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Environmental policy and green export competitiveness: The enhancing effect of economic complexity

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Abstract:

Development depends on a nation's ability to produce sophisticated goods, making economic complexity crucial. Considered as an ecological sophistication of technological, social, and cultural factors, ecological structural change, the core of Green New Developmentalism, can address environmental and socio-economic challenges, particularly in developing countries. As green policies can act as drivers of structural changes, eco-innovations, and international green competitiveness, this paper examines the impact of green policies on green export competitiveness, testing the strictly strong version of the Porter hypothesis and evaluating the moderating effect of economic complexity and pollution intensity. This paper used a panel dataset covering 40 OECD countries from 1990 to 2016, and the results indicate that stringent environmental regulations positively impact green exports only in the medium term. When the moderating factors are introduced, stringent green policies become effective in the short term, and their positive impact increases with the country's economic complexity and pollution intensity. Combining stringent environmental policies and green economic sophistication could allow for integrating economic growth, sustainable production, and international green competitiveness.

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Although leading global institutions such as the European Commission, the International Energy Agency, the United Nations, the Environmental Protection Agency, and the Organization for Economic Cooperation and Development (OECD) have been intensively working to address the multi-faceted challenges posed by climate change, both at the local and the global levels (Bashir et al., 2020), the international community continues to grapple with sustainable development challenges, so that it becomes critical to comprehend the complex interplay between economic development and the ecological transition. The potential benefits of economic development, such as creating employment opportunities, increasing incomes, and reducing poverty, must not compromise the quality of life for future generations or the health of our planet. Experts thus contend that heightened technology adoption, significant economic expansion and a shift from pollution-intensive industrial activities to service-oriented economies will substantially reduce environmental pollution (Agozie et al., 2022). Therefore, promoting a more sustainable and equitable growth path, where economic advancement aligns with environmental preservation and societal well-being, is of the utmost importance (Wang et al., 2023).

A country's productive structure embodies its technological and productive capacities, shaping its pathways for diversification and delineating its potential for economic development (Hidalgo et al., 2007). Economic development theorists like Rosenstein-Rodan (1943), Singer (1950), and Hirschman (1958) highlighted the relationship between a nation's productive structure and its income distribution capabilities, emphasising "structural transformations" as crucial for economic development. According to these authors, development and growth can be understood as a process of structural change of the productive structure, wherein resources are reallocated from lower productivity activities to higher productivity ones. In particular, the New Developmentalism theory emphasises the patterns of structural transformation from the primary sector, which relies on the exploitation of natural resources, to the modern sector, typically represented by the manufacturing industry. Industrialization is fundamental to economic development, proposing a causal relationship between the growth of manufacturing output and the enhancement of both GDP and labour productivity. In contrast to the diminishing returns of the agricultural sector, manufacturing sectors are characterized by significant increasing returns and a high rate of technological change and innovation, as well as strong synergies and linkages driven by labour division, which play a pivotal role in fostering economic development (Angeles-Castro et al., 2023). Technological change is acknowledged as cumulative and path-dependent, balancing disruptive innovations that reshape developmental trajectories (path-disrupting) with cumulative innovations that consolidate existing strengths (path-reinforcing), frequently creating significant entry barriers for new competitors (Arthur, 1983; Schot and Steinmueller, 2018). Path dependence manifests through the persistence and entrenchment of specific technological choices, driven by increasing returns associated with the production or adoption of technologies and products, as well as by positive feedback mechanisms and network externalities (Castaldi et al., 2011).

Moreover, this modern sector is noted for its substantial potential to enhance labour productivity through increasing productive sophistication and economic complexity (Bresser-Pereira, 2015, 2019). The structural transformation toward more complex industries requires specialized inputs like knowledge, infrastructure, and labour training, creating significant barriers for less developed nations. This highlights the need for active state intervention to overcome these challenges and promote economic diversification (Carson, 2010). Less developed countries face constraints in diversifying toward sophisticated goods due to their poorly integrated economic structure (Botta et al., 2018); structural change is path-dependent, and achieving competitiveness in complex goods demands time and learning new capabilities. The need for public intervention is even more obvious when we consider environmental sustainability, since economic development should be grounded in structural transformations that simultaneously modernize the productive system and address climate change and its associated risks (Romero and Gramkow, 2021).

Ecological macroeconomics explores how to achieve environmental sustainability and economic stability. While a strand of literature highlights how green growth may foster cleaner production, job creation, income growth, and poverty alleviation in developing countries by reducing resource use and fossil fuels (Barbier, 2019) and critiques its feasibility, both sides agree on the necessity of effective government intervention to guide economies toward decarbonization and long-term stability (Oberholzer, 2023). In particular, Green New Developmentalism aims to identify an ecologically sustainable growth path by integrating economic development with environmental sustainability and emphasizing net-zero greenhouse emissions, balance of payments stability, and the advancement of productive structural sophistication (Grazini et al., 2024). Focusing on climate change and the current ecological crises, ecological structural change is posited by Guarini and Oreiro (2023) as a viable solution to environmental and social challenges. Promoting the relocation of labour and resources from traditional ("brown") sectors to modern ("green") ones, ecological structural change is imperative for enhancing the environmental aspects of production output. Within this perspective, ecological structural change aligns with environmental objectives and serves as a strategic manoeuvre for firms to navigate the evolving economic landscape; this ensures their long-term viability and international competitiveness through strategies based on green innovations because prevailing technological approaches to climate change mitigation depend on the unsustainable depleting nonrenewable resources (Grazini et al., 2024).

In particular, the escalating challenges of climate change necessitate a more proactive role from institutions and a set of public policies to achieve environmental objectives while fostering social and technological development (Fontana and Sawyer, 2016). This need is even more substantial for several developing and emerging countries where the ecological structural transformation is more difficult; and it is particularly the case for Latin American countries, which, due to a premature de-industrialisation[1] process, have seen an increased reliance on the production and export of primary goods and low-tech manufactured products and an inversion of the sophistication process of the productive structure (Johnson and Papageorgiou, 2020; Oreiro et al., 2020a) and where ecological crisis exacerbates and intensifies the structural disparities that define their socio-economic development. Therefore, ECLAC (2020) highlights the need for a "big push for sustainability" that is based on coordinating policies to mobilise and expedite sustainable investments. These investments aim to create a virtuous cycle of economic growth, increased income, job creation, and reduced inequalities and structural disparities while preserving and regenerating the natural resource base essential for development. The goal of this strategy is to enhance technological capabilities and promote resilient, low-carbon solutions while supporting a more diversified, complex, and competitive integration into the global economy. As empirically observed by Romero and Gramkow (2021), a well-established productive system and a broad range of productive capabilities will create favourable conditions for green innovations and structural change towards more complex high-tech goods, leading to a reduction in the level of greenhouse emissions. So, promoting economic complexity through green industrial policies is crucial for sustainable development, addressing social, economic, and environmental dimensions while fostering innovation and diversification.

Within this framework, Rennings (2000) argues that technology-push and market-pull factors do not provide enough incentives to develop complex green innovations. Ecological policies must transcend compensatory measures for negative externalities, acting instead as drivers of structural changes and innovations to facilitate the environmental transformation of production systems (Guarini, 2020). The Porter hypothesis postulates this crucial role, particularly the strong version, which posits that regulatory policies can foster environmental innovations and facilitate the ecological transition by creating new economic opportunities supporting international competitiveness (Porter and Van der Linde, 1995). However, Petroni et al. (2019) assert that the

[1] In the Latin American countries, the Dutch disease is considered one of the main causes of premature deindustralization, that is, "a reduction of the share of manufacturing industry in output and employment before the "Lewis's point" is reached" (Guarini and Oreiro, 2023, p. 2). In particular, the overvaluation of the exchange rate, driven by the production and export of natural-resource-intensive goods, undermines the price competitiveness of the manufacturing sector, thereby compromising investment profitability and widening the technological gap.

validity of the Porter hypothesis cannot be universally established, as the profitability construct may be significantly influenced by environmental regulation, both positively and negatively; moreover, numerous other factors, such as pollution intensity, substantially impact this construct, which can either validate or refute the hypothesis.

International competitiveness is shaped by both price and nonprice factors, which are enhanced by green activities (Blecker, 2016; Guarini and Porcile, 2016). Green initiatives reduce unit production costs and create new business opportunities, bolstering price competitiveness in manufacturing industries (Gramkow, 2020). Simultaneously, improved environmental efficiency strengthens nonprice competitiveness, driving export growth by enabling the production of secondary raw materials, increasing employment rates, and accelerating output growth (Dávila-Fernández et al., 2023). Indeed, several traditional sectors currently possessing substantial comparative advantages are lagging in green conversion, indicating that they may risk losing their competitive edge (Fankhauser et al., 2013). Conversely, countries that export green products are well-positioned to gain a competitive advantage (Mealy and Teytelboym, 2022). Even examining the energy transition alone, Oberholzer (2023) suggests that green policies can enhance the resilience of the balance of payments by improving the current account; such policies also have the potential to stimulate international competitiveness, offering a promising development strategy for emerging economies (Oberholzer, 2023). In particular, Costantini and Mazzanti (2012) observe that environmental policies, especially those focusing on innovation, play a crucial role in enhancing green exports, an effect that the two authors define as the *strictly strong version*. However, to the authors' knowledge, the drivers of green international competitiveness are still little studied in the literature, and few works have evaluated the possible moderating factors. To fill this gap, this paper wants to verify the strictly strong version of the Porter hypotheses using a panel dataset extracted from the OECD database for 40 countries covering 1990-2016. Our interest is to examine whether environmental regulation could directly support green international competitiveness and the indirect impact of possible moderating factors, such as polluting intensity. According to Hidalgo and Hausmann (2009), a nation's developmental trajectory depends on its capacity to acquire the essential capabilities for producing a diverse array of highly sophisticated goods. Hence, the complexity of the nation's productive structure is a crucial driver of development (Felipe et al., 2012). Therefore, higher economic complexity also signifies enhanced green production capabilities, which may facilitate technological advancements towards a greener economy (Doğan et al., 2022). Within this framework, the notion of ecological structural change can be interpreted as an ecological sophistication encompassing social, cultural, and, in particular, technological dimensions. Leading complex economies, characterised by a green and sophisticated array of export products, can be pivotal in promoting sustainable development and environmental sustainability (Rafique et al., 2022). The Economic Complexity Index by Hidalgo and Hausmann (2009) offers a complementary perspective on economically significant activities, such as trade, technical innovation, and scientific research; this contrasts with traditional aggregate indicators (Caldarola et al., 2024), enhancing our capacity to quantify a nation's productive structure and the macroeconomic significance of structural transformations (Hartmann et al., 2017). This paper wants to contribute to the literature by joining the structuralist and evolutionary economics literature, emphasizing the role of capabilities and sectoral allocation in green innovation and international competitiveness. In particular, the paper's innovative contribution is analysing the single moderating effect of economic complexity, as well as the joint moderate effect of economic sophistication and pollution intensity on the effectiveness of the stringency of environmental regulation on international green competitiveness. Therefore, the paper intends to identify possible complementarity between the different policy tools and the degree of sophistication of the economic system, expressed through the Economic Complexity Index, to validate the hypothesis that stringent environmental policies, combined with a sophistication of technology and exports, could represent a winning strategy to facilitate ecological structural change.

The remainder of the paper is structured as follows: Section 1 introduces the conceptual framework of the paper, section 2 describes the data and the estimation strategy, section 3 discusses the results, and section 4 concludes.

1. The conceptual framework

A firm's environmental and economic success relies on innovations that foster sustainability and competitiveness (Fabrizi et al., 2024a). A "virtuous cycle" starts from innovation, particularly green innovation, which leads to enhanced productivity and increased export market share (Foster et al., 2008). Eco-innovations generate more efficient processes, improve productivity and environmental performance, and provide a competitive advantage for firms (Chistov et al., 2021). Therefore, they represent a crucial driver of industrialisation and international green competitiveness (Guarini and Oreiro, 2023; Fabrizi et al., 2024b). On the one hand, green technological advancements, through the reduction of unit energy and raw material costs, can lead to a depreciation of the real exchange rate, thereby enhancing price competitiveness in the global market (Galindo et al., 2020) On the other hand, implementing an ecological structural change can increase nonprice competitiveness by positively affecting the income elasticity of exports (Dávila-Fernández and Sordi, 2020).

Although favouring environmental sustainability and employment creation, eco-innovations are more complex than standard ones; their implementation requires companies to possess multidisciplinary knowledge and skills concerning the standard technologies, so they necessitate the support of stricter environmental regulations to ensure their successful implementation (Kemp and Pearson, 2007; Horbach et al., 2013). Corrective ecological regulations have been enacted to mitigate environmental damage, thereby fostering the green transformation of the economy through advancements in green technology innovation (Guo et al., 2023). However, two different positions emerge in academic literature. In the neoclassical theory, environmental protection leads to additional costs for firms, eroding their profitability and competitiveness. Ecological regulation forces firms to allocate inputs, such as labour or capital, to reduce pollution, which is unproductive from the common profit-maximisation perspective, identifying environmental policies as a cause of cost increases (Ambec et al., 2013). This perspective gave rise to the Pollution haven hypothesis, which posits that polluting industries may relocate to countries or regions with more lenient environmental regulations, referred to as pollution havens (Dou and Han, 2019).

The other position, in heterodox literature, recognises environmental regulation as stimulating the development and dissemination of new, cleaner technologies, which are crucial for reducing the environmental impact of human activities. Additionally, promoting eco-innovation can create a win-win strategy where the generation and diffusion of technologies that enhance ecological performance lead to knowledge spillovers, thereby improving the international competitiveness of high-tech sectors (Costantini et al., 2017). In particular, Porter and van der Linde contested the pollution haven hypothesis in the early 1990s (Fabrizi et al., 2024a); they found that, while the traditional conflict between ecology and the economy arises from a static view of environmental regulation, where technology, products, processes, and customer needs are considered fixed, the paradigm of international competitiveness is a dynamic, innovation-based model (Porter and Van der Linde, 1995). This vision has been formalised in the well-known Porter hypothesis (PH), which has been divided into four versions: weak, narrow, strong and strictly strong. The *weak* PH states that environmental policies may spur innovation. The *narrow* PH maintains that flexible environmental regulation, particularly market-based instruments, can improve firms' performance by stimulating the adoption of innovations. The *strong* PH affirms that environmental regulation represents an essential driving force of environmental innovations, improving firms' market competitiveness thanks to the generated cost savings and productivity increases (Kunapatarawong and Martínez-Ros, 2016). Indeed, by spurring environmental innovations, green policies can increase price competitiveness by reducing inputs and production costs. At the same time, they can enhance environmental performance and the quality of products as perceived by the international markets, sustaining nonprice competitiveness (Guarini and Oreiro, 2022). Costantini and Mazzanti (2012) introduced the following *strictly strong* version. In their testing, they identified two different positive effects. First of all, the overall impact of environmental policies does not appear to be detrimental to the export competitiveness of the manufacturing sector. Conversely, targeted energy tax policies and innovation initiatives positively influence the dynamics of export flows, supporting the mechanism indicated by the PH. In particular, the authors highlight a significant positive effect of environmental policies, and, in particular, of more incisively environmental innovation efforts on international green competitiveness. Indeed, Mahmood et al. (2022) recently found that environmental regulations significantly stimulate eco-innovations and foster green growth in OECD countries.

Observing the ambiguity surrounding studies aimed at validating or refuting the strong version of the Porter hypothesis, Petroni et al. (2019) highlight that, while its recruitment and policy implications are incredibly relevant, its validity is controversial and subject to certain conditions, under which environmental regulation can lead to profitable outcomes and/or enhance the competitiveness of firms or industries. Different moderating factors can affect the impact of environmental regulation on international competitiveness. For instance, analysing the Chinese manufacturing sector, He et al. (2020) observe how property rights protection influences the relationship between environmental regulation and corporate performance. In particular, the effectiveness of environmental regulation on international competitiveness can especially depend on the country's pollution intensity. However, there is no consensus in literature on the moderating effect of this factor. On the one hand, Petroni et al. (2019) maintain that stringent environmental regulations influence firms' environmental strategies and profitability so that they can favour less-polluting firms; this is because the latter may incur lower compliance costs compared to more heavily polluting industries, which are subject to higher pollution abatement requirements and higher compliance costs, threatening their profitability and market survival. On the contrary, Fabrizi et al. (2024a) observe that pollution intensity has a positive moderating impact on the effectiveness of green policies on international competitiveness, suggesting that higher pollution levels make ecological conversion more economically advantageous globally. Following their work, this paper wants to verify the moderating role of pollution intensity on international green competitiveness.

Another significant factor affecting the impact of environmental regulations on international green competitiveness could be the economic complexity of the productive structure. Technical progress creates increasingly sophisticated and complex products and services, integrating a greater and more diverse array of technical and scientific knowledge as well as structural changes that reallocate productive resources and workers from lower-value to higher-added-value sectors

(Oreiro et al., 2020b). Technical change involves acquiring increasingly complex capabilities, that is, a learning process focused on enhancing the production and export of highly sophisticated goods (Hidalgo and Hausmann, 2009). Therefore, economic complexity reflects a country's capabilities, including human and social capital, institutions, and technology, which collectively contribute to the sophistication level of its exported products (Zhu and Fu, 2013). Indeed, countries that excel in high-tech production and diversification rank highly on the Economic Complexity Index and enjoy a competitive advantage in export markets (Erkan and Yildirimci, 2015).

A body of literature suggests that economic complexity can potentially safeguard environmental quality. Focusing on the ecological transition, at higher levels of economic complexity, there occur structural shifts towards knowledge-intensive industries; these impact energy demand and resource development and allocation, and they exert significant effects on the environment, economy, and society (Neagu et al., 2022). This increase in economic complexity provides the knowledge and technology for economies to transition towards environmentally sustainable activities, including, for example, clean production technology expertise and knowledge of a country (Swart and Brinkmann, 2020; Safi et al., 2023). Consequently, as a country's economic complexity increases, its environmental quality will likely improve through the adoption of advanced knowledge and technologies (Hausmann et al., 2014). Boleti et al. (2021) verify that higher levels of economic complexity correlate with superior environmental performance, as economic complexity may facilitate the adoption of green innovations. Indeed, this relationship is based on the premise that higher economic complexity indices correlate with increased research and innovation activities, which drive green innovation and environmentally sustainable production methods (Agozie et al., 2022). Engagement in green activities can pave the way for novel sources of competitiveness and business opportunities, particularly in sectors characterised by innovation and the generation of significant added value. Empirically, as shown by Shahbaz et al. (2019), more sophisticated exports that are generated by learning-by-doing and learning-by-exporting activities allow, for instance, the control of energy demand, and they are associated with lower greenhouse gas emissions per unit of output (Stojkoski et al., 2023). However, there is no evidence about the moderating effect of economic complexity on the impact of environmental regulations on international green competitiveness. The only evidence is the study of Mealy and Teytelboym (2022) that builds an ad hoc Green Complexity Index showing the country's capability to export green, technologically sophisticated products competitively; in particular, using a linear regression model, they observe that higher green productive capabilities are positively correlated with higher environmental patenting rates, lower CO_2 emissions, and more stringent environmental policies.

2. Estimation strategy and econometric model

This section presents the dataset, the main variables, and the econometric model implemented to verify the validity of the strictly strong version of the Porter hypothesis.

2.1. The dataset, Environmental Policy Stringency index, and Economic Complexity Index

The OECD provides reliable and harmonised data on environmental issues to respond to the growing international concern for sustainable development (Grazini and Guarini, 2023a). To evaluate the impact of environmental regulation on green export competitiveness and the moderating effect of economic complexity, we use the list of environmentally related goods proposed by the OECD[2] to create the dependent variable ENV_EXP, which is the environmental goods export in current USD. Following Costantini and Mazzanti (2012), we use this variable as a proxy for green export competitiveness. The environmental goods exports are built by aggregating the following 11 environmental goods categories proposed by the OECD (Steenblik, 2005): 1) air pollution control, 2) environmental monitoring, analysis and assessment equipment, 3) management of solid and hazardous waste and recycling systems, 4) noise and vibration abatement, 5) waste water management and potable water treatment, 6) cleaner or more resource efficient technologies and products, 7) environmentally preferable products based on end use or disposal characteristics, 8) clean up or remediation of soil and water, 9) heat and energy management, 10) natural resources protection, and 11) renewable energy plant.

We proxy the environmental regulation by using the Environmental Policy Stringency (EPS) index. To confront climate challenges and, particularly, respect the Paris Agreement, nations are committing to more ambitious environmental targets and policy actions. As countries adopt stricter environmental policies, the demand for tools to measure, compare, and evaluate their impacts is increasing. Measuring policy stringency across countries and time serves three purposes: to monitor progress, to identify and benchmark leaders and laggards, and to assess the impact of policies on pollution, economic, and social outcomes. Effective policy implementation requires understanding which measures work best and ensuring protection for vulnerable groups to avoid regressive effects (Kruse et al., 2022). The OECD EPS index was developed in 2014 to overcome the lack of harmonised data that would allow spatial and temporal comparison; it allowed, for the first time, a comprehensive evaluation of a diverse array of policies across different countries and periods. Even though this index encompasses climate change and air pollution policies, as these topics have the most comprehensive data available, it excludes significant environmental areas such as water, biodiversity, and waste management due to the unavailability of extensive cross-country panel data for these sectors. While it initially focused only on market and nonmarket instruments, this index was updated in 2022, adding the technology support policy so that today, it measures the severity of environmental regulation for 40 countries by examining 13 different policy tools.[3] Once the values of the instrument-specific indicators are aggregated into the three broader categories described in footnote 3, these values are aggregated into a composite indicator ranging from 0 to 6, according to the degree of stringency of environmental regulations.

Finally, we use the Economic Complexity Index (ECI) to measure the sophistication of a country's productive structure because it represents the extent of knowledge a society utilises to construct its economic structure and the know-how of its population (Hidalgo, 2015). Developed by Hidalgo and Hausmann (2009) within Harvard's Growth Lab,[4] this index evaluates a country's current production knowledge by analysing trade data and assessing the diversification and

[2] Source: OECD Data Explorer (available online).

[3] The market instrument focuses on tools attributing a price to pollution, such as CO_2 taxes, fuel taxes, NOx tax, SOx tax, CO_2 trading schemes, and renewable energy trading schemes. The nonmarket category is related to policies that impose an emissions standard, such as emission limit value (ELV) for NOx, ELV for Sox, ELV for particulate matter, and sulphur content limit for diesel. "Well-designed environmental policies provide incentives that increase innovation in clean technologies. Accelerating innovation in low-carbon technologies may require further technology support policies incentivising innovation in and adoption of low-carbon technologies" (Kruse et al., 2022, p. 36). The third sub-index related to the strength of technology support policies allows for the isolation of upstream and downstream instruments that directly support innovations in clean technologies: the first category aims to encourage and finance innovations, while the purpose of the second one is to promote their adoption.

[4] Source: https://atlas.hks.harvard.edu/data-downloads.

complexity of its export portfolio by integrating data on a country's export diversity (the number of different products it exports) and the ubiquity of its products (the number of countries that export each product). It considers the interconnectedness of economies in producing technology-intensive outputs or the extent of viable knowledge accumulated within an economy. It also provides information about the diversification of production and output expansion (Usman et al., 2020). Based on these values, the Atlas of Economic Complexity generates an annual global ranking of countries (the last global ranking, for 2023, is reported in appendix A), and it tracks changes in a country's economic complexity since 1995.

2.2. The econometric model

To analyse the impact of environmental policies' stringency on international green competitiveness, we implement the feasible generalized least squares (GLS) estimator to set the econometric model on a panel dataset extracted from the OECD database for 40 countries,[5] covering the period 1990-2016 (the last year available). We use the GLS estimator because it allows us to control for multicollinearity and heteroscedasticity (Blackwell III, 2005; Greene, 2018; Wooldridge, 2019). The main equation estimated is the following:

$$ENV\_EXP_{it} = \beta_0 + \beta_1 WGDP_{it} + \beta_2 RER_{it} + \beta_3 ECI_{it} + \beta_4 EPS_{it} + \beta_5\, EPS_{it} \, * \, ECI_{it} + \tau_t + \mu_i + v_{it} \qquad (1)$$

The dependent variable of the model is the environmental export (ENV_EXP). The control variables are the world GDP ($WGDP$) in constant price and the real exchange rate (RER) as in the standard export equation (Thirlwall, 2011), while the main independent variables are the EPS index and the ECI, as defined in the previous section. To test the moderating effect of economic sophistication on the relationship between environmental policies and green competitiveness, we introduce the interaction term $EPS_{it}\ x\ ECI_{it}$. The pedis $i = 1, 2, \dots, 40$ stands for countries, and the pedis $t = 1990, \dots, 2016$ refers to years. The terms τ_t and μ_i represent the time and country dummies, respectively, while v_{it} is the white noise residual. All variables (here and after) are expressed in logarithm. In appendix B, we report the descriptive statistics (table B1).

Moreover, we verify the single moderating effect of the pollution intensity, discussed in the conceptual framework, and the existence of a possible joint effect of two moderating factors on the influence of stringent environmental policy on international green competitiveness. Following Romero and Gramkow (2021), this paper considers pollution intensity because it can be used as a proxy for economic efficiency by quantifying the greenhouse gas emissions a country produces per unit of GDP, and it is considered a critical metric for assessing relative decoupling and progress toward sustainable economic growth. Therefore, we introduce the GHG_GDP variable, which is the total greenhouse gases and emissions, including land use, land-use change, and forestry per unit of GDP, allowing the control of different countries' pollution intensity levels, as indicated in the following equation:

[5] The sample consists of 40 countries. Of these, 34 are OECD countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Mexico, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. The non-OECD countries are: China, India, Indonesia, Russia, and South Africa.

$$ENV\_EXP_{it} = \beta_0 + \beta_1 WGDP_{it} + \beta_2 RER_{it} + \beta_3 ECI_{it} + \beta_4 EPS_{it} + \beta_5 GHG\_GDP_{it} + \beta_6 EPS_{it} * GHG\_GDP_{it} + \beta_7 EPS_{it} * ECI_{it} + \beta_8 ECI_{it} * GHG\_GDP_{it} + \beta_9 EPS_{it} * ECI_{it} * GHG\_GDP_{it} + \tau_t + \mu_i + v_{it} \quad (2)$$

As suggested by Lanoie et al. (2008) and Martínez-Zarzoso et al. (2019), incorporating lags substantiates the importance of the estimations from both conceptual and methodological perspectives. Consistent with the PH framework, green policies require time to manifest their effects and to be effective. Employing different lags allows for a consideration of various temporal perspectives of policy strategies that encompasses short-, medium-, and long-term horizons. Moreover, the lags permit us to take into consideration potential endogeneities. Therefore, we also estimate all equations by using three-year and five-year lags to approximate medium- and long-term, respectively, as in Fabrizi et al. (2024b).

3. Result and discussion

This section reports and discusses the results of the impact of environmental policies on international green environmental competitiveness concerning the strictly strong PH, as shown in tables 1 and 2. Table 1 refers to the direct effect of environmental policies stringency (EPS) index on environmental export (ENV_EXP) and the moderating effect of the country's economic complexity (ECI), while table 2 considers the joint moderating effect of the ECI and pollution intensity (GHG_GDP).

The baseline model (column 1) is significant, and the control variables maintain a positive and significant impact (at 1%) on international green competitiveness in all equations estimated; this result shows that international green competitiveness as international competitiveness depends on both price and nonprice factors (Blecker, 2016). In particular, exchange rate devaluations enhance the price competitiveness of domestic products relative to foreign products, thereby reducing imports and increasing exports (Bottega and Romero, 2021), as indicated by the positive and significant impact of the real exchange rate on green exports in the short term, as well as in the medium term (columns 6 and 11) and the long term (columns 7 and 12). The positive and significant impact (1%) of WGDP in the short term (column 1), the medium term (column 6), and the long term (column 7) support the idea that countries with increasing income levels export a greater quantity of environmentally friendly products compared to other country groups (Milindi and Inglesi-Lotz, 2022). Indeed, due to their prices, green products are often considered luxury commodities, so, when income increases, consumers' environmental awareness is enhanced and they can prefer green products (Brécard et al., 2009; Busato et al., 2023).

Focusing on table 1, the findings do not support the absolute strictly strong version of the PH. In particular, the non-significant coefficients of the EPS index in columns 3, 4, and 5 do not sustain it in the short term; instead, it is verified with a significance of 5% only in the medium run (columns 6), supporting the existence of a direct impact of environmental regulation on international green competitiveness. The escalating pressures of global competition necessitate that companies continuously adapt and innovate in domains that enhance the competitiveness of green products, such as product design and quality, technical service, and reliability. Supported by stringent environmental policies, green innovation can significantly enhance a company's productivity, elevate its corporate reputation, cultivate a green-conscious image, and secure a competitive advantage in penetrating new markets (Meidute-Kavaliauskiene et al., 2021). However, green policies need time to improve the country's competitive advantages because environmental standards have to enhance consumers' preferences for environmentally friendly products by raising their awareness of and increasing their willingness to pay a premium for environmental protection (Lanoie et al., 2008). At the same time, polluting firms need time to adjust to the new environmental policy (OECD, 2010). Moreover, it is important to consider the time of technology adoption because innovative activities, irrespective of their origin, require time to generate innovation's output (Rennings and Rexhäuser, 2011).

Previous results seem to support the absolute nonvalidity of the PH, which instead depends on the circumstances, as described in section 1. Table 1 highlights the crucial role of production sophistication, represented by the ECI, as an independent driver, but it seems particularly to be an important moderating factor in the relationship between environmental regulation and green exports. All coefficients of the single-term ECI (except in the medium run in column 6), which are always significant (5% in the short term and 1% in the long run) and positive, seem to support the critical question proposed by Caldarola et al. (2024, p. 15): "How prepared is a country for a green transition?" Decarbonizing the economy by eliminating high-emission and energy-intensive industries will necessitate radical transformations and profound structural changes at the core of socio-economic systems. Addressing environmental concerns requires a transition towards industries that have the capacity to produce, adapt, and integrate more eco-friendly technologies (Carrasco et al., 2024). However, not all regions and countries are equally equipped with the requisite knowledge base to transition away from carbon-intensive production and technologies. Complex industrial products, such as green ones, generally necessitate a significant amount of tacit knowledge and a more dispersed knowledge base than do simpler products, which predominantly depend on abundant natural resources or low labour costs (Hartmann et al., 2017; Mealy and Teytelboym, 2022). Firms with higher levels of green absorptive capacity are more likely to transform environmental opportunities into competitive advantages (Zhang et al., 2020) due to the positive association between the share of green products in the export basket and the economic complexity (Neagu et al., 2022). A more complex productive structure improves the country's capacity to produce diversified and export products, increasing the degree of trade openness (Lapatinas et al., 2019). Therefore, over an extended period, green productive diversification can bolster export capabilities and diminish reliance on imports. Conversely, the ecological transition is particularly challenging for emerging countries characterised by not very diversified production structures and, especially, for Latin American countries, which have experienced premature deindustrialization, leading to an increased dependence on the production and export of primary goods and low-tech manufactured products characterized by diminished competitiveness (Hartmann et al., 2017; Yang et al., 2024).

Table 1 shows that economic complexity is not only an essential factor in itself for international green competitiveness but, above all, it impacts the effectiveness of environmental regulation. Indeed, when the EPS index interacts with the ECI, all coefficients of the interaction term EPS*ECI are positive and significant (5% in columns 5 and 6 and 1% in column 7), supporting the idea that economies distinguished by high economic complexity and stringent environmental regulations will likely have the resources and capabilities to advance more sustainable research and development (R&D) and technologies (Saqib and Dincă, 2023). Economic complexity is advantageous for decision-makers and policymakers, offering benefits such as effectively controlling pollution, creating a conducive environment for energy transition, and promoting economic growth while minimizing environmental impact. Utilizing green product spaces allows authorities to prioritize sectors with reduced environmental impact or the production and export of complex goods linked to superior environmental performance, which is essential when formulating economic policies and establishing national energy and environmental objectives. For instance, policies aimed at product diversification stimulate the growth of renewable energy demand within the economy (Shahzad et al., 2021). Therefore, integrating rigorous environmental policies with a diversified and advanced economic framework will likely foster environmental innovations, enhancing environmental efficiency and supporting green exports through newly developed structural competitive advantages. An ecological transition based on the productive structure's technological, social, and environmental sophistication could be a potent sustainable development strategy. This strategy can not only address environmental challenges but also strengthen economic resilience (Hausmann et al., 2007).

Table 1 – *The single and the joint impacts of Environmental Policy Stringency and Economic Complexity indices on environmental exports (ENV_EXP)*

	(1) Base	(2) ECI	(3) EPS	(4) ECI & EPS	(5) ECI*EPS	(6) LAG 3	(7) LAG 5
WGDP	0.633***	0.635***	0.628***	0.635***	0.637***	0.682***	0.675***
	(73.15)	(68.87)	(72.04)	(68.05)	(70.55)	(74.64)	(79.77)
RER	0.384***	0.385***	0.418***	0.389***	0.367***	0.0459	0.137**
	(6.20)	(6.01)	(6.72)	(6.00)	(5.80)	(0.74)	(2.42)
ECI		0.0464**		0.0458**	0.0462**	0.0347	0.114***
		(2.08)		(2.03)	(2.09)	(1.36)	(4.31)
EPS			0.00813	−0.00276	0.0231	0.0445**	0.0235
			(0.42)	(−0.14)	(1.02)	(2.54)	(1.37)
EPS*ECI					0.0377**	0.0434**	0.0236***
					(2.10)	(2.51)	(2.59)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. observations	476.000	428.000	471.000	428.000	428.000	430.000	434.000
Countries	34	31	34	31	31	31	34
Years	14	14	14	14	14	14	14
Wald test	1.07e+07	9612666	1.04e+07	9738198	9430755	9520335	1.80e+08

Note: *t* statistics in parentheses. *, **, and *** indicate 10 %, 5 %, and 1 % significance levels.

The results in table 1 suggest that ecological transition in a context characterized by high economic sophistication can generate competitive green opportunities. Table 2 corroborates the medium- and long-term validity of the strictly strong version of the PH (columns 11 and 12) and the single moderating effect of the ECI expressed by the positivity and significance at 1% coefficients of the interaction terms in columns 10, 11, and 12. Moreover, the table introduces two important elements. Firstly, it highlights that pollution intensity also has an essential moderating role in fostering green export competitiveness, extending the results obtained by Fabrizi et al. (2024a) for international competitiveness to green export competitiveness. Indeed, the positive impact of the EPS index becomes significant at 1% already in the short term when interacting with GHG_GDP, as indicated by the coefficient of the interaction term EPS*GHG_GDP in column 10, and it seems to be pervasive in the medium and the long periods (columns 11 and 12), supporting that the validity of the strictly strong version of the PH and the effectiveness of stringent green policies depend directly on the pollution level. Environmental regulation positively influences firms' technological advancement due to the rising costs associated with environmental pollution; these costs exert additional competitive pressure on firms, prompting them to increase their investment in innovation. The improvement of environmental efficiency, that is, the inverse of GHG_GDP (Guarini, 2015), generated by green innovations can be a source of comparative advantage in industries and can improve export performance; this allows for the mitigation of CO_2 emissions, diminishes the dependence on fossil fuels, and enhances industrial competitiveness by reducing energy expenditures and operational costs (Sakamoto and Managi, 2017; Nawaz et al., 2021). This investment yields a significant "compensation effect" that makes the green conversion a "profitable strategy" (Fabrizi et al., 2024a; Zhang, 2022). The positive effect of green regulation on performance could be more critical in firms that are initially more polluting because they have more opportunities to reduce inefficiencies and benefit from environmental regulation; this increased probability and intensity of green activities stimulate "export green-sophistication" (Ge et al., 2020, p. 2).

Table 2 – *The moderating effects of the ECI and pollution intensity on international green competitiveness (ENV_EXP)*

	(8) GHG_GDP	(9) EPS*GHG_GDP	(10) EPS*ECI*GHG_GDP	(11) LAG 3	(12) LAG 5
WGDP	0.733***	0.736***	0.733***	0.783***	0.765***
	(74.45)	(73.39)	(74.13)	(81.52)	(86.20)
RER	0.406***	0.371***	0.360***	0.0382	0.197***
	(5.85)	(5.21)	(5.14)	(0.57)	(3.17)
ECI	0.0547**	0.0656**	−0.0363	0.0625	0.0708
	(2.19)	(2.49)	(−0.53)	(1.03)	(1.20)
EPS	−0.0172	0.0733*	0.156***	0.141***	0.0786***
	(−0.74)	(1.68)	(3.13)	(4.51)	(2.68)
GHG_GDP	0.0173	−0.0337	−0.150***	−0.0839*	0.0397
	(0.42)	(−0.71)	(−2.80)	(−1.78)	(0.90)
EPS * GHG_GDP		0.0752**	0.121***	0.0722***	0.0374*
		(2.47)	(3.40)	(2.63)	(1.90)
EPS * ECI			0.210***	0.237***	0.129***
			(3.73)	(4.84)	(3.37)
ECI * GHG_GDP			−0.132**	−0.0116	−0.0414
			(−2.17)	(−0.21)	(−0.80)
EPS * ECI * GHG_GDP			0.183***	0.186***	0.0986***
			(3.94)	(4.32)	(2.93)
Time dummies	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes
No. observations	406.000	406.000	406.000	404.000	402.000
Countries	30	30	30	30	30
Years	14	14	14	14	14
Wald test	1.02e+07	1.08e+07	1.29e+07	1.27e+07	1.42e+07

Note: *t* statistics in parentheses. *, **, and *** indicate 10 %, 5 %, and 1 % significance levels.

Secondly, table 2 highlights the existence of a joint moderating effect of pollution intensity and economic sophistication on the impact of green policies on green export competitiveness, as suggested by all the positive and significant (1%) coefficients of the interaction term EPS*ECI*GHG_GDP in columns 10, 11, and 12. The interplay of environmental policy stringency, the ECI, and green innovation is crucial for improving international green competitiveness. However, the need for industrial policy intervention or regulatory reform to stimulate green growth must be evaluated country by country (Kowalska-Styczeń et al., 2023) because the policy effectiveness depends not only on their green knowledge, but also on their pollution intensity. Complex economies are more prone to develop capabilities that can help reduce pollution and produce goods more efficiently. Moreover, they tend to produce more technologically sophisticated products, which are associated with high market output values, leading to economic efficiency by generating greater economic value per unit of pollution emitted (Romero and Gramkow, 2021). Therefore, this combination can represent a winning strategy, especially for the most polluting nations, which have a more significant potential for improving environmental efficiency and obtaining the highest revenue from the ecological structural change based on green sophistication and diversification of the productive structure.

Finally, we have carried out a robustness analysis of equation (2) (see appendix C). Firstly, we have lagged all regressors with lags one, two, and four; we have substituted the ECI with the Fitness Economic Metric (another index that measures economic complexity and diversification) built by the World Bank;[6] and we have estimated equation (2) with the fixed effects instrumental variables model (table C1). Secondly, we have introduced as control variables the following regressors with a lag of one year: a dummy for emerging and transitioning countries (ETC); greenhouse gas emissions per capita (GHG_CAP); GDP per capita (GDP_POP); human capital (EDU), measured by population aged 25-64 with tertiary education; public expenditure on R&D per GDP (GOV_R&D); and the rate of trade openness (TRADE_OPEN), calculated as the ratio of the sum of exports and imports on GDP (see table C2). All results confirm the positive influence of economic complexity on the impact of environmental policy on green export competitiveness.

4. Concluding remarks

This paper has explored the complexity of ecological transition for developed and emerging nations, which must integrate ecologically efficient technological progress and ecological structural change to achieve environmental sustainability. Ecological structural change is vital for aligning with environmental goals and is a strategic approach for firms to adapt to the changing economic environment. This alignment ensures long-term viability and international competitiveness through green innovation. However, this transformation requires significant green investments, which are heavily dependent on public support due to high fixed costs, risk, uncertainty, and knowledge complexity concerning eco-innovation (Ghisetti et al., 2015; Mazzucato and Semieniuk, 2018), as sustained by the strictly strong version of the PH. Moreover, this ecological structural transformation involves continuous advancement in production sophistication within economic complexity, addressing market failures, and mitigating investment risks in cleaner technologies (Grazini and Guarini, 2023b).

This paper has elucidated the intricate interplay between environmental regulations and international green competitiveness, moderated by economic complexity and pollution intensity. The analysis supports the strictly strong version of the PH only in the medium term. Therefore, policymakers should integrate green policies with industrial and trade policies by advocating for a comprehensive approach to achieve sustainable competitiveness. In particular, the study has confirmed what Petroni et al. (2019) have already argued: that the validity of the PH cannot be universally established, but other factors, such as economic complexity and pollution intensity, can influence it. Findings have also underscored the direct importance of economic complexity, a

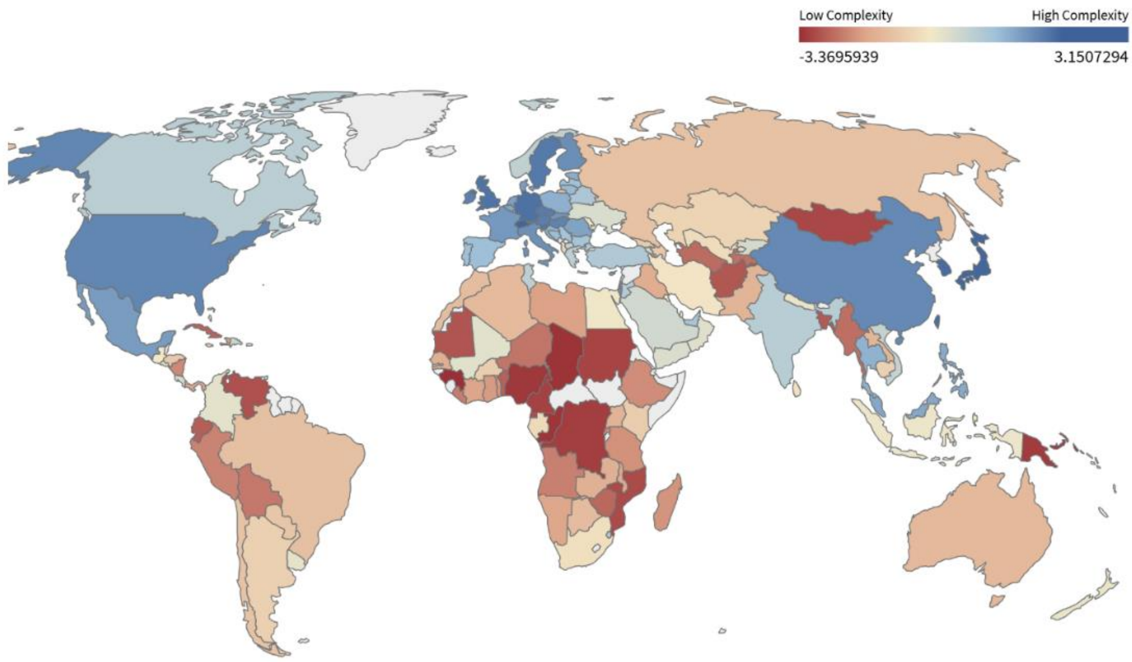
[6] "Economic Fitness (EF) is both a measure of a country's diversification and ability to produce complex goods on a globally competitive basis". For details, see the Metadata Glossary, World Bank DataBank.

proxy of knowledge and green production capabilities within the economy, for enhancing international green competitiveness; but, above all, they've underscored the significant role of economic complexity in moderating the impact of environmental regulations on green exports, which becomes positive and significant even in the short term. Countries with higher economic complexity are more adept at utilizing stringent environmental regulations to stimulate green innovations and enhance their international competitiveness. Conversely, ecological structural change is more difficult for emerging economies, where the low sophistication of the production structure produced by the de-industrialization process can compromise the effectiveness of policies inducing technological change. The joint impact of the ECI and the EPS index highlights the importance of advancing economic diversification and enacting effective environmental policies. As maintained by ECLAC (2020), green conversion needs a "big push for sustainability", which involves the coordination of policies to mobilize and accelerate sustainable investments to foster a virtuous cycle of economic growth, increased income, job creation, and reduced inequalities. At the same time, policymakers can promote investments in innovative and high-value-added activities that facilitate the transition of diversified economic structures and sophisticated green goods production. Governments should prioritize sectors with lower environmental impact and encourage firms to invest in environmentally friendly products. This strategy can address ecological challenges while strengthening economic resilience and enhancing international competitiveness by effectively positioning countries to leverage green innovations and sustainable practices. Moreover, countries that export complex industrial products generally exhibit greater inclusivity and experience lower income inequality levels than do those exporting more straightforward products (Hartmann et al., 2017). Therefore, the combination of stringent environmental policies and green economic sophistication could represent ECLAC's (2012) "*structural change for equality*", which integrates economic growth with sustainable production and universal social protection to promote knowledge-intensive sectors, reduce income disparities, and ensure equal rights for all. Finally, findings have also revealed that pollution intensity influences both the direct effectiveness of environmental regulations and the moderating effect of the ECI. Stringent regulations are more effective in promoting international green competitiveness in highly polluting countries characterised by high economic sophistication, as they have more opportunities to reduce inefficiencies and benefit from green conversion. This implies that the previous green competitive strategy should be tailored to different countries' pollution intensity and green knowledge to maximize their effectiveness.

This paper has limitations due to the availability of OECD environmental data that may guide future research directions. Firstly, although the OECD provides harmonised data for cross-country comparisons, the sample is limited to only 40 countries, most of which are high-income OECD countries. Further research could enlarge the sample, including more emerging and developing countries, to test the validity of the strictly strong version of the PH and provide a more comprehensive understanding of the global dynamics of green competitiveness. Secondly, the time series of environmental exports covers only the period from 1990 to 2016; future research should extend the analysis to include more recent data to capture the latest trends and policy impact. Moreover, further research could fruitfully explore and analyse in more depth the effects of the EPS index and the ECI by disaggregating environmental exports. Confirming and extending the findings of Fabrizi et al. (2024a), this paper has identified pollution intensity as another moderating factor of the relationship between environmental regulation and international green competitiveness. To achieve diversification in green technology, it is often essential to access foreign expertise and develop the necessary domestic capabilities, requiring international linkages and cross-country cooperation, which are crucial for enhancing international competitiveness. Indeed, the UN (UNCTAD, 2023) advocates international cooperation in the green economy, emphasizing the importance of activities in science, technology, and innovation. At the national level, universities and governments can support firms by providing economic incentives and facilitating the transfer of complex knowledge for developing green innovations. Within this perspective, Fabrizi et al. (2024b) identify a positive relationship between environmental networks and green exports. Therefore, further work will evaluate how international collaboration and trade policies influence the adoption of green technologies and practices and include other moderating factors. The narrow version of the PH sustains the effectiveness of environmental regulation on eco-innovation diffusion, and environmental performance varies according to the specific environmental policy tool, so different types of environmental policies have varying impacts on green exports (Kang and Lee, 2021). This paper has identified the existence of a direct impact of environmental policy's stringency and the single and joint moderating effects of economic sophistication and pollution intensity of its effectiveness on international green competitiveness. However, further research could test the narrow versions of the PH by examining in more depth the impact of specific policy instruments and regulatory frameworks, using the decomposition of the EPS index, on international green competitiveness, as well as the moderating factors affecting its validity, to provide more actionable insights for policymakers.

Appendix A

Figure A1 – *The last available global classification according to the ECI (2023)*



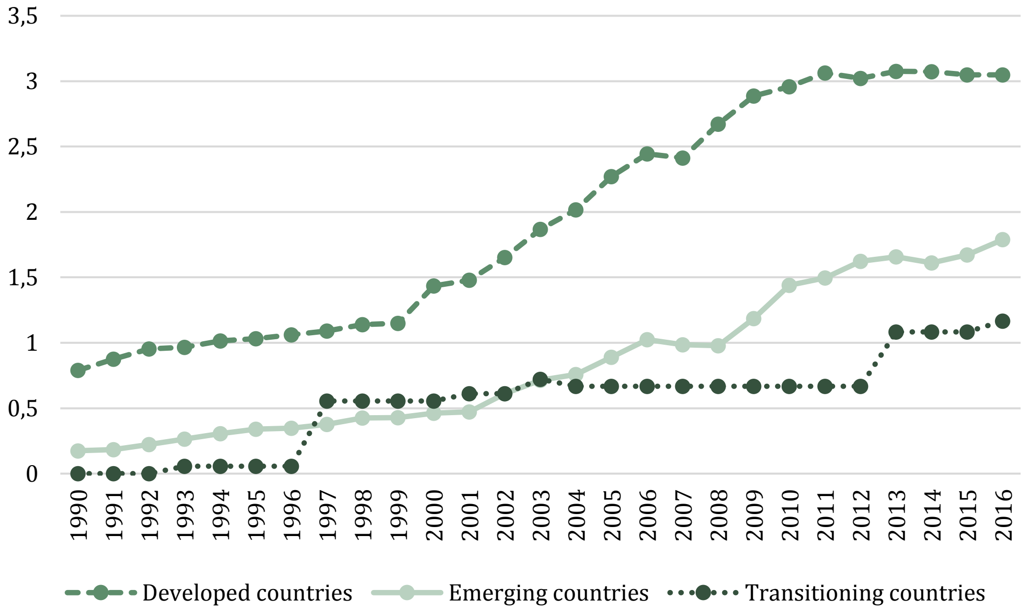
Source: https://atlas.cid.harvard.edu/rankings

Appendix B

Table B1 – *Summary statistics of dependent and independent variables (expressed in logarithms)*

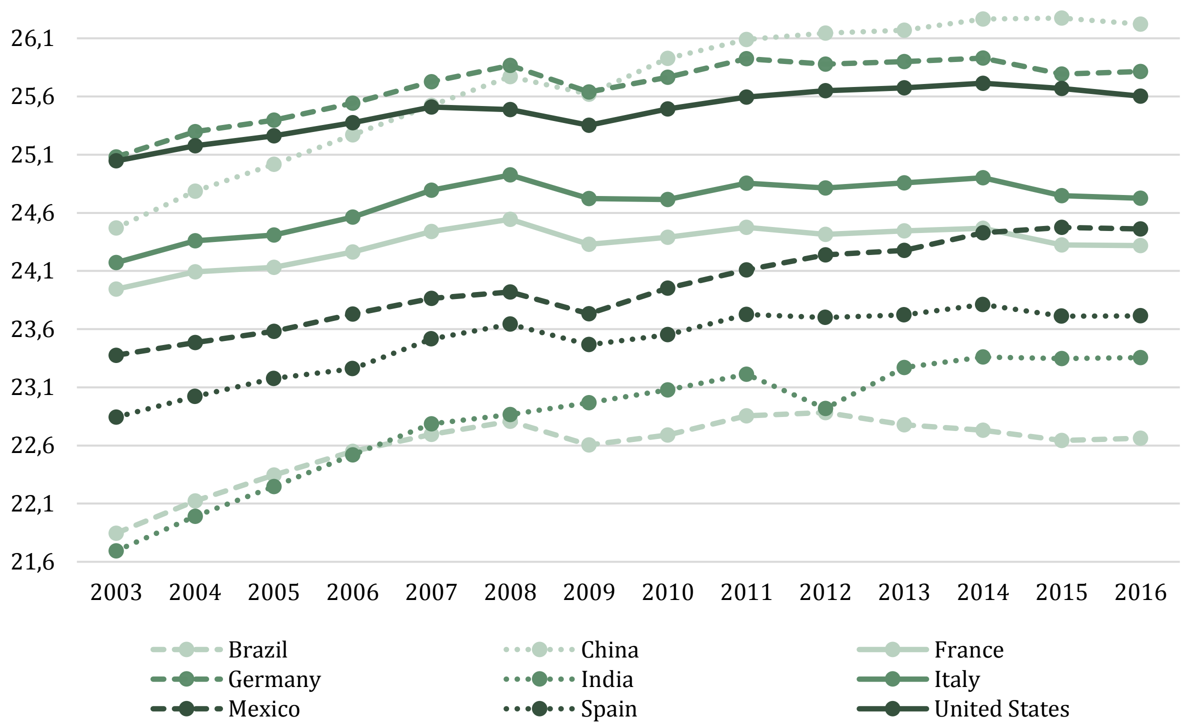
	Obs.	Mean	Std. Dev.	Min.	Max.
ENV_EXP	546	22.85623	1.64420	17.09108	26.2739
WGDP	1240	32.02996	0.30085	31.57146	32.50363 0
RER	1'079	4.572144	0.174392	3.763807	5.102513
ECI	914	−0.0998606	0.9288676	−5.6003275	1.0504261
EPS	1'196	0.2938750	0.9491239	−2.8903718	1.586965
GHG_GDP	1'128	0.37166	0.66423697	−4.42284862	1.626
GHG_CAP	1'120	2.260371	0.658944	−1.870803	3.92235
EDU	852	3.2312	0.5086	1.5597	4.0936
FIT	819	0.7400	0.7937	−2.0241	2.3691
GDP_POP	1'209	3.3319	0.6926	0.3396	4.7447
TRADE_OPEN	1'044	−0.7056	0.4981	−2.3161	0.5200
GOV_R&D	724	−6.3015	0.7041	−9.0496	−4.9230

Figure B1 – *Trend of the average of the EPS index between 1990 and 2016 according to the development level*



Source: Authors' elaboration on the OECD database (https://data-explorer.oecd.org).

Figure B2 – *The dynamic of ENV_EXP between 2003 and 2016 for several countries*



Source: Authors' elaboration on the OECD database (https://data-explorer.oecd.org).

Table B2 – *Correlation matrix*

Nr.	Variables	1	2	3	4	5	6	7	8	9	10	11	12
1	ENV_EXP	1.000											
2	WGDP	0.084	1.000										
3	RER	0.195	−0.090	1.000									
4	EPS	0.437	0.249	0.089	1.000								
5	ECI	0.602	−0.205	0.119	0.232	1.000							
6	FIT	0.810	−0.118	0.100	0.221	0.552	1.000						
7	GHG_GDP	−0.070	−0.273	−0.072	−0.341	−0.113	0.024	1.000					
8	GHG_CAP	0.080	−0.223	0.034	−0.171	0.031	0.017	0.807	1.000				
9	EDU	0.127	0.348	0.116	−0.064	0.031	−0.151	−0.190	0.101	1.000			
10	GDP_POP	0.234	0.140	0.170	0.330	0.235	−0.015	−0.528	0.075	0.468	1.000		
11	GOV_R&D	0.399	−0.034	0.015	0.155	−0.024	0.200	0.276	0.100	−0.048	−0.321	1.000	
12	TRADE_OPEN	−0.293	0.125	−0.095	0.086	0.178	−0.330	0.055	−0.052	−0.313	−0.167	−0.162	1.000

Appendix C

Table C1 – *The introduction of one, two, and four lags and of the Fitness Economic Metric Index, and estimations with a fixed effect instrumental variables model (column 5)*

	(1)	(2)	(3)	(4)	(5)
	LAG 1	LAG 2	LAG 4	Fitness Economic Metric, FIT	FE instrumental variable model
WGDP	0.757***	0.768***	0.771***	0.535	–0.320
	(78.26)	(74.17)	(84.83)	(1.52)	(–0.25)
RER	0.207***	0.150**	0.141**	0.252***	0.456***
	(3.01)	(2.04)	(2.20)	(3.78)	(3.98)
ECI	0.166**	–0.0148	0.00269		0.112
	(2.50)	(–0.21)	(0.04)		(0.40)
EPS	0.0548	0.110***	0.0914***	–0.0395	0.122
	(1.21)	(2.81)	(3.10)	(–1.00)	(0.99)
EPS*ECI	0.280***	0.218***	0.196***		0.524**
	(4.82)	(3.86)	(4.29)		(2.02)
GHG_GDP	–0.109**	–0.0680	–0.0204	–0.00143	–0.0212
	(–2.04)	(–1.33)	(–0.46)	(–0.04)	(–0.21)
EPS*GHG_GDP	0.0639*	0.115***	0.0545**	0.0103	0.177**
	(1.84)	(3.77)	(2.21)	(0.47)	(2.46)
ECI*GHG_GDP	0.00822	–0.119*	–0.0957*		–0.173
	(0.13)	(–1.93)	(–1.78)		(–0.81)
EPS*ECI*GHG_GDP	0.252***	0.193***	0.143***		0.471***
	(5.13)	(3.98)	(3.79)		(2.75)
FIT				0.237***	
				(3.45)	
EPS*FIT				0.110***	
				(2.58)	
FIT*GHG_GDP				0.0212	
				(0.56)	
EPS*FIT*GHG_GDP				0.0949***	
				(3.83)	
Time dummies	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	No
No. observations	405	404	404	444	400
Countries	30	30	30	33	30
Years	14	14	14	14	13
Wald test	1.36e+07	1.30e+07	1.51e+07	64502.51	
Underidentification test (p-value)					0.0545
Hansen J statistic (p-value)					0.3504

Note: *t* statistics in parentheses. *, **, and *** indicate 10 %, 5 %, and 1 % significance levels. In column (5), a fixed effect instrumental variables model is estimated: all economic regressors are considered potentially endogenous by using these regressors with lag 2, population, and population density as instruments.

Table C2 – *The introduction of other control variables*

	(1) ETC	(2) GHG_CAP	(3) GDP_POP	(4) EDU	(5) TRADE_OPEN	(6) GOV_R&D
WGDP	0.757***	0.677***	0.677***	0.694***	0.785***	0.614***
	(78.26)	(57.53)	(57.19)	(57.61)	(77.03)	(42.27)
RER	0.207***	0.130**	0.133**	0.263***	0.201***	0.298***
	(3.01)	(2.04)	(2.08)	(3.77)	(3.00)	(3.62)
ECI	0.166**	0.220***	0.218***	0.0342	0.226**	0.245**
	(2.50)	(3.43)	(3.41)	(0.37)	(2.53)	(2.42)
EPS	0.0548	−0.0463	−0.0453	0.0500	0.0305	0.209**
	(1.21)	(−1.13)	(−1.11)	(1.09)	(0.59)	(2.54)
EPS*ECI	0.280***	0.210***	0.207***	0.294***	0.346***	0.284***
	(4.82)	(3.83)	(3.79)	(4.08)	(4.54)	(2.96)
GHG_GDP	−0.109**	−0.753***	0.00711	−0.176***	−0.155**	−0.336***
	(−2.04)	(−8.89)	(0.14)	(−3.02)	(−2.41)	(−3.92)
EPS*GHG_GDP	0.0639*	−0.0164	−0.0154	0.0952***	0.0233	0.171***
	(1.84)	(−0.49)	(−0.46)	(2.73)	(0.56)	(2.89)
ECI*GHG_GDP	0.00822	0.0589	0.0586	−0.0614	0.0920	0.0625
	(0.13)	(1.01)	(1.00)	(−0.84)	(1.07)	(0.65)
EPS*ECI*GHG_GDP	0.252***	0.199***	0.196***	0.254***	0.296***	0.235***
	(5.13)	(4.32)	(4.25)	(4.79)	(4.21)	(2.88)
ETC	−1.468***					
	(−18.05)					
GHG_CAP		0.757***				
		(8.61)				
GDP_POP			0.759***			
			(8.63)			
EDU				0.452***		
				(6.26)		
TRADE_OPEN					0.610***	
					(8.73)	
GOV_R&D						0.0412
						(1.25)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. observations	405	405	405	367	387	234
Countries	30	29	29	28	21	30
Years	14	14	14	14	14	14
Wald test	1.36e+07	1.58e+07	1.58e+07	1.56e+07	1.68e+07	1.65e+07

Note: *t* statistics in parentheses. *, **, and *** indicate 10 %, 5 %, and 1 % significance levels.

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