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A Conceptual Framework to Measure Green Innovation in Latin America and the Caribbean

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Abstract[*]

In recent years, countries in Latin America and the Caribbean have made considerable steps forward in the measurement of firm innovation. However, no broad cross-country initiative has been undertaken to measure the state of green innovation (GI) in the region and the dynamics at stake. This document contributes to address this gap by drawing up a conceptual framework for GI measurement in the region. First, it defines the concept of GI and sets a common terminology for the analysis. Second, it reviews some international best practices of GI measurement. Next, it identifies elements that could be either replicated or adapted for LAC countries and links them to a number of policy areas in order to develop an analytical framework that could guide efforts by national statistical offices and other data producers to collect a set of policy-relevant indicators. Alongside traditional measures of GI development and commercialization, particular attention is devoted to GI adoption as well as to elements that favor GI adoption, such as the availability of complementary technologies and vocational and technical skills. Finally, this document briefly analyzes a few cross-country GI indicators already available in LAC countries and discusses the broader measurability of GI data in the region.

JEL codes: C80, O31, O33, O54, Q55
Keywords: green innovation, eco-innovation, environmental innovation, data collection, composite indexes, innovation surveys, Latin America, Caribbean

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1. Introduction

The Sustainable Development Goals (SDGs) set by the United Nations in 2015 aim to guarantee rising prosperity while minimizing the negative impacts of climate change on current natural resources. However, existing production technologies and consumer behavior are expected to produce positive outcomes only up to a point, beyond which depleting natural capital has negative consequences for overall growth and wellbeing (OECD, 2011). In this context, green innovation (GI) and the related process of creative destruction is called to play a fundamental role to decouple growth from natural capital depletion by pushing the frontier outward through the generation of new, environmentally sound technologies, enterprises, and business models, which in turn contribute to the establishment of new markets and, therefore, to the creation of new jobs.[1]

Latin America and the Caribbean (LAC) are already suffering from adverse impacts of climate change, such as exacerbation of water scarcity, increase in rainfall and flooding, rise in sea levels, and losses in biodiversity (IDB, 2014). In terms of economic costs, aggregate estimates indicate that a 2.5°C rise in temperature for the region will decrease its present GDP by between 1.5 percent and 5 percent (ECLAC, 2015). This will severely affect the already disappointing long-run economic performance of the region, which has been characterized by low productivity growth, due to a general under-investment in science, technology, and innovation (Navarro, Benavente, and Crespi, 2016). Therefore, in the regional context, GI appears particularly important to head off climate change challenges while stimulating more sustainable economic development. This could be achieved through, for example, the availability of cheaper renewable energy, the necessity of less water for agriculture, or the achievement of improved waste-management systems.

Nevertheless, GI policy initiatives in LAC have been relatively scarce and often poorly coordinated (Rovira, Patiño, and Schaper, 2017), failing to achieve significant results. One of the reasons this has occurred is the lack of knowledge in this field, which has limited the capacity of policymakers to design and implement effective interventions. Up until now there has been little comparative evidence on GI efforts and activities in the region (Cervera-Ferri and Ureña, 2017), making it difficult to understand which LAC countries are performing relatively well in terms of GI and which ones are lagging behind or to identify the main drivers and obstacles that are stimulating or hindering GI creation and diffusion. This situation calls for sustained efforts to collect new data and build a solid knowledge base on GI in the region.

While many LAC countries have generally made considerable steps forward in the measurement of firm innovation (Crespi and Peirano, 2007; Guillard and Salazar, 2017), no broad international initiative has been undertaken to measure the state of GI in the region and the dynamics at stake. Some limited evidence is available for a few countries, but data is not comparable, as it has not

[1] Structural change (i.e., the evolution of the economic structure) is strongly intertwined with climate change. Different economic structures, institutional factors, industrial policies, and geographical factors are related to different paths of GI creation and diffusion. For a review and discussion of how different economic models used in the literature to assess climate change integrate aspects of structural change, see Ciarli and Savona (2019).

been collected in a systematic way, following the same guidelines, nor has it been harmonized afterwards. This calls for a conceptual framework that, after setting definitions and a common terminology, could lay the foundation to collect a system of statistics and indicators capturing firms' GI behavior.[2] A comprehensive measurement of GI is crucial for a number of reasons. It helps policymakers to understand and benchmark the overall trends of GI activity, to identify relevant drivers and barriers, and, therefore, to design effective policies and framework conditions. It can also help to raise environmental awareness in firms, especially if the data helps to point out the benefits for companies and sectors (Arundel and Kemp, 2009).

To address the lack of comparable statistics on GI in the region, this document draws up a framework for GI measurement in LAC. In order to do this, first it reviews a few international best practices of GI measurement. Next, it identifies elements that could be either replicated or adapted for Latin American and Caribbean countries and links them to a number of policy areas in order to develop an analytical framework that could guide efforts by national statistical offices and other data producers to collect a set of policy-relevant indicators. Alongside traditional measures of GI development and commercialization, particular attention is devoted to GI adoption as well as to elements that favor GI adoption, such as the availability of complementary technologies and vocational and technical skills.

This technical note is organized as follows: Section 2 briefly defines the concept of GI and sets a common terminology for the analysis. Section 3 reviews the main international best practices on GI measurement. Section 4 develops a conceptual framework that advances some proposals for specific indicators that could be considered for a pilot data collection exercise. Section 5 briefly analyzes some cross-country measures on GI available for LAC countries and discusses the measurability of such data. Section 6 draws some conclusions.

2. What Is Green Innovation?

Different terms and concepts have been used to define innovations that aim at reducing negative environmental impacts. Among them, green innovation (GI), eco-innovation, environmental innovation, and sustainable innovation have been the most common ones. In line with Kemp and Pearson (2007), we define GI as *new or significantly improved goods and services, processes, marketing methods, organizational structures, and institutional arrangements that—with or without intent—lead to environmental improvements compared to relevant alternatives*.[3]

[2] Even though, besides firms, other actors (e.g., universities, governmental organizations, non-profit organizations, individual inventors) play important roles in producing and/or adopting GIs, this conceptual framework focuses deliberately on *firm* GI behavior.

[3] Several other definitions have been suggested by academics and practitioners. The World Bank defines green innovation as "the development and commercialization of new ways to solve environmental problems through improvements in technology, with a wide interpretation of technology as encompassing product, process, organizational, and marketing improvements" (World Bank, 2012). More narrowly, the United Nations Industrial Development Organization defines it as "products that reduce their overall life-cycle environmental impacts by favoring reparability, disassembly, recyclability and recoverability" (UNIDO, 2015). The EU Eco-Innovation Observatory defines it as "the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle" (EIO, 2012). The United Nations Environment Programme defines it as "the development and application of a business model, shaped by a new business strategy,

The environmental benefit can occur when the introduced innovation reduces the use of natural resources, decreases the production of pollution (in terms of air, water, soil, or noise pollution), replaces environmentally harmful substances with less harmful ones, or has longer service life or a better recyclability than relevant alternatives. This benefit can either be the primary goal or an unintended side effect of the innovation. In line with the Oslo Manual definition, the diffusion and adoption of green solutions new to the firm, but already existing on the market, is also considered a GI (OECD, 2018). Following the globally recognized methodology for the collection and use of innovation statistics set in the Oslo Manual (OECD, 2018), we can distinguish two broad categories of GI:

- **Product GI:** a new or improved good or service that leads to significant environmental improvements compared to the good or service previously produced or used by the firm.
- **Business-process GI:** a new or improved business process for one or more business functions that has been brought into use by the firm and that generates environmental improvements compared to the business processes previously used by the innovating firm.[4]

These types of GI are not mutually exclusive; that is, one green innovation could be a product and a business-process GI at the same time. For example, the introduction of refillable soap bottles may represent both a product and a business-process (more specifically, a marketing) GI. The most relevant types of GIs in Latin America and the Caribbean include the following:

- Green energy technology (renewables including hydropower as well as more fuel-efficient energy conversion technologies)
- Agricultural practices that use less pesticides and herbicides (reducing harm to plants, bees, and humans)
- Energy-efficient process technologies
- Waste prevention and reuse of waste
- Waste treatment
- Water conservation and treatment of polluted water
- Better logistics resulting in less food waste and energy use
- Energy-efficient houses and consumer products
- More sustainable forms of packaging

which incorporates sustainability throughout all business operations based on life cycle thinking and in cooperation with partners across the value chain" (UNEP, 2014).

[4] Note that the taxonomy of business functions introduced in the new version of the Oslo Manual (OECD, 2018) maps reasonably well the categories of *process*, *marketing,* and *organizational* innovation defined in the previous version of the Oslo Manual (OECD, 2005). Following the previous categories, *process GI* can be defined as a new or improved process that generates environmental improvements compared to the processes previously used by the innovating firm; *organizational GI* could be defined as a new or improved organization method that generates environmental improvements compared to the organization methods previously operated by the firm; finally, *marketing GI* could be defined as a new or improved marketing or commercialization method that leads to lower environmental impacts compared to other marketing or commercialization methods previously operated by the firm.

However, it is important to note that GI refers to the first-time introduction or use of a (new) green technology or process by a firm. For example, both the use of a waste-treatment method that is new to the world as well as the first-time use by a firm of an existing one are considered GIs.

As we defined before, GIs are more environmentally friendly than relevant alternatives. Like should be compared with like. For instance, a new process technology should be compared with the one in use. Whether a product or process is more environmentally benign should be determined on the basis of an *environmental life cycle analysis*. Environmental Life Cycle Assessment (E-LCA) evaluates the environmental impacts from producing, transporting, using, recycling, and discarding a product. Producing includes all stages of the value chain, including the extraction of resources and the production of intermediary products and equipment to produce the product. E-LCA has been standardized in the ISO 14040 and 14044 standards. It is appropriate for different types of eco-innovation, including product, process, organizational, and system eco-innovation (Kemp et al., 2019). Further research is needed to integrate E-LCA with social cost-benefit analysis, providing a more comprehensive perspective on the environmental impact of a product or process.

3. Green Innovation Measurement: State of the Art and Best Practices around the World

In recent decades, the international community has increasingly recognized the importance of GI for promoting sustainable economic growth. Hence, more and more attention has been devoted to study, conceptualize, and measure this specific kind of innovation. Dedicated international projects have been developed to monitor GI across different dimensions and geographies. This section reviews four broadly used indicator systems that cover different aspects of GI: the European Union Eco-Innovation Scoreboard, the Asia-Europe Meeting (ASEM) Eco-Innovation Index, the OECD Green Growth Indicators, and the Global Cleantech Innovation Index.

The Eco-Innovation Scoreboard, developed by the Eco-Innovation Observatory and funded by the European Union, gathers a set of indicators in order to measure the strengths, weaknesses, and GI performance of 28 European Union countries. The 16 indicators—collected from different sources—encompass five key areas: (i) eco-innovation inputs, (ii) eco-innovation activities, (iii) eco-innovation outputs, (iv) resource efficiency, and (v) socioeconomic outcomes (see Table 1). For each indicator and each country, a score is assigned relative to the EU average (which scores 100). This also allows for an overall score (calculated as the average of the 16 indicators) and therefore an estimate of how well a country is doing in terms of GI compared to the others.

Table 1. The System of Indicators of the EU Eco-Innovation Scoreboard

Area	Index Name
Inputs	Government's environmental and energy R&D appropriations and outlays
	Total R&D personnel and researchers (% of total employment)
	Total value of green early stage investments (USD/capita)
Activities	Firms that have implemented innovation activities aimed at a reduction of material input per unit output (% of total firms)
	Firms that have implemented innovation activities aimed at a reduction of energy input per unit output (% of total firms)
	ISO 14001 registered organizations (per mill. population)
Outputs	Eco-innovation–related patents (per mill. population)
	Eco-innovation–related academic publications (per mill. population)
	Eco-innovation–related media coverage (per number of electronic media)
Resource Efficiency	Material productivity (GDP/domestic material consumption)
	Water productivity (GDP/water footprint)
	Energy productivity (GDP/gross inland energy consumption)
	GHG emissions intensity (CO_2 equivalent/GDP)
Socioeconomic Outcomes	Exports of products from eco-industries (% of total exports)
	Employment in eco-industries and circular economy (% of total employment across all companies)
	Revenue in eco-industries and circular economy (% of total revenue across all companies)

Source: EIO (2018).

The ASEM Eco-Innovation Index (ASEI) developed by the Asia-Europe Meeting (ASEM) SMEs Eco-Innovation Center (ASEIC) has a broader scope and covers not only European countries but also 21 Asian countries. Similar to the EU Eco-Innovation Scoreboard, the ASEM Eco-Innovation Index includes different indicators whose scales range from 0 to 100 and that rely on a variety of sources (e.g., WEF, INSEAD, Cleantech, Trucost & Sustainalytics, OECD, IEA, EPO, etc.). The scale of the index ranges from 0 (minimum) to 100 (maximum). It includes 20 indicators in four key components: (i) eco-innovation capacity, (ii) eco-innovation supporting environment, (iii) eco-innovation activities, and (iv) eco-innovation performance (see Table 2).

Table 2. The ASEM Eco-Innovation Index Indicators

Area	Index Name	Scoring Method
Eco-Innovation Capacity	Nation's economic competitiveness	WEF GCI for the year
	Nation's general innovation capacity	INSEAD GII for the year
	R&D capacity for environmental sciences	No. of environmental sciences articles for the past 5 years (total) per 10,000 people
	Number of researchers in environmental sciences	No. of environmental sciences article authors
	Awareness of company's sustainability management	No. of companies engaging in sustainable management for the past 5 years (total)
Eco-Innovation Supporting Environment	Government's green R&D expenditure	Government green R&D expenditure
	Impacts of environmental regulations on corporate competitiveness	IMD survey index value for the year
	Corporate priority level of sustainable development	IMD survey index value for the year
	Generation capacity of renewable energy	Renewable energy generation capacity for the year per 10,000 people
Eco-Innovation Activities	Number of companies with green technology	Number of companies with patent applications for the past 5 years
	Firms' participation in environmental management system	Number of environmental certifications for the year per GDP (based on conversion point)
	Industry-academic cooperation on environmental R&D	Average ratio of cooperation for the past 5 years
	Green patents	Share of green patents (of total patents) per year
	Level of renewable energy distribution	Share of renewable energy for the year from the total of primary energy
Eco-Innovation Performance	Quality of life related to environmental impact	Quality of life index for the year
	Greenhouse gas emission intensity	CO_2 concentration per GDP for the year
	Environmental sustainability level	Indexed value of environmental sustainability rank for the year
	Employment rate in green technology industry	Number of green tech industry employees for the year per 10,000 people
	Green industry market size	Average number of family countries per patent

Source: ASEM (2017).

The OECD Green Growth Indicators (GGIs) include a broad set of measures to describe how OECD countries are doing in fostering growth and development while ensuring that natural assets provide the resources and environmental services on which collective well-being relies. They cover 17 macro areas: (i) economic growth, productivity, and competitiveness; (ii) labor market, education, and income; (iii) carbon and energy productivity; (iv) resource productivity; (v) environmentally adjusted multifactor productivity; (vi) natural resource stocks; (vii) renewable

stocks; (viii) non-renewable stocks; (ix) biodiversity and ecosystems; (x) environmental health and risks; (xi) environmental services and amenities; (xii) technology and innovation; (xiii) environmental goods and services; (xiv) international financial flows for green growth; (xv) environmentally related prices and transfers; (xvi) green regulations and management approaches; and (xvii) green training and skill development. These areas comprise both indicators whose basic data are currently available for a majority of OECD countries as well as indicators where basic data is only partially available or is not available for a majority of OECD countries. Several Green Growth Indicators are indirectly related to GI; however, two subsets are directly related to GI: a set of indicators capturing green R&D expenditures and a set of indicators measuring green patents (see Table 3).

Table 3. OECD Green Growth Indicators Directly Related to Technology and Innovation

Area	Index Name
Green R&D	Government's environmental and energy R&D appropriations and outlays
	Total R&D personnel and researchers (% of total employment)
	Total value of green early-stage investments (USD/capita)
Green Patents	Green technology development (number of green patents developed by a country's inventors)
	International collaboration in green technology development (number of patents developed jointly by inventors from at least two countries)
	Green technology diffusion (the number of inventions for which a patent application has been registered in different jurisdictions through national, regional, or international routes)

Source: OECD (2017).

Finally, the Global Cleantech Innovation Index (GCII) developed by the Cleantech Group covers 40 countries, including the G20 as well as nine countries that are not part of the EU Eco-Innovation Scoreboard nor of the ASEM Eco-Innovation Index, three of which are Latin American countries (Argentina, Brazil, and Mexico). It comprises a set of 15 indicators organized over four conceptual areas: (i) general innovation drivers, (ii) cleantech-focused innovation drivers, (iii) emerging cleantech innovation, and (iv) commercialized cleantech innovation (see Table 4).

Table 4. The Global Cleantech Innovation Index Indicators and Sources

Area	Index Name	Source
General Innovation Drivers	General innovation inputs	INSEAD Global innovation Index
	Entrepreneurial culture	Global Entrepreneurship Monitor
Cleantech-Focused Innovation Drivers	Cleantech-friendly government policies	REN21—Renewables Global Status Report; World Bank Group—State and Trends of Carbon Pricing; OECD & Bloomberg Philanthropies—Green Bonds, Policy Perspective
	Government R&D expenditure in cleantech sectors	OECD-IEA database; UN GERD database
	Access to private financing for cleantech startups	Cleantech Group data
	Country Attractiveness of Renewable Energy Infrastructure	Ernst & Young Renewable Energy Country Attractiveness Index
	Cleantech cluster programs & initiatives	Cleantech Group research
Emerging Cleantech Innovation	Patents in cleantech sectors	OECD database
	Early-stage private investment	Cleantech Group data
	High-impact cleantech startups	Cleantech Group data
Commercialized Cleantech Innovation	Trade of cleantech commodities	UN Comtrade
	Renewable energy consumption	BP Statistical Review of World Energy
	Late-stage private investment and exits	Cleantech Group data
	Successful public cleantech companies	Cleantech Group, FTSE, Ardour and WilderHill indices of public cleantech companies
	Renewable energy jobs	IRENA Renewable Energy and Jobs Annual Review

Source: Cleantech Group (2017).

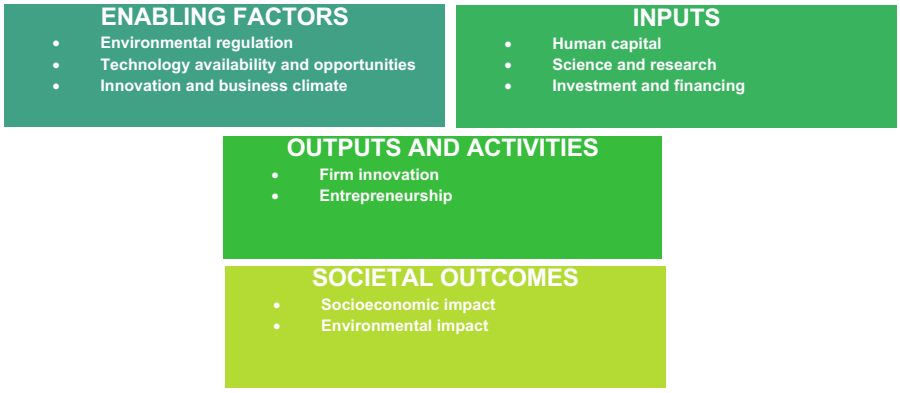
4. A Conceptual Framework to Measure Green Innovation in LAC

A conceptual framework is important to guide statistical offices and other data producers (e.g., ministries and governmental agencies) in their efforts to collect relevant data for measuring GI performance across countries and identifying drivers and barriers, opportunities and risks. It allows for the development of a consistent comparative assessment across countries and the identification of the areas where policymakers need to concentrate their efforts in order to boost GI performance. This conceptual framework builds on the experience of other measurement

frameworks developed in other regions and on the recent Maastricht Manual on Measuring Eco-Innovation for a Green Economy (Kemp et al., 2019),[5] while considering the specificities of the Latin American and Caribbean region, a region characterized by institutional and industrial characteristics often remarkably different from those of more advanced regions. Next to traditional measures of GI development and commercialization, it devotes particular attention to *GI adoption* and to some elements that are very important for technology adoption, such as the availability of *complementary technologies* and of *vocational and technical skills*. When defining such a framework, it is useful to keep in mind that innovation activities occur within different national systems of innovation (NSI) composed of numerous elements such as framework conditions, infrastructure, education and research systems, and political systems.[6]

The present framework is targeted primarily at national statistical offices of the region, as well as researchers, data users, business organizations, and other stakeholders interested in the subject. Apart from its main aim of establishing guidelines for data collection on GI, it can contribute to fostering dialogue and mutual learning across the various LAC actors involved in data collection exercises. The framework distinguishes four main areas to measure GI—enabling factors, GI inputs, GI outputs and activities, and societal outcomes—captured in 10 dimensions, as presented in Figure 1.

Figure 1. A Conceptual Framework to Measure Green Innovation in Latin America and the Caribbean



[5] The Maastricht Manual on Measuring Eco-Innovation for a Green Economy (Kemp et al., 2019) provides a comprehensive overview of how to measure the progress and performance of GI around the world. It offers researchers, policymakers, and statisticians guidance on the measurement of GI to provide high-quality data for research and policies supporting the green economy.

[6] Within the same country, different territories can have very different actors, institutional capabilities, and, hence, very distinctive ways to generate knowledge and promote innovation. This is why, to better understand how innovation activities occur, it may be useful to analyze how Regional Innovation Systems (see for example Cooke, Uranga, and Etxebarria, 1997; Asheim, Smith, and Oughton, 2011) work, rather than national ones. On the other hand, considering the increasing globalization of technological and economic conditions, it would be interesting to adopt global lenses when analyzing the potential impact of sustainable consumption and production (e.g., EEA, 2014; Cantore and Cheng, 2018). Considering that the availability of indicators to measure firms' and institutions' performance in LAC is much broader at the national than the subnational level, this measurement framework focuses on the national level.

Enabling factors illustrates the main conditions, external to the firm, that may facilitate GI. It comprises three dimensions:

- *Environmental regulation*: This dimension measures the extent to which a certain country has implemented environmental rules and policies that favor GI. It measures, for instance, the presence of pollution taxes, emission trading schemes (ETS), or financial subsidies for the adoption of environmentally preferable products. The capacity to formulate, implement, and adapt policies for green technologies requires special intelligence and agencies.
- *Technology availability and market opportunities*: This dimension provides a measure of the availability of complementary technology and market opportunities that can favor GI in a country.
- *Innovation and business climate*: This dimension gives a measure of the culture that facilitates the development of innovation, being that green or traditional, as well as of entrepreneurial activity in a country.

GI inputs includes the main ingredients that firms need to either develop or adopt GI. It comprises three key dimensions:

- *Human capital*: This dimension measures the availability of an educated workforce in subjects that are relevant for GI. It includes both measures of highly skilled workers in STEM and environment-related areas (e.g., number of master and doctoral graduates in environmental engineering) and of workers with environment-related vocational education (e.g., number of solar energy technicians).
- *Science and research*: This dimension captures both the availability of scientific green knowledge (e.g., number of scientific articles in natural sciences published in a certain country) as well as the availability of complementary scientific knowledge (e.g., number of scientific articles in STEM disciplines published in a certain country).
- *Investment and financing*: This dimension captures green investments made in both the public and private sector (i.e., investments in companies or activities that favor the conservation of natural resources, such as energy and environmental R&D investments).

GI outputs and activities describes two different dimensions of GI in the private sector:

- *Firm innovation*: This dimension illustrates to what extent firms of a specific country are active in creating or adopting GI. This could be measured by, for example, the number of green patents registered or by the percentage of firms that have introduced innovation activities aimed at reducing material and energy inputs or by the share of those that obtained relevant environmental certification.
- *Entrepreneurship*: This dimension assesses how a country is doing in terms of cleantech companies, both in early stages and already fully commercialized. This could be measured, for example, by the number of startups in eco-industries or the number of publicly traded cleantech companies operating in a certain country.

Societal outcomes illustrate to what extent GI generates positive socioeconomic and environmental impacts. It includes two dimensions:

- *Socioeconomic impact*: This dimension captures to what extent GI outputs and activities generate positive impacts in terms of firm performances (e.g., revenues and exports in eco-industries) and socially (e.g., employment in eco-industries).
- *Environmental impact*: This dimension captures the environmental impact of GI (e.g., in terms of material productivity, water efficiency, energy efficiency, pollution intensity).[7]

Indicator information on the above issues is essential for tracking progress. To create better policies, policy intelligence is needed about opportunities for innovation and impediments to the exploitation of those opportunities at the sector level and the regional (subnational) level in large countries. Such intelligence requires special measurement activities and the interaction of capable agencies with stakeholders and experts (Miedzinski et al., 2019).

5. A First Overview on Green Innovation Data Availability in LAC Countries

As discussed in the previous sections, little evidence on GI is available in the region, making it difficult to fully understand how much and what kind of GI is taking place in LAC, the conditions that enable or impede it, and its impact. Even less information is available to compare LAC countries to each other or to countries around the world, with the exception of just a few indicators.

Environmental certifications represent a good indicator of the degree of adoption of environmental management practices in companies and are one of the few cross-country indicators available for all LAC countries. The International Organization for Standardization (ISO) publishes yearly the number of certifications of Environmental Management Systems (ISO 14001) by country (ISO, 2018). When looking at the diffusion of ISO 14001 certification, we notice that globally these certifications increased by approximately 180 percent between 2006 and 2017, whereas in Central and Latin American countries they grew by approximately 137 percent. Until 2013, Brazil was the absolute LAC leader in terms of environmental certifications. Colombia—which had almost a nine-fold increase between 2006 and 2017 (+898 percent)—overtook Brazil in 2014 and today leads the regional ISO 14001 ranking together with Brazil, and, further behind, Mexico, Argentina, and Chile (Table 5).

[7] A review of the literature on green or environmental innovation (Barbieri et al., 2016) shows that (country-level) studies on the environmental impact of GI are still scarce and that virtually no sound cross-country analysis has been carried out. Cross-country analysis may be central to understanding how different economic and institutional conditions influence the environmental impact of GI.

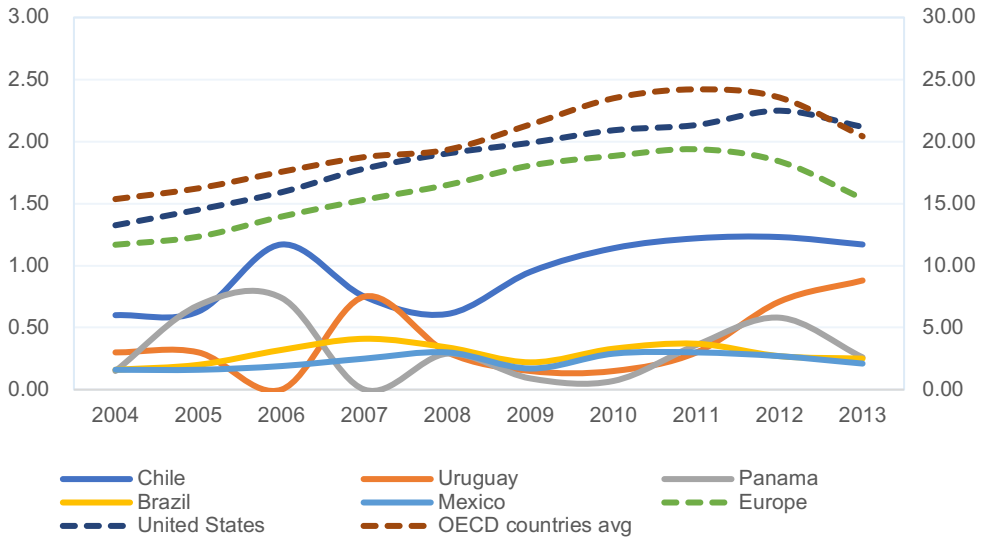
Table 5. Number of ISO 14001 Certificates in LAC Countries, 1999–2017

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	84	114	175	249	286	408	454	862	1011	1163	676	860	784	1268	1308	1339	1422	1619	1458
Bahamas												1	1	135	0	2	3	5	5
Barbados	3	3	3	3			1	1	1	2	3	2	2	4	5	6	6	6	6
Belize			2	2	2		1	2	1	6	4	3	3	3	18		0	1	1
Bolivia		1	3	4	7	14	30	30	32	37	32	23	46	44	53	52	55	52	55
Brazil	165	330	350	900	1008	1800	2061	2447	1872	1428	1186	3391	3517	3300	3695	3220	3113	3076	2948
Chile	5	11	17	55	99	312	277	375	492	686	576	714	617	1080	987	949	1214	1240	1419
Colombia	13	21	41	69	135	217	275	296	309	508	573	1039	1317	1441	2786	3433	2983	2993	2954
Costa Rica	7	20	14	38	38	52	50	55	101	73	90	95	73	81	80	90	111	113	119
Dom. Republic		1	1		1	1	4	2	12	8	25	32	43	31	32	24	28	27	25
Ecuador	1	1	2	1	1	11	14	50	78	98	110	140	113	151	201	189	214	244	192
El Salvador						3	4	4	8	6	12	11	11	14	13	16	14	49	19
Guatemala	1	2	2	1	1	3	7	7	15	18	15	22	18	15	15	22	22	37	18
Guyana			3	3	4	3	1	2			1	1		1	0	1	1	2	2
Haiti																	0	4	2
Honduras		2	2	2	6	5	4	7	18	17	25	9	12	17	14	34	48	30	29
Jamaica			4	1	1	4	5	5	9	11	9	11	9	10	11	10	12	14	119
Mexico	63	159	254	369	406	492	422	409	739	832	870	808	858	1096	1071	1378	1385	1559	1701
Nicaragua						1	2	3	2	4	5	5	6	6	10	8	11	16	15
Panama			1	1	2	2	4	5	31	10	13	14	13	16	19	21	26	31	30
Paraguay		1	1	4	3	3	4	4	6	4	9	4	10	12	14	11	15	30	26
Peru	7	13	15	25	31	41	78	83	114	134	176	401	248	295	344	353	406	427	499
Suriname								1	3	3	8	6	14	17	26	24	19	19	15
Trinidad Tobago	1	1	1	7	9	7	7	4	11	11	11	6	17	18	12	19	23	29	22
Uruguay	10	22	29	32	32	42	52	45	58	82	71	108	113	117	132	147	226	242	237
Venezuela	7	7	9	17	20	17	65	51	49	72	65	66	49	93	85	76	83	97	39

Source: Authors' elaboration based on ISO data (ISO, 2018).

Another indicator consistently available for a few LAC countries is the number of patent applications related to the environment (per million population), provided by the OECD (2017). When comparing LAC performances with those of other countries, we note that in recent years, green technologies have grown faster than other (non-green) technologies, both in LAC countries and the rest of the world. However, the differences between LAC countries, and especially between LAC and the most advanced countries, remain very broad. For example, in 2013, while in the United States there were about 21 green patent applications per million population and in Europe 15, in the Latin American region the country with the best performance in this indicator was Chile, with just 1.17 applications per million population (Figure 2).

Figure 2. Number of (Priority) Patent Applications Related to the Environment *(per million population)*



Source: Authors' elaboration based on OECD data (OECD, 2017). The dotted lines (i.e., Europe, United States, and the average of OECD countries) refer to the scale on the right. The continuous lines (i.e., Brazil, Chile, Mexico, Panama, and Uruguay) refer to the scale on the left.

Firm Surveys on Green Innovation Activities and Practices

Firm surveys are important tools to measure GI in the business sector and the factors that influence its development or diffusion. In fact, surveys can provide a vast array of information in all four areas of the conceptual framework presented here (Figure 1). They could gather data on GI activities and outputs (e.g., new green business processes, goods and services developed or adopted by the firm) and GI inputs (e.g., number of employees with STEM and environment-related degrees working in each firm), as well as on GI enabling factors (e.g., firm reaction to environmental policies) or GI societal outcomes (e.g., goals of the firm in terms of reductions of air, water, and soil pollution). In recent years, a few firm surveys containing questions related to firm environmental performances have been implemented. For example, the UK Survey of Environmental Protection Expenditure—which has gathered yearly firm-level statistics on environmental protection expenditure across industrial sectors in the UK since 1999—or the US Pollution Abatement Costs & Expenditures Survey—which collected information on capital expenditures and operating costs for pollution prevention and pollution treatment—contain important measures of GI outputs and activities.

The 2008 wave of the Community Innovation Survey (CIS), the firm survey conducted biannually by Eurostat to measure innovation activity in enterprises of EU countries, included a set of questions on innovation with environmental benefits. Firms were asked to report the adoption of different types of green innovations and the motivations behind this choice. Alongside the CIS, in 2017 the European Commission developed two ad hoc surveys, the Flash Eurobarometer 455

and 456, that were implemented through phone interviews to firms to gather information on resource efficiency, green markets, and green employment in European SMEs. These kinds of exercises have spurred different studies on the (policy) drivers and economic performance of GI (e.g., Horbach, 2018; Rogge and Schleich, 2018; Cainelli and Mazzanti, 2013; Horbach and Rennings, 2013; Veugelers, 2012; Doran and Ryan, 2012). A similar approach could be replicated in LAC. Following the experience of the European CISs, several LAC countries have undertaken innovation surveys since 1995 (Crespi and Peirano, 2007). The first countries implementing firm innovation surveys in the mid-1990s were Argentina, Chile, Colombia, Mexico, and Venezuela. By the end of the decade a larger group of countries—including Argentina, Brazil, Chile, Cuba, Ecuador, Mexico, Panama, Peru, Trinidad and Tobago, and Uruguay—had designed and implemented their innovation surveys. In recent years, even more LAC countries have started running innovation surveys, even if not all have done it continuously or at recurring intervals. The IDB has taken an active role in improving the quality and comparability of these surveys and is currently piloting a harmonized database. Table 6 provides key information on the innovation surveys that have been undertaken in the region since 1995.

In a few LAC countries (e.g., Argentina, Brazil, Colombia, Costa Rica, Chile, Ecuador, Mexico, Panama, Peru, and Uruguay), innovation surveys already contain some environment-related questions (on the determinants, the effects, and the objectives of the innovation). For example, some of these surveys ask if the (product or process) innovation developed or adopted by a firm in the previous years has led to a reduction of the firm environmental impact and/or of the consumption of natural resources (water, energy, raw materials, etc.). However, these surveys are significantly different across countries and years in terms of the type and number of questions that are asked, making it hard to make cross-country comparisons. Next to their innovation surveys, a few countries (e.g., Argentina and Costa Rica) have developed and implemented other firm-level surveys containing questions on the environmental management (Rovira, Patiño, and Schaper, 2017).[8] However, no systematic cross-country effort has been made to analyze GI on a regional level. This is why we advocate for including a set of questions on GI in future waves of the LAC innovation surveys. In Annex A we include a questionnaire on GI diffusion to integrate into LAC innovation surveys. As the characteristics of GI and its externalities are shaped by the sector the firm operates in, it would be advisable to survey different sectors of the economy, including the less-researched ones (e.g., the service sector). In fact, such coverage would provide important sectoral baselines and counterfactuals. However, if time or budget constraints do not allow for broad sector coverage, the most polluting sectors should be prioritized in the survey (Mazzanti et al., 2016).

[8] The Argentinean National Survey on Innovation and Technological Conduct (ENIT), carried out since 2007 by the National Institute of Statistics and Censuses (INDEC), contains a section on “environmental activities” with questions on firms’ environmental management practices and certifications as well as on the motivations and obstacles that implement environmental activities. In Costa Rica, the Report on National Indicators of Science, Technology, and Innovation published in 2015 by the Ministry of Science, Technology, and Telecommunications (MICITT) contains a section on innovation and environmental performance; it was based on a firm survey containing questions on the environmental impacts, the effects of the productive activities on climate change, the existence of a formal program for disaster prevention, environmental management practices, and the motivations and obstacles to access new environmental management technologies.

Table 6. Presence of GI-Related Questions in Innovation Surveys in Latin American and Caribbean Countries

Country	Institutions involved	Number of rounds	First survey applied	Last survey applied	Observation period	Covered sectors	Continuous dataset	Questions on GI
Argentina	INE and Mincyt Mincyt and Ministry of Labor	8	1997	2008 2017	1992–2008 2010–2012 2014–2016	Manufacturing	No	Yes, on motivations and activities
Bolivia	UPB	1	2016	2016	2013–2015	Manufacturing, services, and others	---	Yes, on motivations
Brazil	IBGE, MCTIC	6	2000	2014	1998–2014	Manufacturing, services, and others	Yes	Yes, on impacts
Caribbean*	Compete Caribbean	1	2014	2014	2011–2012	Manufacturing and services	No	Yes, on motivations
Chile	INE, Ministry of Economy	10	1995	2017	1992–2016	Manufacturing, services, and others	Yes	Yes, on impacts
Colombia	DANE	8	1997	2019	2017–2018 2016–2017	Manufacturing, services (independently)	Yes, 2003 onwards	Yes, on impacts, obstacles, and certification
Costa Rica	MICITT	8	2008	2019	2006–2018	Manufacturing, services, and others (independently)	Yes	Yes, on motivations, impacts, and environmental performance
Cuba	MCYT	2	2001	2006	1997–1999 2003–2005		No	No
Dominican Republic	MESCYT	2	2005	2010	2003–2005 2007–2009	Manufacturing, services, and others	No	No
Ecuador	INEC, Senescyt	3	2001	2015	1998–2000 2009–2014	Manufacturing, mining, trade, and services	Yes, 2009 onwards	Yes, on motivations, impacts, and environmental R&D
El Salvador	DICA, Ministry of Economy	1	2013	2016	2010–2015		Yes, 2010 onwards	Yes, on impacts
Mexico	INEGI, CONACYT	7	1997	2017	1994–1996 1999–2000 2004–2016	Manufacturing, services (independently)	Yes, 2004 onwards	Yes, on motivations, environmental R&D, bio/nanotech, certification
Panama	SENACYT	4	2001	2017	1996–1999 2006–2010 2015–2016	Manufacturing, services	Yes, 2006 onwards	Yes, on motivations, activities, certification, impacts
Paraguay	CONACYT y DGEEC	3	2007	2016	2004–2006 2011–2015		Yes, 2011 onwards	Yes, on certification
Peru	INEI	4	2000	2015	1997–1999 2002–2004 2009–2014	Manufacturing	Yes, 2009 onwards	Yes, on impacts and certification
Uruguay	INE, ANII	5	2001	2016	1998–2015	Manufacturing, services, agriculture (independently)	Yes	Yes, on impacts and certification
Trinidad and Tobago	Economic Development Board, Ministry of Planning and Development	6	2006	2015			No, sector specific	No
Venezuela	OCEI	3	1996	2004	1994–1996 2004		No	No

Source: Adapted from Guillard and Salazar (2017).
* This refers to the PROductivity, TEchnology and INnovation survey (PROTEqIN) conducted in 2014. The surveys cover the following countries: Barbados, Belize, Jamaica, Guyana, Suriname, Antigua and Barbuda, Dominica, Grenada, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, the Bahamas, and Trinidad and Tobago.

Measurability of GI Data in LAC

Below we include a set of potential indicators on GI for LAC, accompanied by an evaluation of their degree of measurability. This set of indicators is not meant to be exhaustive or final, but rather to offer, together with the conceptual framework, a starting point for relevant GI data collection in LAC. We distinguish between three levels of measurability:

- *Short term*, when basic data is currently available for several LAC countries;
- *Medium term*, when basic data is partially available, but further efforts are needed to improve the quality (consistency, comparability, timeliness) and geographical coverage; and
- *Long term*, when basic data is not available for virtually any LAC country and sustained conceptual and data-collection efforts are needed.

Table 7. Measurability of GI Data in LAC

Availability at	**National Level**	**Firm Level**	**Government**
Short Term	• Renewable energy investments and total share of renewable energy capacity • GHG emissions • National ranking in global lists of innovation and competitiveness (INSEAD Global Innovation Index) • Trade of cleantech commodities (UN Comtrade) • Overview of CDM projects • Environmental/renewable energy patents, green patent ratios • Environmental performance index (EPI) • Energy Trilemma Index • Renewable energy capacity/generation	• High-profile firms (foreign-owned and domestic) selling environmental goods and services • Firms who obtained green patents • Firms obtaining environmental certification (e.g., ISO 14001)	• Inventories of policies for renewable energy, waste management, etc. • Environmental policy ranking in EPI
Medium Term	• Ranking in global lists of GI (ASEI index, Cleantech Global Innovation Index) • Sector studies of waste companies, green energy suppliers • Comprehensive information about Environmental Good and Services (EGS) (e.g., workers, sales, exports) • Platforms for the circular economy, bio-economy, precision economy	• Adoption of green measures (such as internal reuse of waste) in manufacturing and service sectors • Involvement in partnerships for circularity • Share of product sales from remanufacturing and EGS • Adjustments to products to facilitate repair and reuse • End-of-life waste management of products	• Data collection for policy evaluation • Assessment of policies • Knowledge about barriers and drivers • Capacity to formulate policies based on identified barriers and drivers

	• Socioeconomic well-being indicators • International collaboration	• Shutdown of dirty production processes and replacement of non-green products with green ones	
Long Term	• High-quality reports from experts about the ecosystem for GI • Conceptual and methodological approaches linking GI to key indicators, for example the UN's Sustainable Development Goals • Profuse media attention to GI • Adequate skills for GI provided through the education and training system	• Widespread adoption of corporate social responsibility, environmental ethos, and collaborative partnerships with NGOs and knowledge institutes to reduce negative environmental impacts	• Capability for policy coordination • OECD environmental policy stringency and green growth indicators for all LAC

6. Conclusions and Next Steps

This document provides a conceptual framework for the collection of data and indicators to measure the performance of Latin American and Caribbean countries in terms of GI, offering key inputs for regional policymaking. In fact, not only do the main current international efforts in the area consider LAC countries only marginally, but they also focus on technology development rather than technological diffusion, a neglected dimension that is extremely relevant in the context of emerging countries. This framework fills this gap by including key conditions for technological adoption such as the availability of complementary technologies and of vocational and technical skills.

Moreover, the framework is designed to be flexible enough to allow countries to add different indicators to map their GI performance depending on their characteristics and priorities. For example, for some countries, energy use might be the most critical issue, while for others it might be waste treatment or water use. Clearly, these differences call for different additional sets of indicators within the dimensions of the framework. However, it is important to emphasize that it is strongly desirable that all the countries accurately collect a core set of harmonized and temporally consistent key GI indicators, to allow for international comparability. To have a handy measurement of GI, the indicators to be collected could be used in various ways such as scoreboards or a composite index. Temporal consistency is often an important issue not only across countries, but also across indicators for the same country. In fact, these indicators are often collected from a broad array of sources that have different reference years, making difficult cross-indicator analysis.

A potential solution to this long-lasting issue is offered by the increasing availability of big data defined as both web data as well as micro-level administrative data. The main advantage of this kind of data is that it can provide a level of granularity and a "high-definition" perspective that was

inconceivable until a few years ago. Furthermore, some of these data are continuously updated, providing a real-time, constantly updated picture, allowing for the proactive measurement of GI trends and potentials. In order to take advantage of these opportunities, national statistical offices across the region, as well as other public and private data producers, should develop new data management skills and establish a common collaboration framework to transform large and diverse masses of data into clear and reliable indicators for policymaking. The possibilities of application are infinite, but a few examples in the area of GI include measuring green skills supply from university websites, measuring green skills demand from job ads, or measuring green financing availability via crowdfunding.

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ANNEX A

A Green Innovation Questionnaire for Firm Innovation Surveys in LAC

Green Innovation

Green innovation consists of new or improved products (goods or services) and processes (including organizational changes) that differ significantly from the products or processes previously on offer or in use and which—with or without intent—lead to environmental improvements compared to relevant alternatives.

Note that

- Products include goods and services, while processes include organizational, production, and marketing changes.
- The environmental improvements can be the primary objective of the innovation or the result of other innovation objectives.
- The environmental improvements of an innovation can occur during the production or provision of a good or service, or during the after-sale use of a good or service by the end user.

1. During the years 20XX–20XX, did your enterprise introduce a product or process innovation with any of the following environmental benefits?

	Yes	No
1a. Environmental improvements from the adoption of new technologies within your enterprise		
Reduced material use per unit of output	☐	☐
Reduced energy use per unit of output	☐	☐
Reduced CO_2 footprint (total CO_2 production) of your enterprise	☐	☐
Replaced materials with less-polluting or -hazardous substitutes	☐	☐
Reduced soil, water, noise, or air pollution	☐	☐
Recycled waste, water, or materials	☐	☐
1b. Environmental improvements from your enterprise's own efforts to improve its existing products or processes or to develop entirely new products or processes		
Reduced material use per unit of output	☐	☐
Reduced energy use per unit of output	☐	☐
Reduced CO_2 footprint (total CO_2 production) by your enterprise	☐	☐
Replaced materials with less-polluting or -hazardous substitutes	☐	☐
Reduced soil, water, noise, or air pollution	☐	☐
Recycled waste, water, or materials	☐	☐

1c. Environmental improvements from the after-sale use of a good or service by the end user

Reduced energy use	☐	☐
Reduced air, water, soil, or noise pollution	☐	☐
Improved recycling of product after use	☐	☐

2. In general, were the green innovations that you adopted from external sources fully tailored to your needs? (Please indicate which of the following statements describes your satisfaction best.)

- ☐ They were fully tailored to our needs.
- ☐ We experienced problems, but they were resolved by the supplier.
- ☐ We experienced problems, but they were resolved by us or hired experts.
- ☐ We have not adopted any green innovation.

3. During the period from 20XX to 20XX, did your enterprise introduce an green innovation due or in response to:

	Yes	**No**
Existing environmental regulations or taxes on pollution?	☐	☐
Environmental regulations or taxes that you expected to be introduced in the next five years?	☐	☐
Availability of government grants, subsidies, or other financial incentives for green innovation?	☐	☐
Current or expected market demand for products or processes with reduced environmental impacts?	☐	☐
Voluntary codes or agreements for environmental good practices within your sector?	☐	☐
Export standards?	☐	☐
Supplier pressure?	☐	☐
Competitor pressure?	☐	☐
Personal reasons?	☐	☐
Associated technological advances?	☐	☐
Positive experience of previous green innovation within the company?	☐	☐
Intention to improve company image or reputation?	☐	☐
Eco or green certifications?	☐	☐

4. Does your enterprise have procedures in place to regularly identify and reduce its environmental impacts? (For example, preparing environmental audits, setting environmental performance goals, ISO 14001 certification, etc.)

- ☐ Yes: implemented before January 20XX
- ☐ Yes: Implemented or significantly improved after January 20XX
- ☐ No

5. Between 20XX and 20XX, did you encounter any of the following problems in *adopting* green innovations? (If yes, please tick the relevant box.)

- ☐ Difficulties in obtaining financing
- ☐ Startup problems with the use of technology for green innovations
- ☐ Inadequate skills
- ☐ Inadequate infrastructure
- ☐ Problems with obtaining permits
- ☐ Repeated malfunction of product or process innovations
- ☐ Strong internal opposition
- ☐ Problems with local communities

6. Between 20XX and 20XX, did any of the above problems cause you to cancel a green innovation project?

- ☐ **Yes, once**
- ☐ **Yes, several times**
- ☐ **No**

7. Which of the following types of support is likely to be the most relevant for your enterprise's investments in green innovation over the next five years? (Select one option only.)

- ☐ Financial support from government
- ☐ Financial support from non-governmental sources
- ☐ Affordable technical assistance
- ☐ Ease of obtaining a permit
- ☐ Information support
- ☐ Not relevant—no plans to invest in green innovation over the next five years

8. Please think of your enterprise's most costly (in terms of capital investment) green innovation between 20XX and 20XX. What were the effects of this *green innovation*? (Select all that apply.)

- ☐ Reduced costs
- ☐ Improved product quality
- ☐ Health and safety benefits for our workers
- ☐ Reduced carbon emissions
- ☐ Reduced air or water pollution
- ☐ Reduced waste

9. What is the origin of the technology for this green innovation? (Please indicate which of the following statements describes the origin best.)

- ☐ The technology is entirely foreign.
- ☐ The technology is wholly or largely domestic.
- ☐ The technology is foreign with a small domestic element.
- ☐ The technology is foreign with a substantial domestic element.