Measuring Firm Greenness: A Comprehensive Review of Corporate Sustainability Indicators

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Measuring Firm Greenness: A Comprehensive Review of Corporate Sustainability Indicators

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ABSTRACT

The major global challenges of climate change, environmental degradation, and resource scarcity have gained centrality in policymaking and academia, with a growing body of research exploring the interlinkages among economic growth, trade, environmental outcomes, and policy interventions. These analyses and their results draw fundamentally on the definitions used to consider a firm, product, or process "green," and on the related operationalization. Despite a proliferation of empirical approaches, however, the literature lacks a comprehensive overview of firm-level sustainability indicators. This article addresses this gap by systematically reviewing existing definitions and the most frequently employed indicators Our analysis shows that, according to prevailing definitions of greenness, a firm can be considered green either because it is purpose-sustainable, meaning that it primarily serves an environmental purpose, or because it is process-sustainable, meaning that its activities reduce or prevent negative environmental impacts even if environmental goals are not its primary purpose. We further classify the existing firm-level sustainability indicators into three groups: (1) product-level indicators; (2) resource and pollution management indicators; and (3) investment, innovation, and commitment indicators. Our findings aim to support researchers in selecting indicators that align with specific research objectives and dimensions of sustainability under investigation.

1 | Introduction

Climate change, environmental degradation, resource scarcity, and declining air and water quality have become central to contemporary policy and academic discourse. In the past decade, governments in advanced and emerging economies have launched unprecedentedly ambitious policy initiatives aiming to reconcile economic growth with ecological preservation. Intensified public concern has, in turn, stimulated a substantial body of research examining the interdependencies between economic growth, international trade, environmental outcomes, and policy measures (Brandi et al. 2020; Cherniwchan 2017; Cherniwchan et al. 2017; Grossman and Krueger 1995; Popp 2006).

A shared, rigorous, and policy-relevant understanding of these dynamics draws on a precise conceptualization of what constitutes a "green" firm, product, or process. The assessment of corporate sustainability—and of its variation in response to external shocks such as regulatory interventions or crises—requires a clear specification of measurement criteria and indicator selection (Waseem and Kota 2017). Yet, despite extensive empirical and theoretical contributions, the literature still lacks a systematic synthesis of firm-level environmental sustainability indicators.

This study addresses this gap through a comprehensive review and classification of the indicators most frequently employed to define and measure firms' environmental sustainability.

Concentrating on firm-level analyses, we consolidate existing contributions and categorize indicators into three main groups: (1) product-level indicators; (2) resource and pollution management indicators; and (3) investment, innovation, and commitment indicators. We examine each category in its definitional scope and main empirical applications.

Our objective is to assist researchers in selecting indicators best suited to their analytical focus—whether evaluating overall corporate sustainability, environmental commitment, product greenness, or the emission performance of businesses—to facilitate the selection of appropriate metrics for specific corporate activities or sustainability dimensions.

The remainder of the article is structured as follows. Section 2 outlines the methodological approach; Section 3 defines the concept of "green activity," which underlies the indicators used to identify green firms; Section 4 presents an overview of our classification of sustainability indicators; Sections 5, 6, and 7 discuss in detail each category of indicators: product-level indicators; resource and pollution management indicators; and investment, innovation, and commitment indicators, respectively. Section 8 discusses their empirical implementation, and Section 9 concludes.

2 | Methodology

This article conducts a systematic literature review (Denyer and Tranfield 2009) to identify and synthesize existing research on firm-level environmental sustainability indicators. Following Snyder (2019), the review proceeded through four stages: (1) design, (2) selection, (3) analysis, and (4) synthesis.

1. *Design*: Our objective was to collect and classify the indicators used to measure firms' environmental sustainability. We searched for studies whose keywords included *environmental sustainability, sustainability indicators, green indicators, green firms, greenness*, and *sustainable firms*. We imposed no temporal restrictions, which yielded a sample covering 1995–2023. We prioritized highly cited papers (at least 100 citations), alongside conceptually or methodologically relevant works. We considered theoretical, empirical, and institutional studies. Importantly, we only considered indicators actually employed in academic studies to assess firms' greenness. Although a wide range of potential indicators of corporate greenness exists in the literature and in corporate practices, our aim is to give a comprehensive review of those empirically applied in previous research, thereby focusing on measures that have been effectively used to evaluate firms' environmental sustainability.
2. *Selection*: A refined screening identified (1) institutional documents defining environmental sustainability and criteria to identify green firms; and (2) theoretical or empirical studies that operationalize corporate sustainability through explicit indicators. The analysis primarily targeted firm-level contributions but, when appropriate, included macro-level studies informing indicator construction. The final dataset contains 95 papers, detailed in Table A1.
3. *Analysis*: For each paper, key bibliographic and methodological information was extracted and organized in a structured database, including publication details, authorship, journal, and content summary. Each study was coded by the sustainability indicator employed. Indicators were grouped into three categories: (1) product level; (2) resource and pollution management; and (3) investment, innovation, and commitment indicators (see Section 4). Targeted searches within each category refined and expanded the classification.
4. *Synthesis*: The final stage integrated and interpreted the collected evidence, providing a structured overview of the selected firm-level sustainability indicators. For each indicator, we report the main conceptual foundations and relevance across different contexts, as well as some applications in empirical studies.

3 | When Is a Firm "Green"?

Terms such as sustainable, green, and environmental—used interchangeably throughout this article—are commonly employed to denote specific dimensions of economic activity (e.g., sustainable finance, environmental industries, green technologies, or environmental goods [EGs]). This complicates the formulation of a comprehensive and operational definition of firm-level sustainability (Waseem and Kota 2017). To capture a broad range of forms of corporate environmental engagement, we draw on existing efforts by several institutions, such as the OECD, Eurostat, and the European Commission. These institutions have long been confronted with the need to establish objective definitions of "green" firms, investments, and activities to support the design and implementation of their environmental policies; their definitions have some relevant commonalities and convergent criteria.

In 1999, OECD and EUROSTAT created an Informal Working Group aimed at standardizing methodologies to measure eco-innovation and collect comparable data across countries. Their report defines the EGs and services industry as "activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and ecosystems. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use" (OECD/EUROSTAT 1999, 9). Within the industry, the report identifies three groups, depending on the clarity of the environmental purpose in the supply of goods and services and on the ease of statistical assessment (p. 11). First, goods and services that are "clearly supplied for an environmental purpose and that have a significant impact in reducing pollution emissions" are included in the *"pollution management"* group. This group includes, for instance, air-handling equipment and systems for chemical treatment and recovery. Second, goods and services that contribute to reducing negative environmental impacts, despite being supplied for purposes that are not strictly environmental, are labelled "*cleaner technologies and products."* This includes, for example, technologies that decrease material inputs or reduce energy consumption. Third, the report recognizes that other activities may be associated with environmental protection, although their prime purpose is different, such as activities aiming to collect, purify, and distribute potable water to households. This category is labelled *"resource management" group*.

Hence, the OECD/Eurostat definition openly recognizes that a product or service can be defined as environmental if it reduces or limits pollution and environmental impact, but also if it helps manage resources more efficiently. The presence of an explicit environmental purpose makes it easier to identify the product or service statistically, but it is not strictly necessary to define it as environmental. For instance, goods and services with a clear environmental purpose, for example, solar panels, are more easily identified than, e. g., energy-saving technologies not specifically targeted to environmental objectives. Almost two decades later, the 2016 classification of environmental economic activities published by EUROSTAT maintained this fundamental approach.[1]

In 2019, the European Commission launched one of the most ambitious policy plans ever introduced in the EU to sustain the twin transition in Europe, the "Green New Deal." The plan included a generous package of support initiatives for green investments, whose implementation, in turn, required a neat identification of sustainable economic activities. An EU Technical Expert Group on Sustainable Finance[2] was set up to outline the foundations for an EU Taxonomy on sustainable economic activities, approved by the European Commission in July 2020 in the popularly known "Taxonomy Regulation."[3]

The Expert Group report outlines six specific environmental objectives to which economic activities can contribute:

- Climate change mitigation,
- Climate change adaptation,
- Sustainable use and protection of water and marine resources,
- Transition to a circular economy,
- Pollution prevention and control, and
- Protection of the ecosystem.

The Experts' Group considers an economic activity as sustainable when, according to technical screening criteria, it fulfills the three requirements of (1) providing a positive sustainable contribution to at least one of the six environmental objectives; (2) not negatively impacting on any of the other five environmental objectives; and (3) meeting the minimum social safeguards approved at the international level.

Moreover, the Expert Group distinguishes two different types of sustainable economic activities, relating to whether the activity directly contributes to one or more environmental objectives or enables other economic activities to do so:

1. *Enabling Activities*: "*The activity is improving the performance of another economic activity, or activities, and does not itself risk harm to environmental objectives*."
2. *Own Performance*: "*The activity itself is being performed in a way that substantially contributes to an environmental objective*" (EU Technical Expert Group on Sustainable Finance 2020, 15).

Again, the Group recognizes that economic activities can contribute to sustainability by reducing pollution emissions or by helping manage natural resources more efficiently. Many of the activities whose primary purpose aligns with one of the six environmental objectives may be employed as enabling activities in further steps of the value chain.

To summarize the definitions proposed by the two above-mentioned reports and to create categories to accommodate the sustainability indicators presented in the following sections, we identify the following broad classifications of firms' economic activities, products, or services. The classification relates to the way in which the activity, product, or service provides its environmental contribution:

1. *Purpose-sustainable*: activities, products, or services that primarily serve an environmental purpose. These activities act as "enablers" for other economic activities to improve their environmental performance. For example, a manufacturing process that produces PV panels.
2. *Process-sustainable*: activities, products, or services whose primary purpose is not necessarily environmental but is pursued in a manner that reduces and/or prevents any negative environmental impact and produces less harm to the environment relative to similar activities that serve the same primary non-environmental purpose. For example, the use of PV panels to obtain renewable energy within the manufacturing process.

In Table 1, we categorize the above definitions according to the categories of purpose- and process-sustainability. Our categorization resonates with the distinction between the process and output approach proposed by Bontadini and Vona (2023), who distinguish between *"the effective pollution content of production (process approach) or in terms of its potential to minimize harmful impacts of production on the environment (output approach)."* (p. 710).

4 | Overview of the Sustainability Indicators in the Literature

In this section, we present an overview of the firm-level indicators used in existing empirical and theoretical works to evaluate the level of environmental sustainability (or greenness) of firms. As discussed in Section 3, greenness indicators should reflect either the presence of a primary environmental purpose in a firm's activities ("purpose-sustainability") or the fact that a firm's activities, products, or services contribute to environmental objectives even when their primary purpose is not explicitly environmental ("process-sustainability").

As acknowledged by the OECD/Eurostat, identifying indicators for "purpose-sustainable" activities through the screening of product descriptions or sectoral codes is relatively straightforward, yielding itself rather directly to a product-level classification. Instead, operationalizing "process-sustainable" activities is a non-trivial task that requires a multidimensional analysis of different phases of firms' activities, and is less easily matched with a univocal product classification (Balineau and De Melo 2013; Mealy and Teytelboym 2022). Hence, along with contributions that have attempted to provide product-level classifications of

TABLE 1 | Criteria to identify sustainable activities, products, or services.

Purpose-sustainable	• *Enabling activities* (European Commission 2020)
	• *Pollution management group* (OECD/EUROSTAT 1999)
	• *Resource management group* (OECD/EUROSTAT 1999)
Process-sustainable	• *Own performance* (European Commission 2020)
	• *Cleaner technologies and products group* (OECD/EUROSTAT 1999)
	• *Resource management group* (OECD/EUROSTAT 1999)

Source: Authors' elaboration based on OECD/EUROSTAT (1999) and European Commission (2020).

EGs capturing the process-sustainability dimension (e.g., Mealy and Teytelboym 2022; UNCTAD 2003), the literature has often employed sustainability indicators that capture objective measures of firms' environmental performance, such as emissions, energy or water use, and pollution intensity (see, e.g., the comprehensive review in Sorroche-del-Rey et al. 2023).

In the context of an already broad set of sustainability indicators relevant for firm analysis, we note that existing reviews have comparatively neglected another dimension of firm decision-making: the one relating to the operational, organizational, and strategic domains of corporate sustainability. Although less central in existing reviews, this dimension is emphasized in a variety of disciplinary approaches. Indeed, firms' governance, policies, and strategic management decisions in the field of sustainability bear substantial economic implications (e.g., Colombelli et al. 2020; Eccles et al. 2014; Lozano 2015), have a recognized role in the good practices of sustainability disclosure of the GRI Universal Standards (2021)[4], and have been identified as key drivers of the circular economy development in the industrial ecology literature (e.g., Blomsma and Brennan 2017; Moraga et al. 2019). The level of firm strategy and organization is also openly acknowledged in existing taxonomies of green innovation (e.g., Marcon et al. 2017). Importantly, recognizing their role enables us to connect sustainability measurement more closely to firms' internal choices and incentives, acknowledging the contributions of prominent microeconomic models of green technological change and their emphasis on the role of green R&D and innovation (e.g., Acemoglu et al. 2016; Aghion et al. 2019).

Based on these considerations, and with the aim of developing an integrated framework for analyzing firm sustainability, we classify indicators not according to what environmental effect they measure, but rather according to which level of firm decision-making they reflect: (1) product design and composition; (2) resource and pollution management; and (3) strategic investment and commitment. *Product-level indicators* capture the environmental features of goods and services; hence, they represent the most straightforward way of classifying the sustainability of firms' production—but they may also be employed to analyze the choice of firms' inputs (e.g., Brandi et al. 2020). *Resource and pollution management indicators* refer instead to firms' operational practices concerning input efficiency, waste minimization, and emission control, as emphasized in many existing literature reviews (e.g., Krajnc and Glavic 2003; Sorroche-del-Rey et al. 2023). Finally, *investment, innovation, and commitment indicators* represent the strategic dimension of greenness, encompassing long-term organizational engagement in developing and adopting cleaner technologies, pursuing green R&D, and signaling commitment through certifications and ESG disclosure.

In essence, we recognize that product-level performance, resource management, and strategic commitment are complementary and jointly determine a firm's contribution to the environmental transition. Our integrated framework connects operational environmental performance with the underlying organizational and technological determinants of firm greenness, helping to bridge the gap between environmental assessment frameworks—which typically capture the effects of firms' activities on the environment—and the economics and management literature, which seeks to understand the drivers of firms' green behavior and innovation strategies. Table 2 reports a summary of our indicators.

5 | Product-Level Indicators

The first category of indicators evaluates firms' sustainability level based on the environmental characteristics of the goods they produce. In other words, these indicators identify a firm as "green" if it produces and/or trades "green" products. Our analysis of the literature revealed two main approaches to identify green products: *EGs lists* and *eco-labels*. Table 3 summarizes the product-level indicators used in the studies reviewed.

5.1 | EGs Lists

5.1.1 | Definition

Many works take the so-called *Environmental Goods (EGs)* on institutional lists as a reference for the identification of green products (Brandi et al. 2020; Can, Ahmed, et al. 2021; Costantini and Crespi 2008; Dai et al. 2021; Kang and Lee 2021; Sauvage 2014; Sinclair-Desgagné 2008), despite the lack of a universally shared definition or list. Over the years, international institutions have encountered various obstacles in establishing a complete and internationally-agreed list. The literature recognizes that, based on the different international definitions proposed, EGs may be divided into two broad classes, depending on the reason why they are defined as "environmental" (Balineau and De Melo 2013; Hamwey 2005; Liu et al. 2022), as follows.

- *Type A EGs (or "traditional" EGs)*: Products whose primary purpose is to reduce environmental risk and minimize the use

TABLE 2 | Summary of sustainability indicators.

	Sustainability dimension	
	Purpose-sustainable	**Process-sustainable**
Level of analysis		
Product	• Type A EGs	• Type B EGs • Eco-labels
Resource and pollution management	—	• Input management indicators • Output management indicators
Investment and innovation	• Green patents (if they refer to technologies and products with a primary environmental purpose) • Green R&D (if they refer to R&D investments to develop technologies or products that serve a primary environmental purpose)	• Green patents (if they refer to technologies and products that are environmentally preferable to others) • Green R&D (if they refer to R&D investments to develop technologies or products that are environmentally preferable to others) • Investments in green technologies and green practices • Environmental certifications • CDP score • Financial ESG indices

Source: Authors' elaboration based on OECD/EUROSTAT (1999) and European Commission (2020).

TABLE 3 | Summary of product-level indicators.

Level of analysis	**Indicator**
Product	Environmental goods (EGs) • Type A EGs • Type B EGs Eco-labels • Type I, environmental labeling (ISO 14024) • Type II, self-declared environmental claims (ISO 14021) • Type III, environmental product declarations (EDPs) (ISO 14025)

Source: Authors' elaboration.

of natural resources (OECD/EUROSTAT 1999). One example is PV panels.

– *Type B EGs (or environmentally preferable products)*: Products that are more environmentally friendly in production, end-use, and disposal than their nearest substitutes that serve the same nonenvironmental purpose (Balineau and De Melo 2013). This term is introduced by UNCTAD (2003). For example, electric cars.

EGs started to gain attention in 2001, during the fourth round of negotiations between the WTO members, when the Doha Ministerial Declaration instructed members to negotiate the liberalization of the trade of EGs through the reduction, or elimination, of tariff and non-tariff barriers. These negotiations aimed to achieve a "triple win": reducing tariffs on EGs allows for lower prices, which stimulate their demand and increase incentives for innovation; in turn, green innovation stimulates greater quality of green goods; higher demand and better quality of green goods can improve environmental quality (Balineau and De Melo 2013). The core of the negotiations was to decide which products qualified for the reduction of trade barriers. To this aim, the WTO members proposed three main approaches: request and offer, integrated project, and lists (Balineau and De Melo 2013). The one adopted by most members is the list approach, whereby countries propose lists of goods that benefit from trade barrier reductions. The list approach raises three main issues, which complicated the negotiations to define EGs and delayed the agreement among countries (Balineau and De Melo 2013; Yoo and Kim 2011):

– *Divided interests over EGs*: In stipulating a potential list, many countries adopted a mercantilist approach, prioritizing their export interests (Hufbauer and Kim 2010). Consequently, developed and developing nations diverged over which goods to include, each seeking to favor products in which they held an export advantage. Developed countries predominantly promoted Type A EGs, while developing countries favored Type B EGs, reflecting their trade imbalances.

- *Multiple-use*: In practice, green goods are mapped to product lists using the 6-digit- level HS classification systems. At this level, it is not always possible to isolate Type A EGs, so the risk is to consider as "environmental" products that both environmental and non-environmental end-uses (Yoo and Kim 2011).
- *Process and Production methods*: For Type B EGs, disagreement arose over whether products could be deemed environmental based on their production process, as no shared criteria exist to define "environmentally friendly" manufacturing, leading to different interpretations by the WTO members.

These issues not only delay international agreement but also influence the economic and environmental outcomes of EG trade liberalization, with impacts varying by how countries address them (Mao et al. 2023). This further affects empirical research on the subject. In line with the Doha Ministerial Declaration, WTO members developed their own lists of EGs, drawing on definitions and lists from key institutions. The first such lists were introduced by the OECD and APEC (Steenblik 2005). APEC's 1997 list, created under the Early Voluntary Sector Liberalization (EVSL) initiative, aimed to promote trade, growth, and environmental protection, while the 1999 OECD/EUROSTAT report offered another reference point. Building on these, WTO members proposed several lists, for a total of 411 products, commonly referred to as the WTO Reference List or WTO list (Balineau and De Melo 2011; Mealy and Teytelboym 2022). From this set, some WTO members put forward a more restricted subset of 26 products, often cited as the WTO Core List. Among these submissions, the most frequently cited was the 'Friends Group' list of 152 products (Sauvage 2014; WTO 2009). Later, the OECD proposed a climate-focused list for the PEGS agreement (2010), and APEC introduced a 54-product list in 2012 (APEC 2012).[5] In 2014, the OECD combined the Friends, APEC, and PEGS lists (Sauvage 2014). While several lists have emerged over time, only the 2012 APEC list has been applied for tariff reductions (Mao et al. 2023). Below is a more detailed description of the aforementioned lists.

a. **OECD list**: This list is based on the definitions provided in the report on Environmental Goods and Services by OECD and EUROSTAT's Informal Working Group (1999). It was compiled for the analytical purpose of defining the environmental industry (Steenblik 2005). Hence, the included definitions are illustrative and not exhaustive (OECD/EUROSTAT 1999). The products and services in the list are divided into three groups:

   - Group A: Pollution Management.
   - Group B: Cleaner Techniques and Products.
   - Group C: Resources Management.

   The list is based on 6-digit HS codes. As this list is not stipulated with the scope of negotiations for trade liberalization, but only to collect information about the environmental industry, it is less specific in the identification of products relative to other lists. It includes 132 unique 6-digit HS codes (Sauvage 2014).

b. **APEC list**: In 1997, within the (EVSL) initiative, APEC leaders meeting in Vancouver agreed to accelerate trade liberalization for EGs, creating a dedicated list. Hence, unlike the broader OECD list, the APEC list was negotiation-based and more restrictive, reflecting concerns over the "multiple-use" issue (Steenblik 2005). Since products are classified globally using a 6-digit HS code, further disaggregation is often not possible, which hinders a precise classification of goods based on their end use. (Hu et al. 2020). To address this issue, the APEC leaders have found two solutions: (1) they inserted within the list only the 6-digit headings that identify predominantly environmental products; and (2) they introduced the so-called "ex-headings" that allow specifying a certain product belonging to a certain 6-digit HS code. For example, under the category "waste separation equipment," the 6-digit HS code 847410 identifies the products "starting, screening, separating, or washing machines"; in this case, the APEC economies decided to insert an "ex-heading" to specify that among these products only the "machines of a kind for use in screening and washing coal" are included in the list (Steenblik 2005).

   As a result, the APEC members agreed on a list containing 104 products (Sauvage 2014). In 2012, the APEC members proposed a new list of EGs qualifying for further reduced tariff rates equal to 5% or less by the end of 2015, including 54 6-digit HS codes. Most goods are related to renewable energy production, environmental monitoring analysis, management of solid and hazardous waste, and recycling systems. Moreover, all products are Type A EGs, with only one Type B EG (Kuriyama 2021).

   Steenblik (2005)'s comparison between the 1999 OECD list and the 1997 APEC list shows that the two are aligned in terms of product categories, but they overlap little in terms of 6-digit HS codes: less than 30% of the goods are on both lists. In general, the OECD list remains rather generic in the definition of products, while the APEC list is more specific. For example, the OECD list refers to "Parts for spark-ignition of internal combustion piston engines" (6-digit HS code: 8409.91), whereas the APEC list covers only the ex-heading category of "Industrial mufflers," for which there is not a specific HS code with more digits. As a result, the APEC list is shorter and more focused on Type A EGs, reflecting its negotiation-based nature. In contrast, the OECD list, conceived for illustrative purposes, offers a broader view of goods that can be considered "green," even when their trade liberalization is politically contested.

c. **Friends of EGs' list**: During the 2001 Doha negotiations of the WTO, the member countries submitted many lists based on the abovementioned OECD list and APEC list. Thirteen countries participated to the negotiation of the list proposing different lists of EGs (Balineau and De Melo 2011). The most comprehensive list was submitted by a group of nine members called Friends of EGs,[6] including 153 products identified with a 6-digit HS code (hereafter the "Friends" list; Sugathan 2013). This list was the result of the collection of products presented in the individual submissions by the countries in the Friends' group (Sugathan 2013).

d. **WTO list (also known as WTO reference list and WTO REFERENCE UNIVERSE)**: This broad list includes product categories proposed as EG in the framework of the WTO negotiations, even if they have only been submitted by a single country. The limited overlap between the individual countries' submissions yielded a rather broad list, including a total of 408 products (to which the study by Mealy and Teytelboym added 3 additional products). From this set, some WTO members put forward a more restricted subset of 26 products, often cited as the WTO Core List, which includes the subset of EG that have wider endorsement from Member States (Balineau and De Melo 2011; Bisio et al. 2025; Mealy and Teytelboym 2022). Balineau and De Melo 2013 provide a graphical overview of the different classifications introduced in the framework of the negotiations.

e. **PEGS list**: The PEGS list was prepared by the OECD for the 2010 Toronto summit of the G20. Rather than focusing generally on the identification of EGs, this list focuses on goods of relevance to combatting climate change. It contains 150 products and provides an indicative list of climate-change-relevant goods for a plurilateral environmental goods and services (PEGS) agreement (Sauvage 2014).

f. **CLEG list**: More recently, in 2014, the OECD endeavored to create a comprehensive list, combining the three existing lists presented above, i.e., the Friends' list, the PEGS list, and the APEC list (2012). It created the Combined List of Environmental Goods (CLEG), composed of 248 6-digit HS codes (see Sauvage 2014). The strength of this list is that it includes a higher number of products than other lists. On the other hand, this implies a higher risk of including non-environmental products. Within the CLEG list, two more restrictive lists with a clear environmental content are identified: the CLEG$^+$ list, which includes 40 products, and the Core CLEG list, which includes 11 products (Sauvage 2014).

Faced with the variety of definitions of EGs employed in the literature, Mealy and Teytelboym (2022) propose to employ a single list of EGs defined as the union of the WTO "Core List," the APEC, and the OECD lists to derive a comprehensive, shared, and expert-validated list of green goods, which includes a total of 293 green products. This list represents a range of environmental categories, such as air pollution, waste water management, and recycling. They also consider a smaller subset of the above list, including 56 renewable energy products, referring more specifically to the Renewable Energy Products category.

In the Online Appendix (Table A2, "Lists of EGs"), we provide a resource that may be of interest to empirical researchers. We report the details of the 6-digit HS 2007 codes appearing in each of the aforementioned lists, along with the corresponding product descriptions. We note that, since HS product codes are updated every five years, some products on the lists have changed codes over the years from those originally assigned in the respective lists at the time of compilation. In particular, some product categories changed codes in 2012, 2017, and 2022. To facilitate the use of these lists in future analyses, we highlight the 6-digit codes that changed in every round of the classification between 2007 and 2022, along with the new codes to which they correspond. We do so for each classification in a separate sheet, reporting the changes in product classification for the OECD, Friends, PEGS, APEC, CLEG, Core CLEG, Core CLEG$^+$, WTO, and WTO Core lists (sheets 1.1–1.9). Using this information, we assemble a comprehensive index of all HS product codes that appear in at least one EG list, specifying the list they belong to. We do so for each revision of the HS classification from 2007 to 2022 in a separate sheet (sheets 2.1–2.4). These classifications can be readily employed in empirical analyses. For reference, we also report the index of product descriptions for each HS code appearing in at least one EG list for every round of revision of the HS codes from 2007 to 2022 (sheets 3.1–3.4). For more information on the methodology, see sheet 0.

5.1.2 | Applications

Most of the papers existing in the literature use information about EGs to evaluate the "greenness" of the trade patterns between trade partners. Although it is possible to trace the trade of green products at the firm level, most papers use information about EGs trade at the country level and not at the firm level. For instance, they assess the level of "greenness" of a country's trade based on databases containing product-level information aggregated by country, such as the UN Comtrade Database (Brandi et al. 2020; Can, Ahmed, et al. 2021; Can, Ben Jebli, et al. 2021; Costantini and Crespi 2008) and the BACI Database (Dai et al. 2021). Empirical works use information about EGs differently, but most of them employ country-level shares of EGs imported and/or exported over total imports and exports (Brandi et al. 2020; Dai et al. 2021; Kang and Lee 2021). In other cases, the information about EGs is further elaborated to lead to more advanced indicators (Can, Ahmed, et al. 2021; Can, Ben Jebli, et al. 2021). Below, we report some examples of empirical works that use indicators relying on the information about EGs included in different lists.

Brandi et al. (2020) analyze the relationship between the presence of environmental provisions in preferential trade agreements (PTAs) and the level of greenness of firms' trade in a certain country, with particular attention to developing countries. The study tests whether the environmental provisions in PTAs reduce exports of dirty goods and promote exports of EGs from developing countries. As a dependent variable, the authors consider the percentage of exports of green goods over the total exports of the country. They regard as green goods the EGs listed in a combination of OECD (1999) and APEC (2012) lists, which include 142 products, mainly Type A EGs. The results indicate that environmental provisions reduce dirty exports while promoting green exports from developing countries, suggesting that stricter environmental policies can curb polluting trade and stimulate greener trade, yielding positive environmental effects.

Dai et al. (2021) reach contrasting conclusions, analyzing how the scope and stringency of environmental regulations affect EG trade. Using data from 112 exporters and 53 importers among OECD members (1989–2013), they estimate two models: one based on the APEC list and the other on the OECD list. Their findings show that stricter environmental regulations generally reduce EG trade, with a stronger effect for APEC-listed goods. These results highlight how differences in EG classifications and trade normalization methods can significantly influence empirical outcomes. Can, Ahmed, et al. (2021) and Can, Ben Jebli, et al. (2021) conduct two similar studies differing mainly in the lists of EGs employed. They introduce a new index called the Green Openness Index, a country-level index that assesses the trade-environment nexus using a measure of the importance of the presence of Green Technology Products in the trade of a country over its total production. The index is calculated as the percentage share of the sum of the current value of the total green goods exported and imported in a country over the total value of goods manufactured in the country. Can, Ahmed, et al. (2021) base the index on the $CLEG^{+}$ list (mainly Type A EGs), while Can, Ben Jebli, et al. (2021) use the broader CLEG list, including both Type A and B EGs. They study the effects of green openness on the environmental quality of a sample of 35 OECD countries over 2003–2016 (Can, Ahmed, et al. 2021) and 31 OECD countries over 2007–2017 (Can, Ben Jebli, et al. 2021). In both studies, the findings suggest that the openness of EGs trade is crucial in the reduction of environmental deterioration.

The recent paper by Bisio et al. (2025) shows that green products (defined according to the combined list of EGs proposed by Mealy and Teytelboym 2022) command higher prices, and that their demand acts similarly to the demand for luxury goods, except when they are protected by patents. For the definition of green patents, see Section 7.1.

5.2 | Environmental Statements and "Green Labels"

The identification of EGs included in the institutional lists discussed above is immediate. However, centralized institutional classifications may fail to capture individual firms' pro-environmental efforts within product categories that would not generally be considered as "green." Another approach to identify and assess the environmental characteristics of goods is to draw on marketing-oriented declarations by firms about the environmental content of their products.

5.2.1 | Definition

Environmental statements are corporate claims that "provide info about a product or service in terms of overall environmental benefits, such as the recyclability of its packaging, or the absence of noxious ingredients" (ISO 2019, 2). As such, they provide a reliable method to select and distinguish green products from other similar products. Worldwide, several environmental statements have been introduced, with some confusion about the different criteria adopted. To standardize environmental labels and claims attributed to products, the International Organization for Standardization (ISO) created the ISO 1420 series of standards, which provides principles and criteria for reporting environmental features and environmental impact of products using environmental statements (ISO 1420:2022). The ISO 1420 includes three different sets of standards that regulate three different types of environmental statements: Type I environmental labeling (ISO 14024), Type II self-declared environmental claims (ISO 14021), and Type III environmental product declarations (EDPs) (ISO 14025).

- *Type I environmental labeling* refers to voluntary, third-party schemes certifying, based on multiple criteria, that specific products can be considered environmentally preferable to other products in the same category. These eco-labels certify the sustainability of a firm's production processes based on an assessment of their entire life cycle. Regulated by ISO 14024, such programs (also called schemes) can operate at international, national, or regional levels. In particular, the ISO 14024 sets standards for the selection of product categories, product environmental criteria, and product function characteristics, as well as for assessing and demonstrating compliance.[7] One example is the EU ECOLABEL introduced by the European Commission. Products receiving this label must comply with specific criteria defined by the European Commission, which guarantee their environmental care.[8]
- *Type II self-declared environmental claims* that ISO 14021 sets the requirements for environmental statements in the form of self-declared environmental claims, including statements, symbols, and graphics, regarding products. Moreover, it identifies and explains the most common terms used to claim a product as environmentally friendly in advertising or companies' reports (e.g., recyclable, compostable).
- *Type III EDPs* refers to declarations including quantified environmental information on specific product features, which can be used to assess and compare the environmental impacts of different products and are obtained using specific tools and methods to assess the products' environmental impacts, such as Life-cycle assessment (LCA) or Ecological Footprint (EF). ISO 14025 establishes the principles and standards for developing this type of environmental declarations.

5.2.2 | Applications

Albino et al. (2009) refer to ISO 14020 to identify green products and investigate whether, among sustainability-oriented companies, those developing green products are more likely to adopt environmental strategies. The authors take as sustainability-oriented companies those included in the Dow Jones Sustainability World Index (DJSWI), and measure firms' involvement in green product development based on the content analysis of firms' websites and sustainability reports. They define green products as products *"designed to minimize environmental impacts during their whole life-cycle"* (Albino et al. 2009, 86) and identify them according to the three types of environmental statements defined in ISO 14021, 14024, and 14025. Their results suggest that green product developers have a higher level of adoption of different environmental strategies than non-developers. Lin et al. (2014) adopt a similar approach, considering as eco-innovators the firms whose products are certified with eco-labels.

6 | Resource and Pollution Management Indicators

Closely related to the idea of "process-sustainable" activities, studies employing resource use and emission management efficiency indicators evaluate the production process as a whole (i.e., from the purchase of raw materials to the transport of final goods). In other words, it is possible to say that these indicators evaluate the environmental performance of the firm as a whole, beyond specific products. According to the stage of production that the

TABLE 4 | Summary of resource and pollution management indicators.

Level of analysis		Indicator
Resource and pollution management	• Energy use	Input management
	• Material use	
	• Water use	
	• Air emissions	Output management
	• Solid and liquid waste	

Source: Authors' elaboration.

indicators evaluate, they can be divided into two groups: the *input indicators*, which measure firm's environmental impact focusing on the beginning of the production process (e.g., energy used, raw materials used), and the *output indicators*, they assess the firm's environmental impact at the end of the production process (e.g., air emission, solid and liquid waste) (Krajnc and Glavic 2003; Wagner 2005). The resource and pollution management indicators identified through the literature review are presented in Table 4. The two groups of indicators are detailed below.

6.1 | Input Management Indicators

6.1.1 | Definition

Input management indicators measure the ability of the firm to use the inputs necessary for its production process in a way that pollutes less than other companies offering the same products or services (Krainc and Glavic 2003; Wagner 2005). The main input management indicators are the following:

- *Energy use indicators*: This set of indicators measures both the quantity and quality of energy used by companies, for example, the total amount of energy used, the specific energy consumption per production, or even the percentage of renewable energy used in the total energy used (Krainc and Glavic 2003).
- *Materials use indicators*: These indicators evaluate the firms' orientation to reduce problematic materials within its input composition and replace them with environmentally safer alternatives (Wagner 2005), for example, the total or the specific material consumption per production unit. Alternatively, indicators that evaluate the quality of the material used can be considered, for example, the amount or share of renewable raw materials employed (Krainc and Glavic 2003).
- *Water use indicators*: This type of indicators assesses the company's ability not to waste water. They can be calculated as the total volume or share of water per production unit (Krainc and Glavic 2003).

6.1.2 | Applications

In the literature, most of the papers using this type of indicators at the microeconomic level employ the energy use indicators, probably because this information is easier to find at the firm level. For instance, Cole et al. (2008) assess the environmental impact of foreign direct investment (FDI) in developing countries, examining how FDI and workers' experience or training in foreign-owned firms influence the environmental performance of local enterprises. To measure this performance, the authors use data on firms' electricity and fuel consumption collected through surveys administered to a sample of manufacturing firms in Ghana. Batrakova and Devies (2012) examine whether exporting improves firms' sustainability in terms of energy use. Using firm-level panel data from the Irish Census of Industrial Production (1997–2007) for the manufacturing sector, they investigate the effect of exporting on energy consumption, measured as the ratio of fuel use to sales. The results suggest that if a firm starts from a low fuel intensity, becoming an exporter increases its fuel intensity. Otherwise, if the firm initially has a high fuel intensity, the exporting status decreases it.

Similarly, Martin (2011) analyzes 19 years of data (1985–2004) from India's Annual Survey of Industries to assess whether trade openness enhances the energy efficiency of the manufacturing sector. Using firm-level data on electricity production, sales, and consumption, as well as fuel expenditures aggregated by industry, she measures energy efficiency through fuel intensity—the ratio of real energy consumed to real output produced. Evaluating the effects of four trade policy reforms (tariffs on final goods, tariffs on intermediate inputs, FDI liberalization, and delicensing), the study finds that trade liberalization leads to improved energy efficiency. Finally, Siewers et al. (2024) examine the relationship between firms' participation in global value chains (GVCs) and their environmental performance. Using data from the World Bank Enterprise Survey Green Economy Module, which records firms' environmental practices, they evaluate the "greenness" of GVC participants based on energy-related measures such as on-site renewable generation, energy efficiency improvements, and energy management. They also incorporate firms' energy use intensity, measured as the ratio of total annual energy costs (electricity and fuel) to total sales.

6.2 | Output Management Indicators

6.2.1 | Definition

Output management indicators measure the firm's environmental performance by assessing the pollutants released into the environment at the end of the production process (e.g., air emissions, solid, and liquid waste; Krainc and Glavic 2003; Wagner 2005). The main output management indicators are:

- *Air emissions indicators*: This set of indicators evaluates the quantity and quality of air pollutants emitted by a firm's production process, for example, the mass of CO2 or SO2 emitted over the total mass of products (Krainc and Glavic 2003). The Greenhouse Gas (GHG)[9] Protocol provides the most widely used international standards and guidelines for corporate GHG accounting and reporting. It distinguishes three emission scopes: *Scope 1*, direct emissions from sources owned or controlled by the company; *Scope 2*, indirect emissions from purchased electricity, heat, steam, or cooling; and *Scope 3*, all other indirect emissions occurring along the value chain, divided into upstream (emissions from suppliers and production inputs) and downstream (emissions from product use and disposal).
- *Solid and liquid waste indicators*: These indicators measure the quantity and quality of solid and/or liquid waste released into the environment by a firm's manufacturing process, for example, solid or liquid waste mass, recycled solid waste mass over total mass of solid waste (Krainc and Glavic 2003).

These indicators can be calculated as a total volume or as volume per unit produced. Some papers, such as Krainc and Glavic (2003), include the product-level indicators discussed in Section 5.1 among the output management indicators, given that products can be considered as part of a firm's output.

6.2.2 | Applications

In the literature, the papers employing this type of indicators at the microeconomic level use information about firms' air emissions (Imbruno et al. 2025) or combine the three (e.g., air emissions, solid waste, and liquid waste; see, e.g., Cui et al. 2016; Cui and Qian 2017; Earnhart and Lizal 2006; Holladay 2016; Holladay and LePlue 2021; Iwata and Okada 2011; King and Lenox 2001; Konadu et al. 2022; Konar and Cohen 2001; Tang et al. 2025; Ye et al. 2023).

Konar and Cohen (2001) find a significant positive relationship between environmental performance and the market value of publicly traded firms in the Standard & Poor (S&P) 500. Among their measures of firms' environmental performance, one relates to the emissions of toxic chemicals, proxied by the TRI88 index, which gives the aggregate pounds of toxic chemicals emitted per dollar of firm revenues. The list of toxic chemicals is provided by the US Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI),[10] in 1988.

Similarly, King and Lenox (2001) demonstrate that firms' environmental and financial performance go hand in hand, proxying a firm's pollution level with its amount of toxic chemical emissions. Again, toxic chemicals are identified from the list in the EPA's TRI

Holladay (2016) investigates whether there is a relationship between international trade, namely the firms' export and import orientation, and the environmental performance at the plant level, considering a sample of 35,000 manufacturing establishments in the United States over 1990–2006. To proxy for establishments' level of pollution, he employs three different measures: first, he uses an establishment-level measure of the hazard score, an indicator that measures the hazard level of a plant's emissions based on the quantity and toxicity of the released substances, without considering where the substances are released or who might be exposed; second, he uses pounds of toxic emissions; and, third, he employs a plant-level risk score, an indicator similar to the hazard score but also accounting for where the substance is released and its actual impact on human health. All these data are collected from EPA's Risk-Screening Environmental Indicators (RSEI) annual reports.

Konadu et al. (2022) analyze the impact of board diversity on firms' environmental sustainability in terms of carbon emissions reduction, employing firms' self-declared total GHG emissions in a million metric tons as their dependent variable. They find a significant negative relationship between firms' board gender diversity and carbon emissions.

Barrows and Ollivier (2018) analyze how product mix influences firms' greenness, defining the cleanest firms as those with the lowest emission intensity. The study connects input and output management indicators by using firms' energy consumption data to estimate CO_2 emissions per unit of output as a measure of environmental performance. Since energy use alone does not accurately reflect pollution levels, given that emission rates vary by technology, the authors convert each type of energy into emissions using constant conversion factors, providing a more precise measure of pollution intensity.

The recent study by Imbruno et al. (2025) employs firm-level emission data from the European Union Transaction Log (EUTL) to study the impact of foreign acquisitions on the emissions of acquired firms participating in the European Union Emissions Trading System (EU ETS).

7 | Investment, Innovation, and Commitment Indicators

Recognizing the key role of firms' strategic commitment to the green transition in shaping long-run incentives, accessibility, and usage of green technologies, many studies assess firms' environmental sustainability through their commitment to adopt environmentally sustainable practices and cleaner technologies. Investment, innovation, and commitment indicators cannot be univocally linked to either products or processes. They capture firms' overall effort to reduce pollution and improve resource efficiency, reflecting their broader engagement in minimizing the environmental impact of production activities and products. According to the dimension of firms' environmental effort being evaluated, the indicators can be grouped into two categories. The first includes indicators of firms' *investments in eco-innovation, green technologies, and green practices*, which capture their proactive commitment to reducing the environmental impact of their activities (Colombelli et al. 2015; Lee and Min 2015). The second refers to firms' *level of environmental disclosure*, reflecting the current extent of their engagement in environmental practices and the transparency with which they report their environmental performance (Almaqtari et al. 2023; Eccles et al. 2014; Hardcopf et al. 2024). Table 5 provides an overview of the investment, innovation, and commitment emerging from the literature. The two groups of indicators are detailed below.

TABLE 5 | Summary of investment, innovation, and commitment indicators.

Level of analysis	Indicator
Investment, innovation, and commitment	Investment in eco-innovation, green technologies, and green practices • Green patents • Green R&D expenditures • Investment in green technologies and green practices Environmental disclosure, • Environmental certifications • CDP Score • Financial ESG indices

Source: Authors' elaboration.

7.1 | Investment in Eco-Innovation, Green Technologies, and Green Practices Indicators

In the literature, many studies assess a firm's greenness through its level of eco-innovation or, more generally, through its investments in green technologies and practices. Eco-innovation (also called *environmental* or *green innovation*) is a broad and widely studied concept (Castellacci and Lie 2017; Galbreath et al. 2021; García-Granero et al. 2018; Ghisetti et al. 2015; Horbach 2016; Konadu et al. 2022; Lee and Min 2015; Marcon et al. 2017; Vasileiou et al. 2022), receiving significant institutional attention for its potential to promote sustainable production while sustaining economic growth[11] (European Commission 2022). The European Environmental Agency (EEA) defines eco-innovation as *"any innovation that makes progress towards a more green and sustainable economy by reducing environmental pressures, increasing resilience, or using natural resources more efficiently"* (EEA 2024).[12] To offer a conceptual clarification of eco-innovation and discuss possible indicators to measure it, the European Commission founded the so-called Measuring Eco-Innovation (MEI) project.[13] The MEI project further refines the concept of eco-innovation as *"the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"* (Kemp and Pearson 2008, 4).

The measurement of firms' eco-innovation can further be articulated at different levels of analysis. Marcon et al. (2017) propose four types of eco-innovation: (1) *product eco-innovations*, improvements reducing the environmental impact of products (e.g., the extension of product life or the replacement of the material used with recyclable material); (2) *process eco-innovations*, technological or procedural changes enhancing production sustainability (e.g., introduction of cleaner technologies); (3) *organizational eco-innovations* structural or managerial changes promoting sustainability (e.g., investment in human resources specialized in environmental issues.); and (4) *marketing eco-innovations* refer to environmentally oriented marketing and distribution practices (e.g., introduction of environmentally friendly distribution processes). Following this classification, García-Granero et al. (2018) propose a literature review of eco-innovation indicators at the firm level. They find 30 main indicators used in the literature, split into the four types of eco-innovations.

Our review of the existing literature shows that studies evaluating firms' greenness by measuring their proactive engagement in eco-innovation activities and green practices mainly rely on three key types of indicators: (1) number of green patents; (2) green R&D expenditures; and (3) investment in green technologies and practices.

7.1.1 | Green Patents

7.1.1.1 | Definition. The number of patent applications filed by firms is widely employed as a measure of their commitment to innovation because it reflects innovations that are novel, inventive, and have an industrial application (Kemp and Pearson 2008), so they give information about the firms' technological innovation achievement (Desheng et al. 2021; Favot et al. 2023; Hoang et al. 2020). A key advantage of patents is that they provide detailed technological information, and all patent data is publicly available. In this vein, green patents can be taken as a measure of firms' eco-innovation level (Chen and Ma 2021; Favot et al. 2023; Ghisetti and Quatraro 2017; Javed et al. 2023; Kemp and Pearson 2008; Luo et al. 2025; Tao et al. 2024; Wang et al. 2024; Xiong et al. 2025).

Green patents are patents that cover inventions involving green technologies, i.e., technologies that aim to reduce environmental pollution and/or improve the use of natural resources (Favot et al. 2023). Favot et al. (2023) collect different methodologies to select green patents. They state that green patents can be classified according to four criteria: classifications based on codes (e.g., IPC—International Patent Classification and CPC—Cooperative Patent Classification), keywords, a combination of both, and manual selection.

Some international institutions propose classifications and methodologies to identify green patents. In 2010, the World Intellectual Property Organization (WIPO), in collaboration with the United Nations Framework Convention on Climate Change

(UNFCC) and the Intergovernmental Panel on Climate Change (IPCC), publicly provided the IPC Green Inventory list that collects IPC codes related to the so-called Environmental Sound Technologies (ESTs; Bisio et al. 2025; Favot et al. 2023). In 2011, the OECD developed the OECD Indicator of Environmental Technology (OECD-ENVTECH indicator) that includes 7 IPC categories considered as environmental (Colombelli et al. 2015). The European Patent Office (EPO), in 2012, proposed a new classification, the Y02/Y04S tagging scheme, to capture climate change mitigation technologies, in terms of buildings, energy, transportation, and capture, storage, and disposal of GHG (Colombelli et al. 2015; Favot et al. 2023). Finally, in 2015, the OECD provided a comprehensive methodology to measure innovation in environmental-related technologies (Haščič and Migotto 2015).

7.1.1.2 | Applications. Many papers in the literature evaluate firms' environmental commitment using information about green patent data (Agostino and Randinella 2025; Castellani et al. 2022; Colombelli et al. 2015; Hu et al. 2023; Marín-Vinuesa et al. 2020; Zhao et al. 2023).

Colombelli et al. (2015) investigate the impact of eco-innovation on firms' growth processes, mainly focusing on the high-growth firms, that is,' "gazelles." They regress firms' sales growth on the firms' eco-innovation effort, measured by whether the firm has produced at least one green patent according to the WIPO IPC green inventory. Their results show that eco-innovations tend to augment the effects of generic innovation on firms' growth, and this is particularly true for gazelles, which actually appear to run faster than the others.

Marín-Vinuesa et al. (2020) employ a similar metric to analyze the impact of eco-innovation on corporate financial performance. In their case, the data on companies' investments in eco-innovation and green patents are drawn from ad-hoc surveys, in which they asked firms to indicate the extent to which they carried out different eco-innovation activities and whether they had registered green patents in the last three years. Their results show that, although there is a positive relationship between investment in resources and the financial performance of eco-innovative companies, the possession of green patents does not have a significant direct impact on financial performance.

Green patents can also be used to classify firms' activities and regional specialization. For instance, Castellani et al. (2022) investigate the effects of greenfield FDIs on regional specialization in environmental technologies, testing the hypothesis that green-tech FDIs in R&D have the largest effect on regional green-tech specialization. They define green-tech FDI based on the share of total environmental patents over total inventive activities in the industry, and measure regional green-tech specialization with the number of green patent applications filed in that specific region. To this end, they retrieve patent applications data at the EPO from the OECD-REGPAT database, and identify regional green patents based on the OECD-ENVTECH indicator.

Finally, Zhao et al. (2023) examine how institutional investors influence firms' green innovation, distinguishing between green management innovation (GMI), the improvement of organizational and environmental management practices, and green technology innovation (GTI), the development of new green products or processes through technological means. Firms' GMI is measured using a dummy variable equal to 1 if the firm holds ISO 14001 certification (see Section 7.2) and 0 otherwise, while GTI is evaluated through data on green patents obtained from the China National Intellectual Property Administration (CNIPA) for 2013–2019, where green patents are identified according to the IPC Green Inventory.

7.1.2 | Green R&D Expenditures

7.1.2.1 | Definition. Another core measure of innovation for firms is their expenditures on research and development (R&D) activities. In turn, the investments in *green* R&D represent a good proxy of eco-innovation, as they capture the firms' attempts and actual capabilities to use internal resources to improve productivity, efficiency, and environmental impacts (Lee and Min 2015). Chen and Chen (2021) show that the extent to which R&D activities react to CO2 emissions is a key driver of firms' eco-innovation commitment.

In practice, however, firms declare their general R&D expenditures in the financial statement, but they do not always declare the percentage allocated to green R&D. Hence, this information must be retrieved by specialized surveys and databases, or estimated. Key resources in this regard are the Asset4 database, where eco-innovation is measured as the "percentage of commitment and effectiveness in advancing R&D of eco-efficient products and services" (Konadu et al. 2022, 6), and the Nikkei Economic Electronic Databank System (NEEDS), which distinguishes between general and green R&D spending.

7.1.2.2 | Applications. Lee and Min (2015) analyze the effect of firms' eco-innovation activities on environmental and financial performance using data from Japanese manufacturing firms between 2001 and 2010. Eco-innovation is proxied by green R&D expenditures, derived from the NEEDS database. The results show that investments in green R&D reduce carbon emissions, indicating improved environmental performance, and enhance firm value.

Another study that considers the firms' eco-innovation is Konadu et al. (2022). It investigates how board diversity affects firms' carbon emissions reduction and whether environmental innovation moderates this relationship, employing a sample of companies listed on the S&P 500 index from 2002 to 2008. Drawing on the environmental innovation score of the Asset4 database, they demonstrate that eco-innovation amplifies the effects of board gender diversity on reducing firms' carbon emissions.

7.1.3 | Investment in Green Technologies and Green Practices

7.1.3.1 | Definition. This indicator assesses firms' sustainability by looking at their investments in different types of green practices. This refers to the expenses that companies sustain to invest in technologies related to environmental protection (Chen and Ma 2021; Garcia-Quevedo et al. 2022), but also to a broader range of green purchasing strategies, defined as *environmentally conscious purchasing practices that reduce waste* *and promote recycling and reclamation without compromising material performance* (Min and Galle 2001, 1223). This includes expenses to reduce the environmental impact in administrative work, improve the recycling of residues and reduce waste, and train employees in environmental practices (Aguilera-Caracuel et al. 2012). García-Quevedo et al. (2022) distinguish between two types of green technologies: end-of-pipe and cleaner production technologies. End-of-pipe technologies mitigate environmental impacts at the end of the production process (e.g., air filters). In contrast, cleaner production technologies combine environmental and economic benefits by improving resource efficiency and reducing emissions, while also lowering operating costs and enhancing competitiveness over time. Energy-saving technologies are a key example of this second category.

7.1.3.2 | Applications. Many papers employ the investment in green technologies (also referred to as clean technologies) and green practices (Aguilera-Caracuel et al. 2012; Le 2022; Min and Galle 2001; Neumann 2021; Nguyen and Adomako 2022; Zeng et al. 2010) as a measure of the level of firms' greenness (Antonietti and Marzucchi 2013; Borghesi et al. 2015; Chen and Ma 2021; Forslid et al. 2018; Kaiser and Schulze 2003; Siewers et al. 2024)

Given that the destination of firms' investment is unavailable from administrative and balance sheet data, in most studies, the authors retrieve information from ad-hoc firm surveys. Yet, a growing stream of research is emerging that employs web scrapers and machine learning algorithms to identify green firms based on their green practices (Colombelli et al. 2024; Colombelli et al. 2025; Gidron et al. 2023; Jha and Pande 2024; Tiba et al. 2021). For this reason, we distinguish between two types of applications: *survey-based applications* and *machine learning-based applications*.

7.1.3.3 | Survey-Based Applications. Min and Galle (2001) investigate the factors influencing firms' willingness to invest in green purchasing strategies, as defined above. The study uses this concept to assess firms' environmental responsibility within industries that generate large amounts of scrap and waste. Data were collected through questionnaires sent to firms, asking them to evaluate their level of involvement in green purchasing practices

Zeng et al. (2010) employ cleaner production practices as a measure of firms' environmental commitment, and analyze their impact on business performance in the Chinese manufacturing sector. The study distinguishes between low-cost and high-cost cleaner production activities, where the former involve management and operational improvements, while the latter require significant investments in green technologies and innovations in production processes. To assess the adoption of these activities and thus measure the level of greenness of the firm, the authors sent a questionnaire to their sample of firms, where respondents had to indicate which cleaner production activities they had implemented.

Borghesi et al. (2015) analyze the relationship between the EU ETS[14] and the adoption of eco-innovations by Italian manufacturing firms. The study identifies eco-innovation as the adoption of green technologies aimed at reducing CO_2 emissions and improving energy, drawing on the Community Innovation Survey (CIS) data for the period 2006–2008. The findings show that firms subject to the EU ETS tend to adopt more eco- innovations compared to non-regulated firms, although this effect may be mitigated by sectoral constraints and the stringency of regulation.

Forslid et al. (2018) develop a theoretical model showing that exporting firms tend to be cleaner than non-exporters, where "cleaner" refers to greater investment in abatement technologies. They argue that investment in green technologies depends on production volume, which is linked to productivity and, consequently, to a higher likelihood of exporting — making exporters more environmentally efficient. The authors test this mechanism using Swedish firm-level data, measuring abatement investments through annual survey responses on firms' spending for equipment and technologies aimed at reducing pollution and improving resource efficiency (e.g., energy-saving machinery or air filters).

7.1.3.4 | Machine Learning-Based Applications. Bianchini et al. (2025) and Colombelli et al. (2025) propose AI-based methodologies for the identification of green startups. They define green startups starting from the view that green entrepreneurship is the discovery, creation, evaluation, and exploitation of opportunities to create future goods and services consistent with Sustainable Development Goals, specifically the subset of green SDG targets identified by the 6th Global Environment Outlook (GEO6) included in the guidelines published by the United Nations Environment Programme (UNEP).[15] The authors developed a new AI-based methodology that performs unsupervised topic modelling on text from companies' websites. This machine-learning algorithm detects companies' alignment with green SDG targets, allowing researchers to save time during the data collection phase by avoiding manual information selection or creating ad-hoc surveys. The study draws on earlier efforts that, in a similar spirit, employed keyword searches, web scrapers, and machine learning approaches to extract information publicly available on firm websites (Colombelli et al. 2024; Gidron et al. 2023; Jha and Pande 2024; Tiba et al. 2021).

7.2 | Environmental Disclosure Indicators

These indicators measure the current level of a firm's engagement in environmental practices and the transparency with which it discloses its environmental performance (Almaqtari et al. 2023; Hardcopf et al. 2024). The main indicators in this category identified in the literature are: (1) *environmental certifications*; (2) *the CDP Score*; and (3) *financial ESG indices*.

7.2.1 | Environmental Certifications

7.2.1.1 | Definition. Firms' environmental commitment beyond the sustainability of specific products can also be formally certified by third parties with environmental certifications issued both by private organizations, such as ISO 14001 and ISO 50001 (certifications of compliance with international standards for environmental and energy management systems developed by the ISO)[16] and B Corp (a certification granted by the non-profit B Lab assessing overall social and environmental performance),[17] and by public authorities, such as the EU Eco-Management and Audit Scheme (EMAS), established by the European Commission to promote continuous improvement in corporate environmental performance.

The main existing certifications are the ISO 14001 and the EMAS, aiming to certify the implementation of an Environmental Management System (EMS)[18] in the organization. EMS is a set of processes and practices through which an organization manages and improves its environmental impact, focusing on policies, procedures, and audit protocols for activities that generate waste or emissions. Some studies extend this perspective by considering not only efforts within the firm's operational boundaries but also its commitment to reducing environmental impacts across its whole supply chain. Although this article does not examine *green supply chain* practices, readers may refer to the extensive literature on the topic for further insights (Eltayeb and Zailani 2014; Walton et al. 1998; Zhu et al. 2008).

To obtain such certifications, a company must undergo a process that involves the creation, implementation, and verification of the respective standards.

The ISO 14001 international standard specifies the requirements for the implementation of an EMS,[19] providing a framework for organizations that wish to enhance their environmental performance, reduce negative environmental impacts, and ensure compliance with environmental regulations (Balzarova and Castka 2008; Campos et al. 2015).

The EMAS certification was established under the EMAS Regulation (Reg. 1221/2009) of the European Commission to support organizations in enhancing environmental performance, saving energy, and optimizing resource use.[20] As a voluntary policy tool, EMAS requires organizations not only to implement an EMS but also to continuously improve environmental performance beyond legal compliance and to publicly report their results (Testa et al. 2014).

Even though the two standards are similar, they differ in some aspects. EMAS, managed by public authorities, imposes stricter requirements, such as the mandatory publication of the Environmental Statement, ensuring greater transparency. The ISO 14001, on the other hand, is a private standard that is more flexible and widely adopted globally, especially among multinational companies. Moreover, while ISO 14001 has always had international validity, EMAS expanded beyond Europe only in 2010 (Testa et al. 2014).

7.2.1.2 | Applications. Various studies analyze the impact of these certifications on the competitiveness of the companies that obtain them (Freimann and Walther 2001; Iraldo et al. 2009; Testa et al. 2014). Other works, on the other hand, use the presence of these certifications in their analyses as an indicator of the environmental sustainability of companies (Bellesi et al. 2005; Helmina et al. 2022; Lo et al. 2012; Miroshnychenko et al. 2017; Rao and Holt 2005; Teixeira et al. 2016; Zhao et al. 2023).

Rao and Holt (2005) investigate the relationship between green supply chain management, economic performance, and competitiveness in a sample of companies in South East Asia. The authors employ the ISO 14001 certification as an indicator of the presence of formal and structured environmental management practices within companies. Similarly, Teixeira et al. (2016) use the ISO 14001 certification to select their sample companies with a high level of environmental responsibility.

Helmina et al. (2022) examine the impact of adopting a *green industry strategy*[21] on firm market value, considering ISO 14001 certification as an indicator of corporate sustainability and employing the Tobin's Q as the dependent variable. A closely related study by Bellesi et al. (2005) examines the impact of the ISO 14001 certification on Israeli exports. Using a survey of companies in six Israeli trading partner countries, they demonstrate that high levels of sustainability commitment, measured via the ISO 14001 certification, play a significant role in the selection of Israeli suppliers among foreign trade partners.

Finally, as mentioned in Section 7.1, Zhao et al. (2023) assess the role of institutional investors for firms' green innovation employing the ISO 14001 certification as a measure of firms' GMI level.

7.2.2 | The Carbon Disclosure Project Score

7.2.2.1 | Definition. The not-for-profit charity CDP introduced the *Carbon Disclosure Project (CDP) Score* to provide information about the environmental disclosure and environmental performance of entities and organizations (e.g., cities, states, regions, and companies).[22] To the ends of this article, we consider the CDP Score for companies. The score is based on firms' responses to the CDP questionnaire, which gathers information on how they assess, manage, and reduce their environmental impact. The CDP scoring methodology evaluates the quality and completeness of disclosures, the firms' awareness and management of environmental issues, and their commitment to continuous improvement. Companies are rated across four progressive levels of environmental management: (1) *disclosure (D)*, measuring the completeness of a firm's reporting; (2) *awareness (C)*, measuring the comprehensiveness of a firm's evaluation of how environmental issues intersect with its business; (3) *management (B)*, measuring whether a firm is actively managing its environmental impact; and (4) *leadership (A)*, assessing the extent to which the firm acts as a leader and introduces best practices in its strategies. Companies receive a score from D to A. To receive a high score (A or B), firms must demonstrate both awareness of their environmental impact and appropriate actions to reduce it.

7.2.2.2 | Application. We are not aware of many empirical papers that use this firm's sustainability indicator in their analysis. One example is Calza et al. (2016), which investigates the effects of national culture on the environmental proactivity of firms, proxied by their 2012 CDP Score. Their findings suggest that some characteristics of the national culture, such as the values of in-group collectivism, performance orientation, assertiveness, and uncertainty avoidance, have a negative effect on firms' environmental proactivity, while future orientation and gender equality have positive effects.

7.2.3 | Financial ESG Indices

7.2.3.1 | Definitions. Another way to assess firms' environmental commitment is through financial ESG indices, which evaluate the market performance of companies that meet specific Environmental, Social, and Governance (ESG) standards. To determine which firms are included in these indices, each rating agency develops its own ESG score to assess how companies manage risks and opportunities related to these dimensions. Based on these scores, only firms that meet certain thresholds are selected for inclusion in the index. For the purposes of this article, the focus is on the Environmental (E) component, which reflects a firm's commitment to environmental practices and the transparency with which it discloses its environmental impact. Although ESG indices are primarily financial instruments, the set of companies included in them is used in some studies to identify firms with stronger environmental characteristics, making these indices a valuable proxy for measuring corporate "greenness" (Albino et al. 2009; Pérez-Calderón et al. 2012; Swidler and Crutchley 2009).

The most widely used families of indicators in the literature are the S&P Global, the MSCI ESG, and the FTSE Russell. Below, we illustrate their main features.

a. **S&P Global**: S&P Global provides two main ESG index methodologies: the Dow Jones Sustainability Indices (DJSI) and the S&P ESG Index Series. Both aim to guide investors toward more sustainable investments, though they differ in approach and objectives. The DJSI, launched in 1999, were among the first global sustainability indices,[23] and include several regional versions (e.g., DJSI World, DJSI Emerging Markets, DJSI Europe, and DJSI North America). They follow a best-in-class approach, selecting the leading companies in ESG practices based on their S&P Global ESG Score, derived from the annual Corporate Sustainability Assessment (CSA) conducted by S&P Global Sustainable1. Companies invited to participate in the CSA ("Invited Universe") complete an industry-specific questionnaire covering economic, environmental, and social dimensions. Firms achieving at least about 45% of the top CSA score enter the "Eligible Universe," from which the best-performing companies in each sector are selected for inclusion in the DJSI.[24]
   In contrast, the S&P ESG Index Series uses an exclusion-based approach, mirroring the composition of its underlying market indices while excluding companies that do not meet minimum ESG standards or are involved in controversial sectors such as weapons, tobacco, or thermal coal (S&P Dow Jones Indices 2024).
b. **Morgan Stanley Capital International**: The Morgan Stanley Capital International (MSCI) provides a family of ESG indices known as the MSCI ESG Leaders Indexes. Company selection is based on the MSCI ESG Ratings, which assess "a company's resilience to long-term, financially relevant ESG risks." Using a rule-based methodology, these ratings identify the most material ESG risks and opportunities for each sector and evaluate firms accordingly, assigning scores on a AAA–CCC scale based on their exposure and management of such risks. The MSCI ESG Leaders Indexes include firms that demonstrate a superior capacity to manage ESG risks and opportunities compared to industry peers, while excluding companies involved in controversial activities such as weapons, gambling, or tobacco (MSCI 2024).
c. **FTSE Russell**: In line with the financial indices discussed above, FTSE Russell has developed the FTSE4Good Index Series (e.g., FTSE4Good All-World Index, FTSE4Good Developed Index, FTSE4Good Europe Index; FTSE Russell 2024a). To be eligible for inclusion, firms must be constituents of a defined underlying index (e.g., the FTSE All-World Index for the FTSE4Good All-World Index) and meet the FTSE4Good Eligibility Criteria based on their ESG Score, derived from FTSE Russell's ESG Data Model. This model assesses companies' exposure to ESG risks and their ability to manage them, assigning scores built around three Pillars—Environmental, Social, and Governance—further divided into 14 Themes (e.g., biodiversity, climate change, pollution and resources, water security). Each Theme is evaluated through over 300 indicators, combining measures of a company's exposure to specific ESG issues and its management performance. Companies from developed markets must achieve an ESG Score of at least 3.3, while those from emerging markets must score at least 2.9 to be included. As with other sustainability indices, firms involved in controversial activities, such as the weapons industry, are excluded (FTSE Russell 2024a; 2024b).

7.2.3.2 | Applications. Our review reveals a paucity of empirical papers using financial indices to assess the sustainability of companies within their analysis. Moreover, among those few, most works use financial indices at the sampling stage to create the sample of companies (Albino et al. 2009; Swidler and Crutchley 2009; Pérez-Calderón et al. 2012), and only a minority use them to construct a variable within the analysis (Lassala et al. 2017). This may be attributed to the limited time variation available in these indices.

Albino et al. (2009) employ the list of companies in the DJSI in 2004 to identify firms with a sustainable orientation. Similarly, Pérez-Calderón et al. (2012) use the Dow Jones Sustainability Index Europe to select a sample of firms that can be considered environmentally sustainable, to understand the relationship between companies' environmental performance and the generation of firm value. The choice to consider companies included in the DJSI Europe allows the authors to have easy access to the financial and economic information of the companies since they are listed on the market and the information is publicly available, and to be certain that they are companies with a high commitment to environmental practices.

Lassala et al. (2017) propose a similar analysis to Pérez-Calderón et al. (2012). They investigate the relationship between environmental performance and financial performance using the FTSE4Good IBEX (i.e., the FTSE4 Good index that has as the underlying index the FTSE Spain All Cap) to distinguish the green firms from non-green ones. They assess Spanish firms' environmental performance by considering their inclusion in the FTSE4Good IBEX index, assuming that constituent companies are environmentally and socially responsible. In particular, they construct a dummy variable, which is equal to 1 if the firm is included in the FTSE4Good IBEX, and 0 otherwise.

8 | Discussion

From the analysis of the existing literature, it emerges that certain indicators are more commonly used than others to measure firms' environmental sustainability. Specifically, among the papers we reviewed, the most frequently adopted indicators are output management indicators, investment in green technologies and green practices, and product-level indicators (especially EGs). These are followed by green patents, environmental certifications, and financial ESG indices. In contrast, the least utilized indicators are input management indicators and green R&D expenditures.

These preferences may be driven by several factors, one of which is the ease of data access. Firm-level data on some of the most widely used indicators, such as product-level indicators, particularly EGs, and green patents, can be obtained from readily accessible databases. For instance, as previously mentioned, UN COMTRADE provides data for product-level indicators at the country level, but equivalent firm-level databases are also available. Similarly, WIPO serves as a key source for green patent data. Due to their accessibility, these indicators are frequently utilized in empirical analyses.

Yet, some indicators that are comparatively challenging to obtain, for example, output management indicators and investment in green technologies and practices, are still used more frequently than other similar indicators like input management indicators and green R&D expenditures. This could be because the former measures provide a more accurate measure of a firm's environmental impact compared to the latter. For example, two firms consuming the same amount of energy (an input management indicator) might produce different levels of pollution (an output management indicator) depending on the efficiency and type of technology they employ (an investment in green technology indicator; Barrows and Ollivier 2018). Therefore, utilizing output management indicators and investment in green technologies and practices provides a more accurate measure of a firm's environmental impact compared to relying on input management indicators.

Another important point to consider is the association between the type of indicator and the firm aspect to be evaluated. In the analyzed papers, the authors show some preference in the association between the type of indicator and the firm aspect to be evaluated. In particular, product-level indicators, especially EGs, are mainly used to measure the greenness of companies' trade (or countries' trade). The other two categories of indicators (i.e., resource and pollution indicators and investment, innovation, and commitment indicators) are mostly used to assess the environmental performances of companies as a whole, based on the entire production process (from the purchase of raw materials to the transport of final goods). Moreover, green patents and investments in green technologies are often used to evaluate the firms' eco-innovation level.

Finally, an important aspect to consider when evaluating these indicators is their traceability over time, meaning that it is possible to observe how they change over time for the same firm or group of firms. In fact, not all the indicators examined in this study can be tracked over time, making them unsuitable for analyses that assess changes in the greenness of the same sample of firms over time.

Product-level indicators and resource and pollution management indicators are all trackable over time. For example, if we assess firms' greenness by considering the percentage of EGs it trades or produces, we can track how this percentage evolves over time. This allows us to determine whether a firm is becoming more or less green over time, or if it has changed its level of greenness in response to a specific event. The same logic applies to indicators measuring pollutant emissions or natural resource usage—although changes may take longer to observe. Moreover, these two types of indicators enable the classification of firms into different levels of greenness. Returning to the previous example, a firm that produces or trades a higher percentage of EGs can be considered greener than one with a lower percentage.

On the other hand, all indicators of green investment, innovation, and commitment can be tracked over time. Green patents, for example, are often used to create a dummy variable indicating whether a firm has registered at least one green patent. This shows when a firm becomes green but not how its level of greenness changes. The indicator becomes time-traceable only when dynamically considering the number of green patents. The same applies to green R&D expenditures and investments in green technologies or practices: many studies record only whether a firm has invested, without capturing how these indicators evolve. Time variation becomes observable when longitudinal data are available, and the analysis includes the actual amounts spent. Finally, environmental certifications and ESG indices also indicate when a firm becomes green, but they do not allow tracking how its greenness evolves over time.

9 | Conclusion

In recent years, we often talk about environmental sustainability and tend to compare the greenness of different activities, products, and companies. This implies the need to be able to measure the level of greenness of an activity, product, or firm, and to state on the basis of which indicators the evaluation of this level takes place. In this article, we have collected as many possible indicators used in the literature to assess, measure, and compare the greenness levels of different firms. Moreover, we have classified the indicators according to the firm's aspect that they consider.

The main findings of this analysis suggest, first, that researchers in the literature tend to favor certain indicators over others. This preference may be driven by the ease of data availability and the accuracy with which an indicator can measure a firm's environmental impact.

Second, the authors of the analyzed papers show specific preferences regarding the association between the type of indicator and the firm aspect being evaluated. In particular, *product-level indicators* are primarily used to assess the greenness of companies' trade, whereas the other two categories of indicators, *resource and pollution management indicators* and *investment, innovation, and commitment-related indicators*, are mostly employed to evaluate firms' overall environmental performance.

Finally, not all the indicators examined are trackable over time, meaning that some do not allow for an analysis of changes in the level of greenness of the same firm or group of firms over time. This is a crucial aspect to consider when selecting the most appropriate sustainability indicator for a given analysis.

The broad range of indicators identified in our review calls for future studies to investigate how the employment of an indicator rather than another may influence the estimates of changes in the greenness of companies in response to external shocks (e.g., the introduction of a new environmental policy or a crisis). Our review also points a the simple consideration that different indicators may capture specific aspects of the complex and multifaceted concept of "sustainability."

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available in the supplementary material of this article.

Endnotes

[1] See Eurostat (2016), "Environmental goods and services sector accounts practical guide."

[2] Sustainable finance is the process of taking environmental, social and governance (ESG) considerations into account when making investment decisions in the financial sector. See https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en.

[3] EU taxonomy for sustainable activities, https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en.

[4] https://www.globalreporting.org/standards/standards-development/universal-standards/

[5] See https://www.apec.org/Meeting-Papers/Leaders-Declarations/2012/2012_aelm/2012_aelm_annexC.

[6] The Friends of Environmental Goods include Canada, the European Union, Japan, Korea, New-Zealand, Norway, Chinese Taipei, Switzerland, and the United States.

[7] See also https://www.iso.org/obp/ui/en/#iso:std:iso:14024:ed-2:v1:en.

[8] See https://environment.ec.europa.eu/topics/circular-economy/eu-ecolabel/about-eu-ecolabel_en.

[9] See https://ghgprotocol.org/.

[10] For more information, see https://www.epa.gov/toxics-release-inventory-tri-program.

[11] https://green-business.ec.europa.eu/eco-innovation_en.

[12] https://www.eea.europa.eu/en/analysis/indicators/eco-innovation-index-8th-eap?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b.

[13] https://cordis.europa.eu/project/id/44513/reporting.

[14] For more information, see https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en.

[15] For more information, see https://www.unep.org/resources/global-environment-outlook-6.

[16] For more information, see https://www.iso.org/home.html.

[17] For more information, see https://www.bcorporation.net/en-us/certification/.

[18] See https://www.iso.org/home.html.

[19] For more information, see https://www.iso.org/home.html.

[20] For more information, see https://green-business.ec.europa.eu/emas_en.

[21] With the term green industry strategy, the authors mean "*a series of corporate strategic policies to create low-carbon products and processes based on green growth*"

[22] For more information, see https://www.cdp.net/en/scores/cdp-scores-explained.

[23] https://www.spglobal.com/spdji/en/documents/methodologies/methodology-dj-bic-indices.pdf.

[24] The procedure entails the following three steps: (1) for each industry, companies in the Invited Universe are ranked in descending order of CSA Score; (2) within each sector, companies falling both within the Eligible Universe and the top Target % of the ranked Invited Universe are selected; (3) finally, companies that are within 6.0 points of the last company selected in step 2 are also selected (S&P Dow Jones Indices 2023)

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Appendix

TABLE A1 | Full list of papers.

Sustainability indicator group	Sustainability indicator	Papers
Product-level indicators	Environmental goods	
	Definition	OECD/EUROSTAT (1999) UNCTAD (2003) Hamwey (2005) Steenblik (2005) WTO (2009) Hufbauer and Kim 2010 Belineau and De Melo (2011) Yoo and Kim (2011) APEC (2012) Belineau and De Melo (2013) Sugathan (2013) Sauvage (2014) Hu et al. (2020) Kuriyama (2021) Mao et al. (2023) Mealy and Teytelboym 2022
	Applications	Costantini and Crespi (2008) Sinclair-Desgagné (2008) Brandi et al. (2020) Can, Ahmed, et al. 2021 Can, Ben Jebli, et al. 2021 Dai et al. (2021) Kang and Lee (2021) Liu et al. (2022) Bisio et al. (2025)
	Green labels	
	Definition	ISO (2019) EC (eco-labels) ISO 14024
	Applications	Albino et al. (2009) Lin et al. (2014)
Resource and pollution management indicators	Input management indicators	
	Definition	Krainc and Glavic (2003) Wagner (2005)
	Applications	Cole et al. (2008) Batrakova and Devies (2012) Martin (2011) Siewers et al. (2024)
	Output management indicators	
	Definition	Krainc and Glavic (2003) Wagner (2005)

(Continues)

TABLE A1 | (Continued)

Sustainability indicator group	Sustainability indicator	Papers
	Applications	King and Lenox (2001) Konar and Cohen (2001) Earnhart and Lizal (2006) Iwata and Okada (2011) Holladay (2016) Cui and Qian (2017) Barrows and Ollivier (2018) Holladay and LePlue (2021) Konadu et al. (2022) Ye et al. (2023) Tang et al. (2025) Imbruno et al. (2025)
Investment, innovation, and commitment indicators	*Definition*	Roome (1994) Kemp and Pearson (2008) Colombelli et al. (2015) Horbach (2016) Lee and Min (2015) Castellacci and Lie (2017) Garcia-Granero et al. (2018) Marcon et al. (2017) Galbreath et al. (2021) Konadu et al. (2022) Vasileiou et al. (2022) EC (2022) EEA (2024) UNEP
	Green patents	
	Definition	Kemp and Pearson (2008) Colombelli et al. (2015) Haščič and Migotto (2015) Ghisetti and Quatraro (2017) Hoang et al. (2020) Chen and Ma (2021) Desheng et al. (2021) Favot et al. (2023) Javed et al. (2023) Tao et al. (2024) Wang et al. (2024) Luo et al. (2025) Xiong et al. (2025)
	Applications	Colombelli et al. (2015) Marín-Vinuesa et al. (2020) Castellani et al. (2022) Hu et al. (2023) Zhao et al. (2023) Agostino and Randinella (2025)
	Green R&D	
	Definition	Lee and Min (2015) Chen and Chen (2021)
	Applications	Lee and Min (2015) Konadu et al. (2022)

(Continues)

Sustainability indicator group	Sustainability indicator	Papers
	Investment in green technologies and green practices	
	Definition	Garcia-Quevedo et al. (2022)
	Applications	Min and Galle (2001) Kaiser and Schulze (2003) Zeng et al. (2010) Aguilera-Caracuel et al. (2012) Antonietti and Marzucchi (2013) Borghesi et al. (2015) Forslid et al. (2018) Chen and Ma (2021) Neumann (2021) Le (2022) Nguyen and Adomako (2022) Siewers et al. (2024) Colombelli et al. (2025) Bianchini et al. (2025)
	Environmental certification	
	Definition	ISO (2019) EC (EMAS) Balzarova and Castka (2008) Campos et al. (2015) Testa et al. (2014)
	Applications	Freimann and Walther 2001 Bellesi et al. (2005) Rao and Holt (2005) Iraldo et al. (2009) Lo et al. (2012) Testa et al. (2014) Teixeira et al. (2016) Miroshnychenko et al. (2017) Helmina et al. (2022) Zhao et al. (2023)
	The carbon disclosure project (CDP) score	Calza et al. (2016)
	Financial ESG indices	
	Definition	S&P Dow Jones Indices (2023) S&P Dow Jones (2024) MSCI (2024) FTSE Russell (2024a) FTSE Russell (2024b)
	Applications	Albino et al. (2009) Swidler and Crutchley (2009) Pérez-Calderón et al. (2012) Lassala et al. (2017)

TABLE A2 | Lists of environmental goods.

The lists of Environmental Goods reported in this document are the OECD list, which is the combination of two lists proposed by the OECD, one in 1999 and the other in 2001 (OECD 1999; OECD 2001) containing 130 products, the Friends' list (WTO 2009) containing 154 products, the PEGS list stipulated by the OECD in 2010 which contains 170 products, the list items correspond to the one presented by Sauvage (2014), the APEC list (APEC 2012), containing 54 products, and the CLEG list (Sauvage 2014) which is the combination of the Friends' list, PEGS list and APEC list and contains 248 products. Moreover, the OECD along with the CLEG list, the OECD has proposed two more restricted lists. The Core CLEG that contains 11 HS codes that cover product categories for which environmental products make up more than two thirds of all measured trade, and the Core CLEG$^+$ including 40 HS codes where environmental products account for more than a third of all measured trade (Sauvage 2014). We also include the WTO Reference list (413 products) and the WTO Core list (26 products).

The above-mentioned sources provide the Friend's list, the PEGS list, APEC list, and the CLEG list containing the codes referring to HS 2007, while the codes in the OECD list refer to HS codes prior to 2007, to make the codes uniform we the OECD list's code to HS 2007. The WTO lists are drawn from the 2002 classification.

Moreover, product codes are updated every five years, and some products on the lists have changed codes over the years from those originally assigned in the respective lists at the time of compilation. In particular, we saw that some product categories changed codes in 2007, 2012, 2017, and 2022. To facilitate the use of these lists in future analyses, where relevant, the tables show the changes that occurred between 2002 and 2022.

In the tables referred to as OECD, Friends, PEGS, APEC, CLEG, Core CLEG, Core CLEG$^+$, WTO, and WTO Core we have listed all the changes that have taken place in the respective years. The symbol '-' indicates that the code has not changed since the previous version. Some codes are marked with the symbol '?', indicating that they are codes proposed by the list, but which we could not find in any valid correspondence in later updates of the codes.

The procedure used to convert the codes that change from one year to the next is as follows: we downloaded from the COEWEB[a] site the annual lists, from 2002 to 2022, containing all the NC8 codes (8 digits version of HS6) referring to the year in question. For each code in each of the above-mentioned lists of Environmental Goods, we checked its presence in each year's list. When a code did not appear from a certain year onwards, we went to see which new code that particular description of product category corresponded to. In this way, we created the tables below. As mentioned above, the Environmental Goods lists provide HS codes at the 6-digit level, so our conversion was also done at the same level. Where relevant, we referred to official conversion tables.

Two problems may occur due to the fact that we are considering 6-digit codes:

1. It may be the case that when changing HS6 codes, the underlying NC8 codes are separated into two different HS6 codes after the change, in which case we have included additional HS 6d codes in the list. (ex. In the OECD list we have the codes 285300 with reference to HS2007, that contains the NC8 codes that after the change in 2017 split between 285390 and 285310 with reference to HS2017).
2. It could happen that by changing HS 6d codes, several NC8 codes are merged under the same HS 6d, and the new HS 6d contains more NC8s than the previous one, in which case we cannot do anything about it since the lists of EGs provide a detail up to 6d.

In the referred to as "Comparisons", we make a comparison between the lists, for the HS 2007, HS 2012, HS 2017, and HS 2022 codes.

Finally, in the Table referred to as "Products Description" we report the descriptions of the HS 2007, HS 2012, HS 2017, and HS 2022 codes, provided by BACI CEPII.[b]

This file contains the following information:

1. The list of 6-digit codes that changed in every round of the classification between 2007 and 2022 along with the new codes to which they correspond (sheets 1.1–1.9).
2. Complete index of HS product codes appearing in at least one EG list along with the list to which they belong. The index is compiled for every round of revision of the HS codes from 2007 to 2022 (sheets 2.1–2.4).
3. Reference index of product descriptions for each HS code appearing in at least one EG list. The index is compiled for every round of revision of the HS codes from 2007 to 2022 (sheets 3.1–3.4).

Note: [a] https://www.coeweb.istat.it/. [b] https://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37.