PM_{2.5}$), an air pollutant linked to serious health risks, since prolonged exposure significantly increases the likelihood of cardiovascular and respiratory diseases. Figure 8 presents the 2019 annual average exposure for populations living

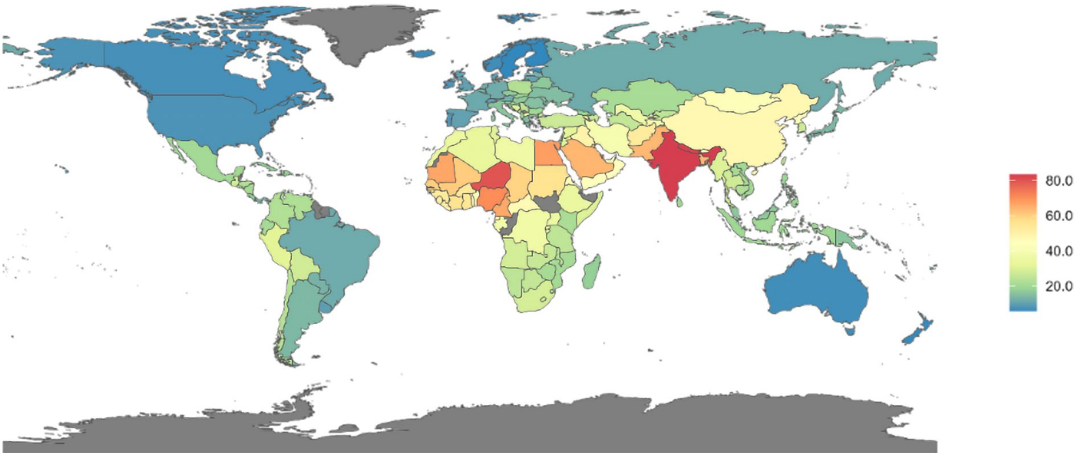

FIGURE 8 – Exposure to air pollution ($PM_{2.5}$) (2019).

SOURCE: Author's elaboration using data from OECD (2023).

in areas with $PM_{2.5}$ levels exceeding 10 µg/m³; darker red shading indicates a higher percentage of the population exposed. Developed economies, the U.S., EU's member states, Canada and Australia, exhibit lower exposure levels, consistent with their WTO notifications. In contrast, China's national average of 47.33 µg/m³ is markedly higher, making it the worst-performing country on this indicator. Pui, Chen & Zuo (2014) observe that China's primary sources of $PM_{2.5}$ emissions include the combustion of coal, oil, gasoline, diesel and wood, as well as high-temperature industrial processes in foundries and steel mills.

In response to severe air pollution, China's State Council launched the Air Pollution Prevention and Control Action Plan (APPCAP) in September 2013, aiming to reduce urban $PM_{2.5}$ concentrations by 10% to 25% from 2012 levels by 2017 (Yeu *et al.,* 2022). This China's effort to air-quality control involved an estimated investment of roughly US $270 billion across more than 300 cities, covering energy, industry, transport, legal and regulatory sectors. By 2018, the Ministry of Ecology and Environment reported that national $PM_{2.5}$ levels had met the 2017 targets, demonstrating that despite persistently high emissions, China achieved substantial reductions. Figure 9 charts the $PM_{2.5}$ Chinese emissions trend from 1995 to 2019: between 2013 and 2017, the average concentration fell from 63.32 µg/m³ to 49.98 µg/m, a decline of 21.06%, and continued to decrease by an additional 4.5% between 2017 and 2019.

Cheng *et al.* (2021) report that approximately 80% of the Chinese population experiences annual average $PM_{2.5}$ levels above 35 µg/m³, and over 99% are exposed to concentrations exceeding the World Health Organization's guideline of 10 µg/m³. The authors emphasize that meeting current international climate targets, especially limiting warming to 1.5 °C and achieving carbon

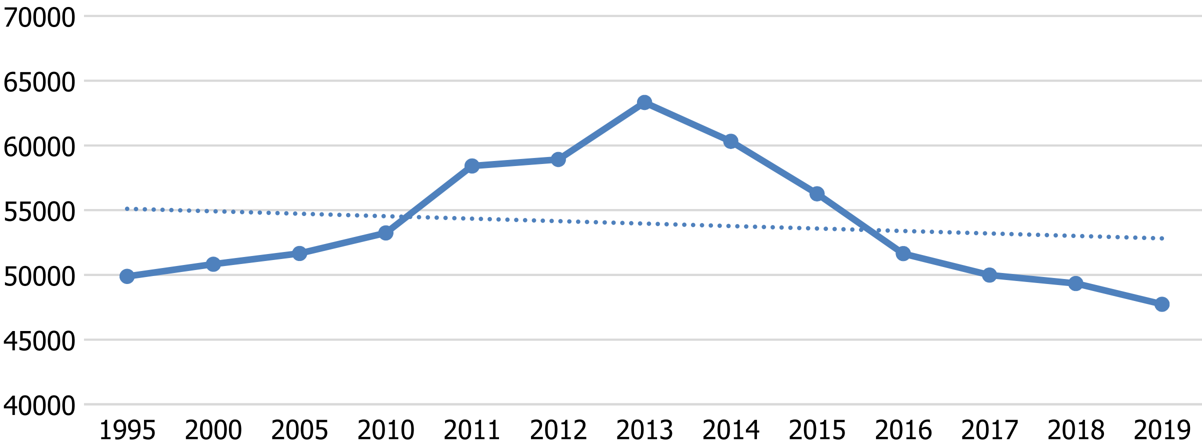

FIGURE 9 – China's air pollution ($PM_{2.5}$) exposure (1995-2019).

SOURCE: Author's elaboration using data from OECD (2023).

NOTE: The dotted line represents the trend for each country. There is no complete information from 1995 to 2010, only data for every five years.

neutrality by 2050, will be essential for sustained improvements in China's air quality.

Another important indicator of air quality is greenhouse gas (GHG) emissions, measured in total carbon dioxide (CO_2) equivalent. This metric includes CO_2 emissions from energy production, industrial processes and fossil fuel combustion, as well as methane (CH_4) emissions from sources such as solid-waste decomposition, livestock, coal mining, rice cultivation, agriculture and pipeline leaks. It also encompasses nitrous oxide (N_2O) and fluorinated gases (hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride and nitrogen trifluoride). Indirect CO_2 emissions are excluded from this indicator.

Figure 10 presents global GHG emissions averaged over three decades: 1990–1999, 2000–2009 and 2010–2019. Averaging across these intervals accounts for gaps in annual data, since some countries report only periodic figures. To avoid distortions caused by the COVID-19 pandemic, when reduced economic activity temporarily lowered emissions, the analysis concludes in 2019. Over these periods, the U.S., the EU and Russia show improvements in GHG performance, whereas China's emissions have risen steadily.

Figure 11 offers a detailed comparison of GHG emission trends for the five leading WTO notifiers between 1995 and 2019. During this period, Australia and Canada experienced modest increases in emissions, yet their absolute levels remain relatively low compared to those of the EU and the U.S.. The EU shows a consistent decline, dropping from 4.5 thousand ppm in 1995 to 3.5 thousand ppm in 2019. The U.S. saw emissions peak in 2007 before entering a downward trend; overall, U.S. emissions were virtually unchanged, moving from 6.8 thousand ppm in 1995 to 6.6 thousand ppm in 2019.

Historically, the EU has been a major global emitter of greenhouse gases due to its early industrialization and the development of energy, transportation and agricultural sectors. In recent decades, however, it has adopted aggressive climate policies, most notably the European Green Deal and related initiatives to expand renewable energy and improve energy efficiency, which have resulted in a sustained decline in emissions. According to the European Environment Agency, total EU greenhouse gas emissions fell from 4.5 thousand ppm in 1995 to 3.5 thousand ppm in 2019, and continued to drop to 37% below 1990 levels by 2023 (European Environment Agency, 2024a, b). The transition away from fossil fuels poses a significant challenge, as it requires overcoming political resistance, economic adjustments and infrastructure constraints to maintain momentum toward climate neutrality (Pontes, 2023).

The U.S. has also maintained high absolute emission levels, though a downward trend has emerged since the late 2000s. Between 2008 and 2019, U.S. energy-sector emissions declined as coal-fired generation gave way to natural gas and renewables, and improvements in vehicle fuel efficiency took hold. Since 1970, energy intensity, measured as energy use per unit of gross domestic product (GDP), has fallen by an average of 2% per year, reflecting slower population growth, stricter fuel-economy standards, gains in power-plant efficiency and the retirement of

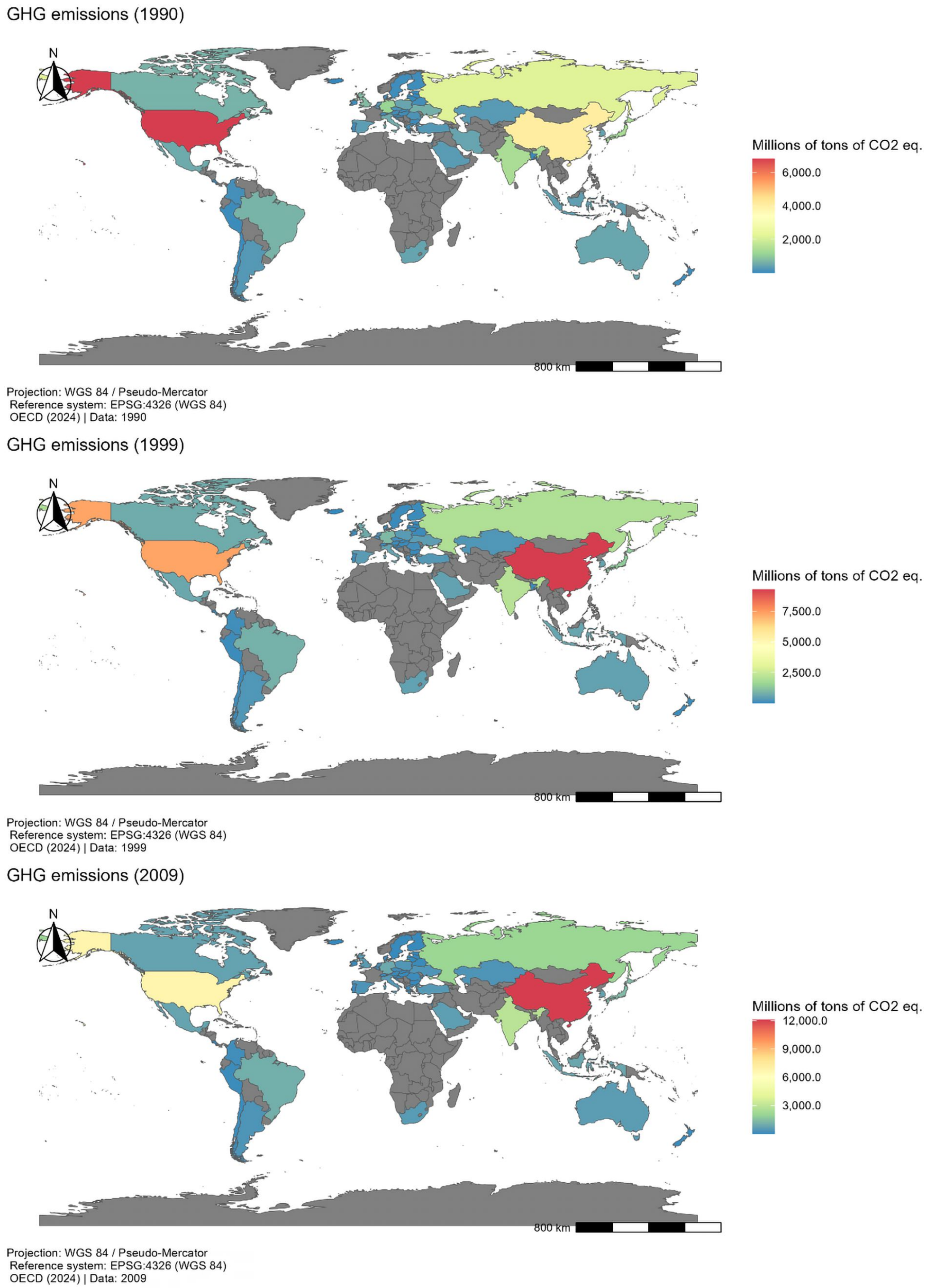

FIGURE 10 – GHG emissions in millions of tons of CO_2 equivalent (1990-2019).

SOURCE: Author's elaboration using data from OECD (2023).

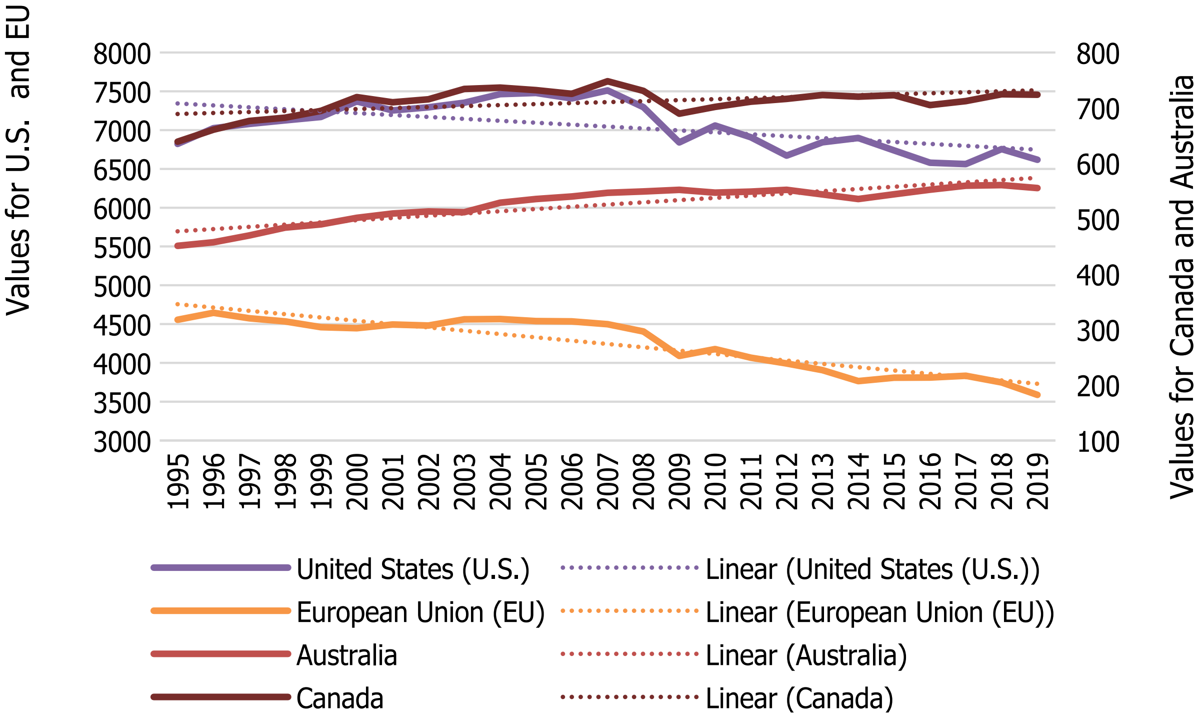

FIGURE 11 – GHG emissions from Australia, Canada, China, the U.S. and the EU (1995-2019, in thousand ppm or tons of CO_2 equivalent).
SOURCE: Author's elaboration using data from OECD (2023).
NOTE: The dotted line represents the trend for each country.

older generators. Meanwhile, energy dependence, defined as the share of imported energy in total supply, has also decreased, reducing vulnerability to global price shocks (Lahiani *et al.*, 2021).

The OECD database on GHG emissions provides limited data for assessing China's recent emission trends. Data are available only for 2005 (8.0 thousand ppm), 2010 (10.2 thousand ppm), 2012 (11.2 thousand ppm), and 2014 (12.3 thousand ppm). These figures imply a 53.4% rise in China's GHG emissions between 2005 and 2014. Throughout this period, China remained the leading GHG emitter among the countries analyzed.

Estevo (2020) indicates that China is responsible for approximately 30% of global emissions, largely due to its heavy dependence on coal. Although China has expanded renewable-energy capacity in recent years, air pollution and public-health concerns harden. The country occupies a prominent position in international climate negotiations, seeking to align economic development with environmental protection by restructuring its energy mix. China's climate policy underscores the responsibility of developed countries, the transfer of technology, and international financing to ensure equitable solutions that address the developmental needs of emerging economies. Since the U.S. withdrew from the Paris

Agreement, China's leadership in global climate discussions has become more pronounced, with mitigation plans that integrate both domestic and international objectives (Estevo, 2020).

Continuous evaluation and monitoring of the CO_2eq emissions indicator is necessary. Rising global temperatures have intensified concerns about environmental and climate issues that have persisted for years. Policymakers are discussing the combustion of fossil fuels, identified as responsible for nearly 80% of greenhouse-gas emissions, to reduce emissions (Lahiani *et al.*, 2021).

Figure 12 presents the share of total energy supply derived from renewable sources, using 2019 data. This indicator is calculated as the ratio of energy produced from renewables, such as solar, wind, hydro, geothermal, and biomass, to total energy supply, which also includes non-renewable sources like oil, natural gas, and coal. Expressed as a percentage between 0 and 100, higher values indicate greater reliance on renewables and reduced dependence on polluting, non-renewable sources. Equatorial countries, including Brazil, Ecuador, Kenya, Uganda, and Gabon, exhibit levels exceeding 80% of their energy supply from renewables. Albania, Paraguay, Iceland, Costa Rica, Ethiopia, and the Democratic Republic of the Congo generate nearly 100% of their energy from renewable sources.

In this indicator, developed countries such as the U.S., Japan, and EU members display relatively low values. Most OECD countries and BRICS economies, aside from Brazil, continue to depend heavily on fossil fuels, which account for over 80% of their total energy consumption. Several nations have seen rapid increases in coal use, and even those with significant renewable energy potential, such as Russia, exhibit low

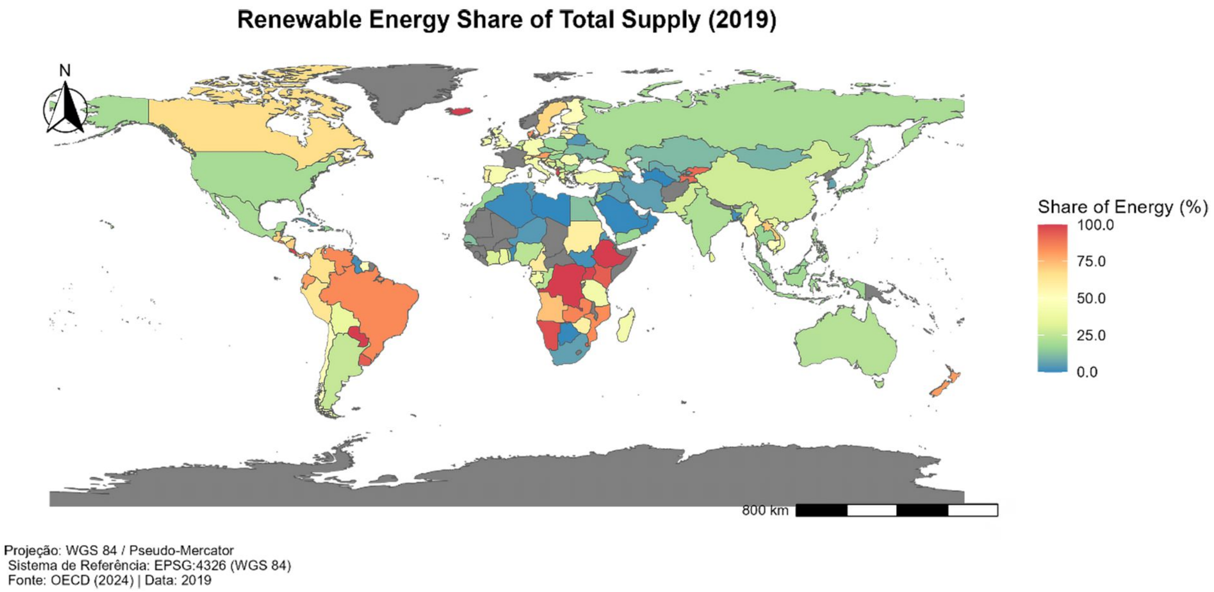

FIGURE 12 – Proportion of renewable energy in comparison to the national energy supply (2019).

SOURCE: Author's elaboration using data from OECD (2023).

adoption rates of renewable energy sources. Energy productivity could improve substantially by systematically phasing out government subsidies for fossil fuels and removing barriers to energy efficiency (OECD, 2017). Figure 13 illustrates subsidies and alternative support for fossil fuels as a percentage of GDP for major economies; these figures ranged from around 2% to 0% of

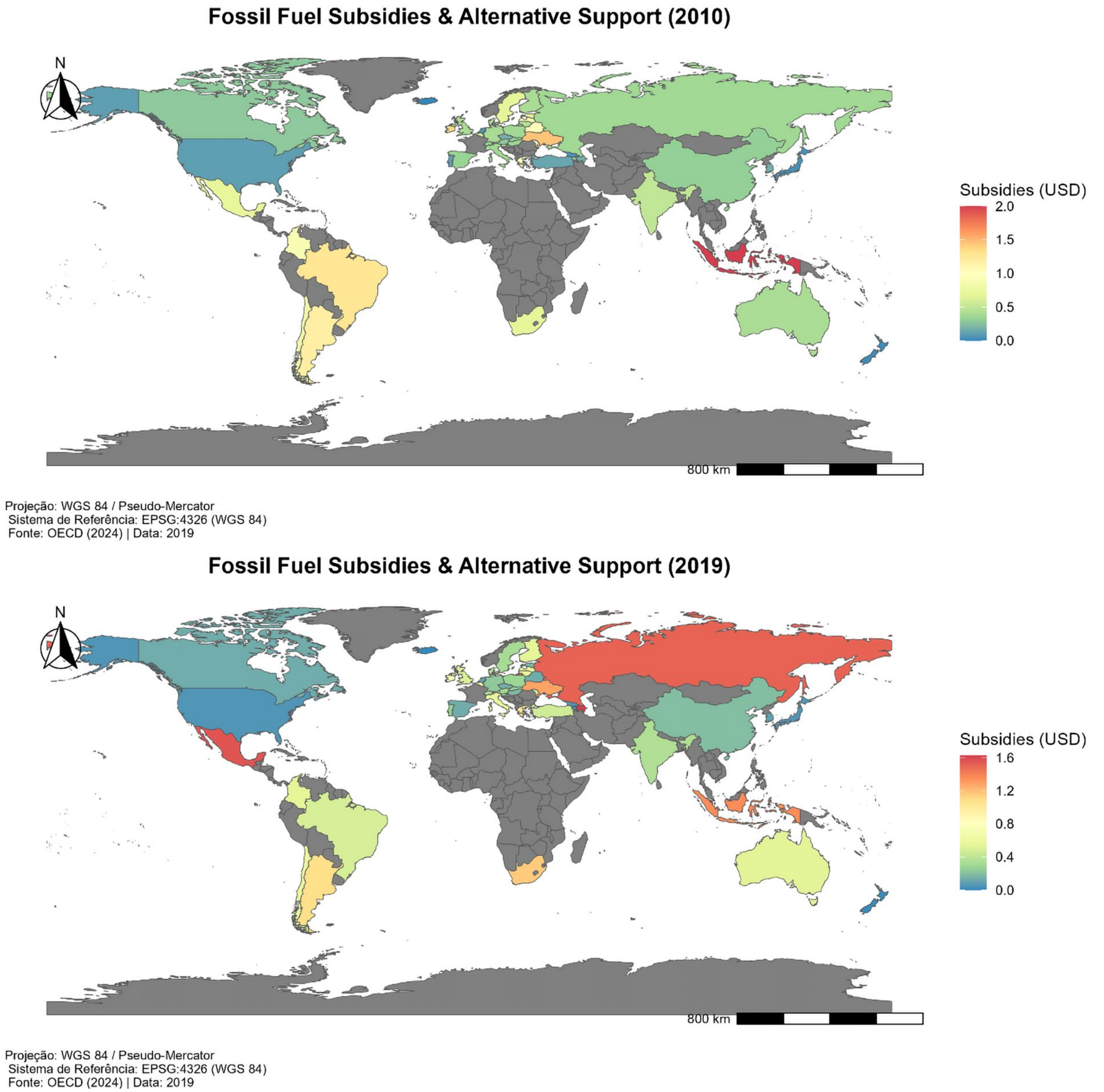

FIGURE 13 – Subsidies and alternative support for fossil fuels (2010 and 2019).

SOURCE: Author's elaboration using data from OECD (2023).

GDP in 2010, and from approximately 1.6% to 0% in 2019.

In 2010, the highest fossil fuel subsidy rates were observed in Indonesia (2%), Ukraine (1.45%), Ireland (1.36%), Brazil (1.27%) and Argentina (1.18%). By 2019, the record shifted to Azerbaijan (1.63%), Mexico (1.56%), Russia (1.51%), Indonesia (1.36%) and Ukraine (1.29%). Over the 2010–2019 period, the U.S.' subsidies declined from 0.10% of GDP to 0.05%, while Canada's fell from 0.28% to 0.13%. Australia's fossil fuel support oscillated between 0.41% and 0.53% of GDP, and China's subsidies diminished from 0.31% to 0.19%. Within Europe, Ireland (1.36%), Greece (1.04%) and Latvia (0.83%) recorded the highest shares in 2010, whereas in 2019 Greece (1.04%), Ireland (0.75%) and Belgium (0.66%) led the region. Although the dataset extends through 2021, this comparison focuses primarily on the pre-pandemic years to ensure consistency in cross-national analysis.

The Red List Index (RLI) measures changes in species' extinction risk based on the IUCN Red List. It ranges from 0 to 1, where values near 1 indicate that all species are classified as Least Concern (indicating minimal extinction risk), while values near 0 imply that species are extinct. The RLI for a given region evaluates species' extinction risk relative to their global conservation status and serves as a tool for tracking progress toward SDG target 15.5, which aims to protect vulnerable species and prevent biodiversity loss by 2030.

Figure 14 presents RLI values for all countries, illustrating the trajectory of species toward extinction. Most nations have indices close to 1:

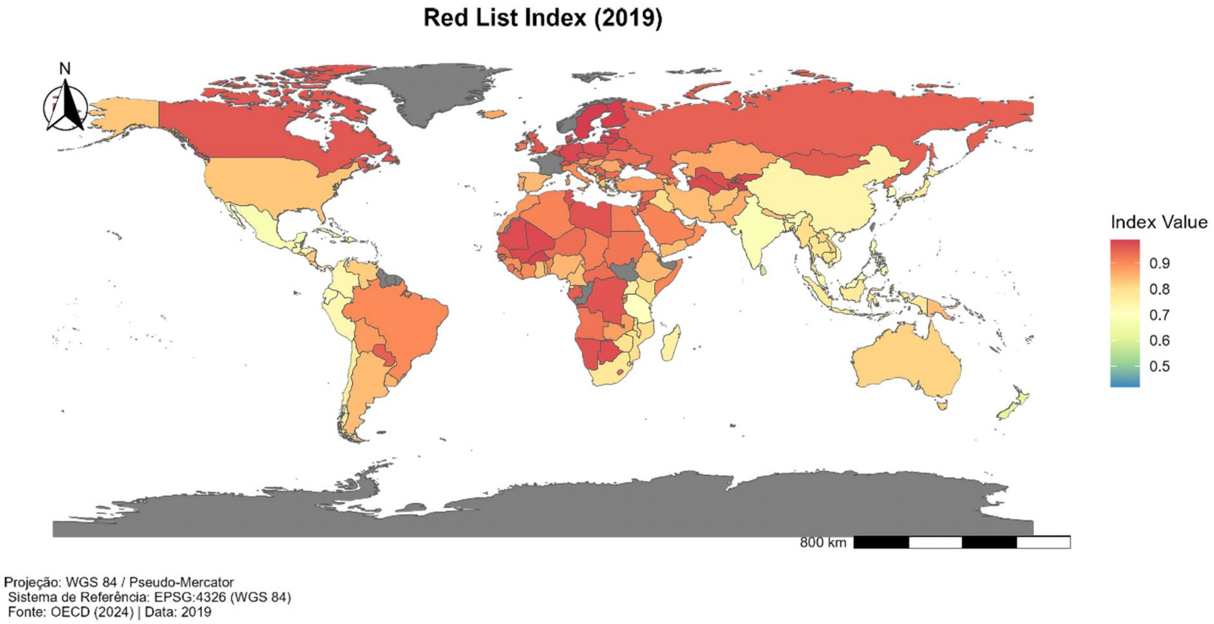

FIGURE 14 – Red List Index (2019).

SOURCE: Author's elaboration using data from OECD (2023).

the EU exceeds 0.84, Australia's index is 0.816, the U.S. index is 0.832, and China has the lowest index among the countries examined, at 0.742. These figures suggest that, overall, these countries are in a relatively favorable position regarding species extinction risk.

The OECD Environmental Policy Stringency Index (EPS) measures how strictly environmental regulations penalize activities harmful to the environment. Comprising thirteen policy instruments, mainly focused on climate and air pollution, the EPS ranges from 0 (low stringency) to 6 (high stringency). Figure 15 presents EPS values for Australia, China, the U.S. and eighteen EU countries (data for additional EU members were unavailable). Among these, Slovakia has the lowest score at 2.5, while France tops the list with 4.9. The average EPS across the observed countries is 3.1.

China's Environmental Policy Stringency (EPS) has exhibited a notable upward trajectory since the early 1990s. Beginning at approximately 0.00 (Figure 16), the index climbed to about 3.14 by 2020, reflecting a substantial tightening of environmental regulations over the past three decades. During the 1990s and 2000s, policy stringency increased at a steady, gradual pace; however, from the 2010s onward, the rate of improvement accelerated, indicating a stronger national focus on environmental protection. This shift likely stems from growing international concern about environmental degradation, the imperative to curb pollution, and China's own ambitious ecological targets. Despite these advances, significant challenges remain, air pollution and soil degradation persist in many regions, underscoring the need for even more rigorous regulatory measures and concrete actions to mitigate ongoing environmental risks.

Results indicate that high-income nations

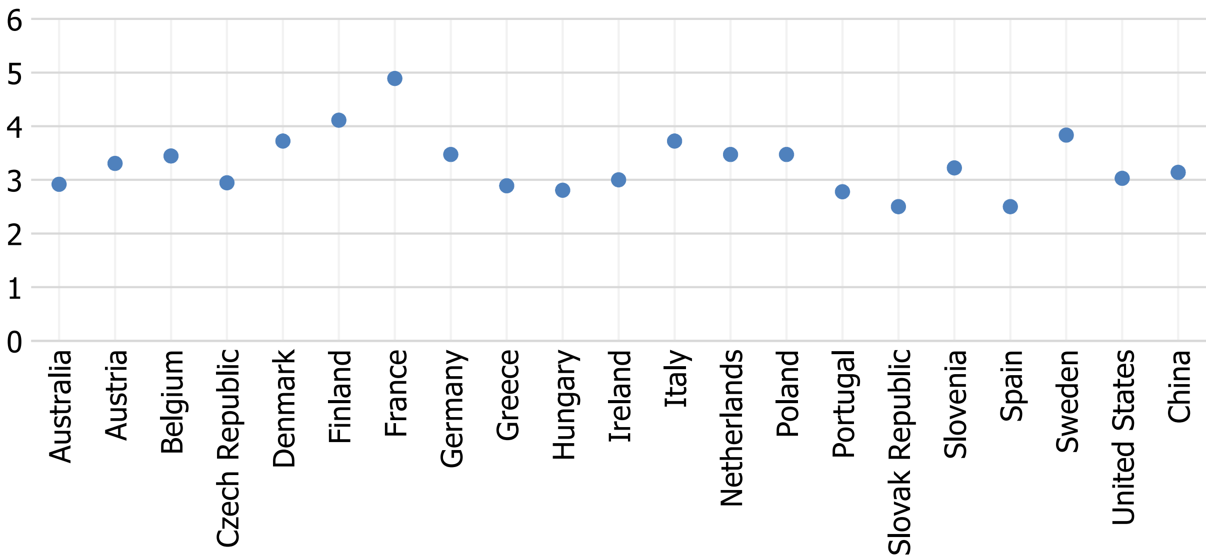

FIGURE 15 – OECD Environmental Policy Stringency Index (EPS) (2019).
SOURCE: Author's elaboration using data from OECD (2023).

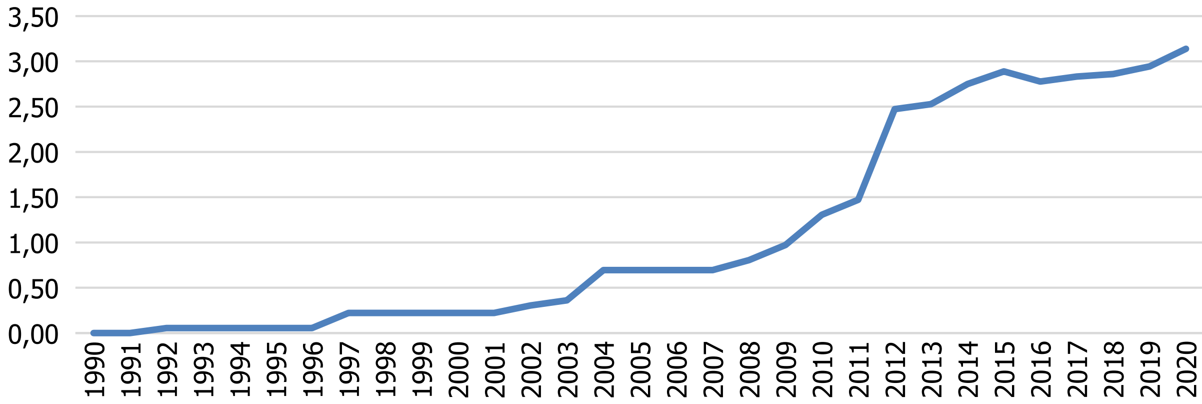

FIGURE 16 – Evolution of China's EPS (1990-2020).

SOURCE: Author's elaboration using data from OECD (2023).

and China are at the forefront of issuing environmental measures. Historically, many of these countries contributed heavily to pollution and environmental degradation due to rapid industrial and economic expansion following the Industrial Revolution. In recent years, however, they have pursued actions to reverse this trend and improve environmental indicators, driven by recognition that past production and consumption patterns can cause water and resource scarcity, air and water pollution, climate change and biodiversity loss, irreversible outcomes (OECD, 2011).

China stands out for experiencing a peak in economic and industrial expansion in recent years, which is reflected in its environmental indicators, as rapid industrialization has generated high GHG emissions. Nonetheless, China has also sought to align economic growth with mitigation efforts, enacting policies to reduce environmental damage from its activities. Although this represents a notable step toward more balanced and sustainable development, further ambitious initiatives are required to mitigate the adverse effects of its growth.

5. Discussions

The results presented in this study reveal interesting patterns at the interface between international trade and environmental policies, offering reflexions for researchers and policymakers. The predominance of environmental notifications in the agricultural and manufacturing sectors, particularly by developed economies such as the U.S. and the EU, reflects the growing integration of environmental considerations into global trade policies. However, this trend raises important questions about equity and sustainable development within the multilateral trading system.

The relationship between environmental notifications and environmental performance indicators suggests that, in general, countries that implement trade measures with environmental motivation also demonstrate a commitment to improving their domestic indicators. This partly contradicts the green protectionism hypothesis, indicating that many of these measures are part of comprehensive environmental strategies. The case of China is particularly illustrative: despite facing challenges related to pollution and emissions, the country has shown consistent progress in its environmental indicators, alongside an increase in its environmental notifications at the WTO. This evolution indicates a commitment to transitioning toward a more sustainable economy, although issues of implementation and enforcement remain.

However, the concentration of notifications in certain sectors and types of measures reveals potential imbalances in the system. The predominance of technical regulations and subsidies can create barriers for exporters from developing countries, who often face technical and financial capacity limitations when adapting to increasingly stringent environmental requirements. This dynamic can exacerbate existing asymmetries in international trade, running counter to the principle of common but differentiated responsibilities established in multilateral environmental agreements.

Analysis of OECD data on environmental indicators reveals a positive trend in reducing carbon intensity and improving energy efficiency among the countries analyzed. However, the heterogeneity of the results suggests that the effectiveness of environmental policies depends not only on their formal existence but also on contextual factors such as institutional capacity, economic structure and level of development. This highlights the importance of differentiated approaches and support mechanisms for developing countries, ensuring that the transition to more sustainable economies is inclusive and equitable.

The implications of these results for the multilateral trading system are profound. On one hand, the growing integration of environmental considerations into trade policies represents an important step forward in promoting sustainable development. On the other hand, the proliferation of unilateral measures, without adequate coordination or consideration of countries' differentiated capacities, can fragment the trading system and create unnecessary obstacles to trade. In this context, strengthening international cooperation, both within the WTO and in environmental forums, becomes critical to ensure that trade and environmental policies are mutually complementary rather than contradictory.

In the case of Brazil, a major agricultural exporter, must balance economic competitiveness with environmental sustainability. Its key trading partners, especially the EU, are imposing increasingly stringent environmental requirements on imports. At the same time, Brazilian abundant natural resources and green economy potential could position it as a leader in sustainable trade. Joining the WTO's Environmental Sustainability Initiative marks an important step toward aligning Brazil's trade and environmental policies. To advance this goal, the country should proactively invest in technical capacity, innovation and green infrastructure, while advocating in international negotiations for a system that recognizes developing countries' different needs and capabilities, thereby supporting a fair global transition to more sustainable economies.

6. Conclusions

Countries with the highest number of environmental notifications, such as the U. S., the EU and China, have generally demonstrated notable improvements in environmental indicators over time, especially in energy efficiency and emission reductions. This suggests that trade measures driven by environmental objectives are often integrated into broader sustainability strategies. However, the strength of these relationships varies by sector and measure type. For example, notifications related to technical regulations in agriculture show a stronger connection with improvements in water quality and reductions in pesticide use, whereas energy-sector subsidy notifications correlate more closely with increased deployment of renewable energy and efficiency gains. This heterogeneity underscores the complexity of the trade-environment nexus and the need for sector-specific analysis (Zugravu-Soilita, 2019).

Analysis of environmental measures and indicators indicates that countries recognized for issuing large numbers of environmental notifications are committed to achieving positive outcomes and improving their performance metrics. In other words, the volume of environmental measures these countries issue appears to reflect genuine efforts to promote more sustainable production and consumption practices, rather than disguised protectionism. It may also reflect growing public concern about climate change among a widening segment of the electorate, particularly in Europe.

The sectors receiving the greatest share of notifications often correspond to areas in need of substantial improvement. For instance, 25.9% of the United States' environmental notifications target the energy sector, and within that group, 21.2% focus specifically on alternative and renewable energy. Despite ongoing challenges with greenhouse gas emissions, U.S. policymakers have enacted important measures, as evidenced by the decline in CO_2-equivalent emissions. In China, roughly 32.7% of notifications are linked to the manufacturing sector, with 16.7% aimed at energy conservation and efficiency. The country is actively working to reduce pollution exposure and greenhouse gas emissions, which are directly related to these sectors and objectives.

This study does not evaluate the direct impact of environmental measures on trade or examine whether their effects are protectionist. Instead, it provides an overview of the dynamics of environmentally focused trade policies and draws conclusions based on observed trends rather than on empirical impact assessments. Although this limitation is acknowledged, the increasing volume of WTO environmental measures may nevertheless reflect an attempt by countries to impose stricter environmental standards on trading partners, encouraging compliance with environmental norms.

In conclusion, countries are not only working to improve their own environmental indicators but are also influencing others to collaborate in enhancing global environmental conditions through regulatory requirements. This collective effort reflects a broader agenda to address environmental challenges and promote global sustainability.

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