Measuring green industrial performance: a regional outlook of Eastern Asia and Europe

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Abstract
Is it possible to measure the green performance of the manufacturing sector? Which world regions are doing better in terms of green industrialization? This paper develops a novel methodology to respond to these questions by improving the green industrial performance (GIP) index through the refinement and expansion of the green product list that lies at its core. The paper constructs a new database using international comparable data sources such as the UNIDO’s industrial statistics database and the UN COMTRADE, to compute the GIP index and rank 116 economies in terms of their ability to produce and export green industrial products. The paper shows that industrialized economies outperformed other economies with Switzerland, Denmark, Germany, Czechia and Austria topping the GIP ranking of industrial green performance in 2019. Then it estimates and compares the relative green industrial performance of eight country groupings to conclude that Northern America, Europe and Eastern Asia perform significantly better than the other country groupings. Our analysis of Europe and Eastern Asia serves to display significant differences in green industrial performance of economies even within these two leading country groupings. Finally, the paper puts forward recommendations for future research and measurement of the green performance of the manufacturing sector of the world’s economies and regions.

Keywords Economic development · Environment and development · Green economy · Industrialization · Comparative studies of countries

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1 Introduction

Last decades have witnessed an unprecedented interest in exploring how to conciliate the economic, social, and environmental dimensions of development. The importance of sustainable development to meet today world’s needs without jeopardizing our future can be traced back to the influential report “Our Common Future” (Brundtland et al 1987). Subsequently, Pearce et al. (1989) introduced the concept of green economy in the Blueprint for a Green Economy in the UK while the Rio Declaration (UNGA, 1992) underlined the relevance of the conciliation of the three pillars of sustainable development: social, economic, and environmental. The increasing attention paid to green concepts is illustrated, for instance, by Georgeson et al (2017) who undertook a review of the main green definitions. UNEP (2011) definition of green economy emphasized the conciliation of well-being and equity with the reduction of environmental and ecological impact. Loiseau et al (2016) introduced a framework to assess how green economy concepts support the transition to sustainability. UNDESA (2012a) provided, in turn, a review of the green economy as well as of other concepts including green growth while the OECD (2011) definition of green growth underlined how it contributes to economic development and growth without depleting natural assets. The World Bank (2012) stressed that green growth is efficient growth in its use of natural resources and clean in minimizing pollution and environmental impact while Bowen and Hepburn (2014) underlined that it is growth that enhances the well-being and continued GDP growth and preserves aggregate natural capital. Some authors underlined the similarities between green growth and green economy. Jacobs (2013) argued that both concepts view growth as compatible with environmental protection. UNDESA (2012b) indicated that the differences between the two concepts have become unclear over time whereas Barbier (2012) suggested the interchangeability of green growth and green economy. More recently, international efforts to integrate the economic, environmental and social dimensions of development are exemplified by the 2030 Sustainable Development Agenda (UNGA 2015). The leading role of the manufacturing sector in economic growth due to its increasing returns of scale as proven by Kaldor (1960; 1967; 1981) and the evidence that industrial development can be sustainable (UNIDO 2020a) lie at the core of the green industry concept (UNIDO 2011), which emphasizes industry that does not have negative (or limited) impact on natural systems or human health.

The emergence of the above concepts, i.e., green economy, green growth and green industry has underlined the necessity to design measures to compare the performance of economies and sectors. The OECD (2017a) put forward a framework of indicators to measure the green growth while UNEP (2014) introduced the use of indicators to design national green economy policies. The Green Growth Knowledge Platform (2013) proposed a green growth and green economy indicator framework. Finally, the UN Environment (PAGE 2017a) put forward a set of individual indicators together with the Green Economy Progress index (PAGE 2017b). The Environmental Performance Index (Wendling et al 2020) ranked countries on environmental health and ecosystem vitality while the Green Growth Index (Acosta et al 2019) benchmarked countries according to their efficiency in resource use, the protection
of natural capital, the economic opportunities related to green economy, and the availability of social inclusion. One can also find relevant composite indicators that focus prominently on the industrial performance of countries such as the Competitive Industrial Performance Index (UNIDO 2019) that benchmarks national industrial competitiveness of countries and the Inclusive and Sustainable Development Index (Fang Chin Cheng and Cantore 2020). In the case of wider frameworks, efforts to track the progress of economies in terms of the 17 Sustainable Development Goals (SDGs) contained in the 2030 Agenda (UN ECOSOC 2016) are also noticeable. Researchers are confronted with multiple methodological challenges such as the interlinkages among SDGs (Dawes 2022; Nilson et al. 2016), the high complexity of SDG measurement (MacFeely 2020), and the need to set up metrics to measure progress at the national level (Allen et al 2018). The United Nations (UN 2021; UN ECOSOC 2020, 2021) and the Sustainable Development Solutions Network (SDSN 2015) report annually on progress towards the SDGs.

Despite concerted international action, which is encapsulated in the 2030 Sustainable Development Agenda (UNGA 2015) and the Paris Agreement on Climate Change (UNFCCC 2015), the impact of human activity on the environment, and, more particularly, on climate change has become clear (IPCC 2021). The COVID-19 pandemic affected the global economy, which contracted by 3.5 per cent in 2020 (IMF 2021), as well as industrial production a domain that underwent contraction in many countries and industrial sectors (UNIDO 2020b). Existing policy initiatives to support regional and national moves towards a green economy have been revised to become part of wider endeavors to recover from COVID-19. The EU Green Deal (European Commission 2019) has thus been embedded in the EU’s COVID-19 recovery plan (European Commission 2020) while Korea’s New Green Deal in the country’s New Deal for recovery post-COVID-19 (Government of the Republic of Korea 2020). Future research could explore the way such public policies shape up and contribute to the national and regional green performance of the manufacturing sector.

Despite such efforts, we consider that the existing body of knowledge still lacks an appropriate framework that allows the systematic and comparable measurement of the green industrial performance of economies and regions. This is of particular relevance to policymakers due to the contributions of the manufacturing sector to economic growth and its impact on the environment. How can one define and measure green industrial products? Which economies and regions have the capacity to produce and export green industrial products? Which is the role played by green manufacturing in the manufacturing sector of a given economy? What is the contribution of green manufacturing employment to total employment in the manufacturing sector? We put forward in this paper a novel methodological approach based exclusively on comparable data produced by international organizations to respond to all these questions. This paper builds upon the Green Industrial Performance Index (GIP) index, which to the best of our knowledge is the only attempt to measure in a systematic manner national green industrial performance (Moll de Alba and Todorov 2018a, b; 2020a, b). Kolomeytseva (2020) benchmarked the industrial performance of the Eurasian Economic Union countries using the GIP index, Acosta et al (2019) used one of its components, i.e., the share of green employment to
compute their Green Growth Index, and Halkos et al. (2021) expanded it to establish the inclusive and green industrial performance index.

This paper makes five key contributions. First, we review and expand the list of green industrial products used to compute the GIP index. Second, we construct a unique green industrial performance dataset for 116 economies for the period 2000–2019. Third, we compute the revised GIP index for 116 economies and eight world’s regional country groupings. Fourth, we analyze and compare the green industrial performance of economies. Fifth, we analyze regional performance and focus on Europe and Eastern Asia to illustrate the potential of the proposed methodology to benchmark regional green industrial performance. Following this introduction, the remainder of the paper is organized as follows: Sect. 2 describes the research methodology and introduces the improved green industrial performance (GIP) index. Sect. 3 presents an analysis of the green industrial performance of economies and geographical regions. The key findings and the ideas for future research are presented in Sect. 4.

2 Research methodology

The popularity and reliance of researchers and international organizations on composite indices to simplify the measurement of complex realities is worth mentioning (Saltelli 2007). Bandura (2011) identified, for instance, more than 400 such composite indices covering diverse domains. Ravallion (2011) stressed the importance of defining what one seeks to measure whereas Saisana and Saltelli (2011) saw composite indices as a tool to raise general interest in a given (technical) domain in line with Lall’s previous observation (2001), which underscored that (competitiveness) composite indices might be helpful tools to inform policymakers. The OECD (2008) studied industrial competitiveness and sustainable development using the composite index approach while Mazziotta and Pareto (2013) developed guidance on the construction of socio-economic indexes. Booysen (2002) focused on the methodology for the construction of composite indices and Greco et al (2019) provided a review of existing methodological approaches. To analyze the national progress in terms of SDG achievement, Kroll (2015) developed an SDG index, which was used by the sustainable development report series to provide annual updates on the progress towards reaching the SDG targets. Halkos and Gkampoura (2021) demonstrated an uneven progress of countries towards the SDGs while the impact of the COVID-19 pandemic was highlighted by other authors (Sachs et al., 2020, 2021). Diaz-Sarachaga et al. (2018) pointed out the limited coverage of such composite indicators compared to the SDGs due to limited data availability. Lin et al (2019) introduced an index that focuses on inclusive sustainable transformation and seeks to assess the movement of countries to a “new” economy.

We extend the Green Industrial Performance Index (GIP) index introduced by Moll de Alba and Todorov (2018a, b; 2020a, b) with the purpose to study the status of green manufacturing in the country level and gain a general understanding of its development around the world. The methodology behind the GIP index is inspired by the leading index developed by UNIDO for measuring competitive
manufacturing performance (CIP) (UNIDO 2017), which is based exclusively on objective data collected from internationally comparable sources. The UNIDO CIP index is used to benchmark the industrial performance and competitiveness of the countries. The GIP index can be used as a complementary tool to UNIDO’s CIP index for analyzing the progress of inclusive and sustainable industrial development (ISID) at the country level.

2.1 The indicator framework

In the selection of indicators for the Green Industrial Performance (GIP) index two equally important aspects of economic development must be considered: (1) the domestic production of goods, and (2) their international trade. A relevant indicator is the share of green manufacturing production in the total manufacturing production, which will measure the relative importance of the green manufacturing in countries’ economy. At the same time, we look at the development of green jobs in manufacturing. UNEP/ILO/IOE/ITUC (2008, p. 3) defined these as “work in agricultural, manufacturing, research and development, administrative, and service activities that contribute substantially to preserving or restoring environmental quality”, however, in our work we restrict this definition to manufacturing only. The above-described concepts can be wrapped up into a simple, straightforward framework that captures different aspects of a country’s green industrial performance through three key dimensions. The framework is presented in Fig. 1 and details on the indicators used are provided in the remainder of this section.

2.2 The green products list

A key component of our framework is the green products list, which is used to measure green exports, and indirectly, green domestic production and green
employment. The development of a comprehensive list of environmental goods has been approached as a research question but at the same time work has been done to facilitate trade negotiations by removing or reducing tariffs. As pointed out by Sugathan (2013), one of the biggest challenges has been that most environmental goods, particularly in the six-digit subcategory of the Harmonized System (HS), can include products that have both environmental and non-environmental end-uses. To create the basis for our methodological proposal for measuring green manufacturing we consider several well-established lists of environmental goods, namely: the OECD list (Steenblik 2005), the World Bank classification (World Bank 2007), the APEC list (Steenblik 2005), and the report “Measuring the green economy” by the U.S. Department of Commerce (2010).

The product codes contained in the list of the U.S Department of Commerce are according to the North American Industry Classification System (NAICS) codes (United States Census Bureau 2017). The six-digit NAICS codes used for classifying the manufacturing or services industries are further disaggregated into individual 10-digit product/service codes. The first challenge with this list was that it was necessary to translate the codes into six-digit Harmonized System (HS) codes, which allowed us to use the international trade data from the UN COMTRADE database. We admit that this translation cannot be precise and further work would be necessary to better validate and align the DC-ESA product codes to HS ones. We ended up with 148 HS sub-groups.

Next, we make use of the widely accepted list of climate-friendly products developed by the World Bank (World Bank 2007). This list contains 45 goods described by HS sub-headings that allow us to add them directly to our initial list. Merging the DC-ESA and World Bank lists and removing the duplicated sub-headings, we remain with a list of 184 products.

![Fig. 2](image)

**Fig. 2** A Venn diagram illustrating the overlap between the four lists
Further, we extend our green products list by including the environmental products from the OECD list with 126 entries and from the APEC list with 54 entries (Steenblik 2005; Reinvang 2014). The two lists have less than 30% in common (34 products out of 126).

Figure 2 illustrates the overlap between the four lists through a Venn diagram. The DC-ESA list has 103 unique products, followed by OECD with 65, World Bank with 27, and APEC with 16. DC ESA and OECD are the two largest lists. They have 43 products in common. The cross-sections of the other lists count just a few products in common (DC-ESA and WB, 7; WB and APEC 10; WB and OECD also 10).

Source: Authors’ elaboration based on U.S. DC-ESA (2010), Steenblik (2005) and World Bank (2007) and Reinvang (2014)

After adding the two new lists and removing the duplicated entries, we remain with an improved and expanded list consisting of 280 products which we will call the UNIDO green product list. The list can be found in Appendix C of Moll de Alba and Todorov (2022).

2.3 Measuring green exports

To calculate the shares of green products in the total manufacturing products exported by a country, we use the UN COMTRADE database (United Nations Statistics Division 2022) and the UNIDO green product list, described in the previous Section. The UN COMTRADE database is considered the most comprehensive database on international merchandise trade statistics (IMTS). It contains detailed import and export statistics for around 200 countries from the period starting in 1962 until the most recent year. The database covers only trade of goods and presents statistics collected as administrative data; however, these statistics might be supplemented by survey data. Data are stored in current US dollar values (using an average annual exchange rate) according to the Harmonized System (HS), a six-digit product classification maintained by the World Customs Organization (WCO 2012).

Applying the UNIDO green products list to the data selected from UN COMTRADE, we can compute two indicators related to exports, which we will represent the capacity to export green products in our index: the share of green exports in the manufacturing exports (\(GMX_{sh}\)) and the green manufacturing exports per capita (\(GMX_{pc}\)) measured in current US dollars.

2.4 Measuring green domestic production

As in the case of the exports indicators, we use the UNIDO green products list to map these products to the manufacturing industries, identified at four-digit ISIC Revision 3.1 or ISIC Revision 4 code (United Nations, 2002 and 2008), which produce them. We acknowledge that such a mapping is not precise, as we move from six-digit HS product codes to four-digit economic activities codes. We do not have production data (value added) by product and rely on the shares of exports which are considered green as proxy for green production. For example, if 20 percent of
the exported products classified within a given 4-digit activity code (ISIC), for a given country, are considered green, we will assign 20 percent of the value added produced in this ISIC to the green manufacturing of this country.

The two indicators: Manufacturing value added (MVA) and Number of employees in the manufacturing sector constitute suitable indicators to measure the size of the green manufacturing sector and can be obtained from an annual industrial survey or manufacturing census. UNIDO maintains a global industrial statistics database INDSTAT (UNIDO 2022a), which contains these two indicators together with six other variables for more than 140 countries in the last 20 years.

Using the UNIDO INDSTAT databases and applying the shares calculated for the green exports, as proposed in Moll de Alba and Todorov (2018a), we can compute the next three indicators, which are related to green manufacturing: green manufacturing value added share in total manufacturing value added ($GMVA_{sh}$), green manufacturing value added per capita ($GMVA_{pc}$) measured in current US dollars and the green manufacturing employment (green jobs) measured as their share in total manufacturing employment ($GEMP_{sh}$).

### 2.5 The social and environmental aspects

The third pillar in our analysis underlines social inclusiveness. It will be covered by the indicator measuring the green jobs: the share of green employment in the total manufacturing employment $GEMP_{sh}$.

Carbon dioxide (CO2) emission accounts for around 80% of all greenhouse gas emissions from manufacturing processes. Not only is CO2 an important measure of emissions but also of use and type of energy consumed. The indicator that we use for the construction of our composite index is carbon dioxide (CO2) emissions per unit of manufacturing value added ($CO2VA$). This indicator captures the intensity of the energy use, energy efficiency of production technology and most importantly the use of fossil fuels. The data necessary to compute this indicator comes from the IEA “CO2 Emissions from Fuel Combustion Statistics” (OECD 2021) and the UNIDO National Accounts database.

### 2.6 Summary table of the green industrial performance indicators

Table 1 lists the indicators which we have selected to use in this paper for building the green industrial performance (GIP) composite index. Please note that two of these indicators map to the SDG 9 indicators.

### 2.7 The actual computation of the index

To calculate the composite index, values for all six sub-indicators must be available and to achieve this imputation of the missing values takes place before
Table 1 Summary of the GIP indicators

| Indicator | Description                                      | Countries\(^a\) | Source                                      |
|-----------|--------------------------------------------------|-----------------|---------------------------------------------|
| 1         | GMVAp\(c\) Green MVA per capita (current USD)   | 130             | UNIDO INDSTAT\(^c\)                        |
| 2         | GMXpc\(c\) Green manufactured exports per capita (current USD) | 192             | UN COMTRADE\(^d\)                         |
| 3         | GMV Ash Share of green MVA in total MVA (%)     | 130             | UNIDO INDSTAT\(^c\)                        |
| 4         | GMXsh Share of green manufactured exports in total manufactured exports (%) | 192             | UN COMTRADE\(^d\)                         |
| 5         | GEMPsh Share of green manufacturing employment in total manufacturing employment (%) | 130             | UNIDO INDSTAT\(^c\)                        |
| 6         | CO2VA\(^b\) CO2 emission from manufacturing per unit of manufacturing value added (kg/USD) | 145             | IEA\(^e\), UNIDO MVA\(^f\)               |

(a) Number of countries for which the indicator is available in the considered period. (b) Negative indicators, i.e., indicators for which higher values indicate lower performance (c) UNIDO (2022a) (d) United Nations Statistics Division (2022) (e) OECD (2021) (f) UNIDO (2022c)
normalization and aggregation. Details about the procedures for handling missing data and outliers can be found in Moll de Alba and Todorov (2022, pp 20–21).

The indicators for which higher scores represent better outcomes (i.e. the “positive” indicators) are normalized into the range \([0, 1]\) by the min–max method. The minimum and maximum values of each indicator are taken, and the computation is presented in Eq. (1). Similarly, for the indicators for which higher scores represent worse outcomes (i.e. “negative” indicators), Eq. (2) is used. Thus, for each indicator we compute:

\[
I_{ijt} = \frac{X_{ijt} - \min_{j} X_{ijt}}{\max_{j} X_{ijt} - \min_{j} X_{ijt}} \quad (1)
\]

\[
I_{ijt} = \frac{\max_{j} X_{ijt} - X_{ijt}}{\max_{j} X_{ijt} - \min_{j} X_{ijt}} \quad (2)
\]

where \(X_{ijt}\) is the value of the j-th country on the i-th indicator in year t. For any index, the country with the highest score will be given the value of 1, and the country with the lowest score—a value of 0.

As an aggregation method geometric aggregation is chosen. Under the geometric aggregation method, the index is constructed as a weighted geometric average of the \(q\) sub-indicators, using equal weights for each indicator and each country. The following formula is used:

\[
GIP_{jt} = \left( \prod_{i=1}^{q} I_{ijt} \right)^{1/q} \quad (3)
\]

where the GIP\(_{jt}\) values are also in the range \([0,1]\).

It is obvious that Eq. (3) can be represented using logarithms since the geometric mean is equal to the exponential of the arithmetic mean of the corresponding logarithms as shown in Eq. (4)

\[
GIP_{jt} = \exp \left[ \frac{1}{q} \sum_{i=1}^{q} \ln I_{ijt} \right] \quad (4)
\]

The reasoning for choosing equal weights is that the higher the correlation between the normalized sub-indicators, the smaller the impact of changing the weights (Foster et al 2012) and preliminary tests of the GIP index showed that the year-average correlations between almost all normalized indicators are rather high.
3 Results

Sect. 2 introduced the revised GIP index based on an improved definition of green products as well as the methodological approach adopted to compute its value. We then calculated the revised GIP index for the period covering the years from 2000 to 2019, and we computed the revised GIP components for 116 economies in 2019. The revised GIP index contributes to the ongoing debate on green growth and green economy by offering both policymakers and researchers a solid, comparable tool to measure, analyze and compare the relative green industrial performance of both world’s economies and regions and its evolution over time. This section makes use of our comparable dataset to compute the improved GIP index in 2019 and then introduces the world economies’ green industrial performance in 2019. The section also analyzes the evolution of their green industrial performance from 2016 to 2019 through the identification of changes in GIP values and rankings. For the first time ever, the paper uses the revised GIP index to analyze regional green industrial performance by UNIDO geographical regions.

3.1 The GIP ranking at the country level

A first noticeable observation when looking at the GIP values relates to the significant differences from one economy to the next. It is striking to notice that in 2019 the GIP values range from 0.644 in Switzerland to 0 in seven countries, i.e. Syrian Arab Republic, Botswana, Cuba, Niger, Eritrea, Nigeria, and Iraq. The latter might also be, at least partly, a reflection of the limited data available in some developing economies and LDCs, particularly in Africa. This paper provides the complete ranking of world’s economies according to the revised GIP index in 2019 in Table 2. Five European industrialized economies, namely Switzerland, Denmark, Germany, Czechia and Austria, topped the GIP index in 2019. The top five performers displayed no changes in their rankings during the period 2016–2019. In 2019, the top 24 GIP quintile economies were all industrialized. We also look at the changes over the period 2016–2019 and find out that Poland (20th position) and Estonia (21st position) moved to the top quintile in 2019 by gaining 6 and 5 positions compared to 2016 whereas Hungary (14th position) and Norway (23rd position) lost 6 positions during the same period. While one can observe, in general, some stability in terms of GIP rankings, one can also find some economies that display changes in green industrial performance over time. Even within the top quintile, one can easily notice significant differences in green industrial performance as proven by a value of 0.644 in Switzerland, the top GIP performer, 0.376 in Italy, which is the 10th performer, and a comparatively lower 0.282 in Lithuania, the 24th performer. Most emerging industrial economies are among the three middle quintiles including China with a remarkable 0.189 score and 42nd place ranking—compared to 36th position in 2016—whereas India places 74th with a GIP index of 0.068. Developing countries are included in the middle, lower-middle and bottom quintiles with their performances ranging from Georgia placed 56th with 0.113 to Iraq at the bottom of our list. Finally, all LDCs in our sample, with the sole exceptions of the United
Republic of Tanzania, Bangladesh, Angola and Senegal, which rank 87th, 88th, 90th and 92nd, are part of the GIP bottom quintile.

Figure 3 introduces the scores and ranks of the top-performing economies per region and per development group. We find out that the United States of America with 0.363 and its 12th world rank leads the performance in Northern America, the
Republic of Korea with its 8th position and a GIP index of 0.398 is the Eastern Asia leader in 2019 whereas Singapore ranks 7th in the world and achieves a GIP score of 0.40 to lead South and South-eastern Asia. Finally, South Africa tops the performance of African economies with its 52nd position and a GIP value of 0.124.
Source: Authors’ elaboration based on UNIDO (2022b).

Note: If a country is already listed in the first section containing the top 3, the one following after is shown in the group of regional leaders. Similarly, if a country is included in the group of regional leaders, the one following after will be shown among the development group leaders. See Moll de Alba and Todorov (2022), Appendix Table A.1 for country classifications.

In Fig. 4, we present a straightforward and visually intuitive depiction of how the GIP values vary throughout the world. The darker the color, the higher the GIP score of a given economy. This figure is instrumental to highlight those economies, mainly in the African region, for which there is no data that allow us to compute the revised GIP (see countries in grey color). This constitutes a constraint limiting the comparability of the analysis we conduct, as the coverage of African economies is, to say the least, limited. This should be borne in mind when looking at the results stemming from our analysis.

Source: Authors’ elaboration based on UNIDO (2022b).

3.2 GIP performance by geographical region

This paper introduces a novel approach, namely, the analysis of the green industrial performance (measured by the revised GIP index) of economies by geographical region. Using UNIDO’s eight regional country groupings as presented in the International Yearbook of Industrial Statistics 2021 (UNIDO 2021), this paper computes the GIP index for Northern America, Latin America and the Caribbean, Eastern Asia, Central and Western Asia, Southern and South-eastern Asia, Europe, Pacific, and Africa. To keep the length of the paper within reasonable limits we present in detail the findings of our analyses for two regions, namely Eastern Asia and Europe, for which data availability and green industrial performance are comparatively good.

![Fig. 5 Score distribution for the three GIP dimensions, World (2019)](image-url)
We present for Eastern Asia and Europe the results of both the GIP regional and global rankings, the position of each of the three dimensions as well as the absolute change in ranking compared to 2014, i.e. to see the changes over a five-year period, for each of the countries in those two regions. We present the various dimensions of the GIP index with a box plot diagram that provides a visual overview of their distribution. Figure 5 serves to illustrate such a diagram, presenting the score distributions of all 116 countries in the world. Figures 6 and 7 introduce the score distributions of Eastern Asia and Europe (2019).
The use of geographical regions allows policymakers and practitioners to identify regional leaders in terms of green industrial performance, as well as to find out common strengths and areas in further improvement.

### 3.3 Analysis of Eastern Asia’s GIP performance

The GIP performance of the Eastern Asia economies shows significant differences. Three economies in the region, namely the Republic of Korea, Japan and Taiwan, Province of China are among the top GIP quintile, whereas Hong Kong, SAR of China and China are part of the upper-middle quintile, and Mongolia is in the bottom quintile. The Republic of Korea improved its global ranking by two positions during 2014–2019 to rank 6th in the GIP whereas Japan remained in position 17th whereas China lost ground and dropped by 9 positions to the 42nd place in 2019 (Table 4).

In terms of green manufacturing value added per capita, the Republic of Korea (5th), which achieved USD 829.94 in 2019, and Japan (12th) with 480.68 are the top economies in the region. With regard to in green manufactured exports per capita, the performance of China, Hong Kong SAR (2nd with USD 3,178 in 2019), Taiwan, Province of China (16th US$1,117.17 and the Republic of Korea (19th with US$974.78) was comparatively strong. We conclude that overall Eastern Asia performed better than all other geographical regions, with the exception of Northern America, when looking at the regional capacity to produce and export green manufactured products as proven by its median score of 0.1329 (see Table 3). Eastern Asia’s performance in terms of the role played by green manufacturing was comparatively stronger too with a median score of 0.2494, driven by the share of green

| Dimension 1 | Dimension 2 | Dimension 3 |
|-------------|-------------|-------------|
| Capacity to produce and export green manufactured | Role of green manufacturing | Social and environmental aspects of green manufacturing |
| Northern America | 0.1717 | 0.3580 | 0.6759 |
| Latin America and the Caribbean | 0.0074 | 0.1267 | 0.4110 |
| Eastern Asia | 0.1329 | 0.2494 | 0.5227 |
| Central and Western Asia | 0.0062 | 0.1151 | 0.3704 |
| Southern and South-eastern Asia | 0.0066 | 0.1760 | 0.3412 |
| Europe | 0.123 | 0.311 | 0.576 |
| Pacific | 0.0461 | 0.1586 | 0.5391 |
| Africa | 0.0006 | 0.0724 | 0.3023 |
| World | 0.0166 | 0.1821 | 0.4202 |

Source: Authors’ elaboration based on UNIDO (2022b)
Table 4  GIP ranks: Global, regional and by each dimension, Eastern Asia (2019)

| Regional rank | Economy                | Global rank | Rank in the first dimension | Rank in the second dimension | Rank in the third dimension | Absolute change compared to 2014 |
|---------------|------------------------|-------------|----------------------------|------------------------------|-----------------------------|---------------------------------|
| 1             | Republic of Korea      | 8           | 8                          | 20                           | 7                           | 1                               |
| 2             | Japan                  | 19          | 20                         | 24                           | 37                          | -3                              |
| 3             | China, Taiwan Province | 22          | 15                         | 49                           | 22                          | -4                              |
| 4             | China, Hong Kong SAR   | 39          | 33                         | 55                           | 59                          | 2                               |
| 5             | China                  | 42          | 46                         | 39                           | 44                          | -9                              |
| 6             | Mongolia               | 101         | 100                        | 104                          | 105                         | -14                             |

Source: Authors’ elaboration based on UNIDO (2022b)
manufacturing value added of the Republic of Korea (22nd with 88.27%) and Japan (47th with 63.96%) and by the share of green manufactured exports of Japan (10th with 11.80%) and the Republic of Korea (26th with 9.26%). This region’s performance in terms of the social and environmental aspects of green manufacturing was also stronger, with a median of 0.5227 (see Table 3), with the Republic of Korea playing a leading role (ranked 10th with 10.85%) in green employment share and 20th ranking in CO₂ emissions. The long-standing efforts of the Republic of Korea, which one can cite as a successful manufacturing-based economy, to promote green growth and move away from fossil-dependent growth, date to the promulgation of the 2009–2050 National Strategy for Green Growth and the 2009–2013 5 Year Plan. Led by the government, the above initiatives sought to reduce greenhouse gas from industry, provide incentives for green products and technologies, and increase demand for green products by the public sector (Kang et al 2012). The Government has played different roles to define the key technology areas, produce national strategies and support financially the national efforts (GGGI 2015). Korean experience illustrates the need for continued political support and the benefits of aligning sectoral strategies and enhancing government coordination (OECD 2017b). Some authors such as Kalinowski (2021) concluded that the green growth policies of the Republic of Korea are the result of existing industrial policies and the cooperation between the government and enterprises.

### 3.4 Analysis of Europe’s GIP performance

The GIP’s top five European economies, i.e., Switzerland, Denmark, Germany, Czechia and Austria, were the best global performers in 2019 according to the revised GIP index. It is noticeable that eight European economies are included in the GIP world’s top ten list. We can observe a certain degree of consistency over time, particularly among the world’s top five performers –only Denmark and Germany shifted positions during 2014–2019 (Table 5). Switzerland ranks 1st in terms of the capacity to produce and export green manufactured products and in social and environmental aspects of green manufacturing. Switzerland is thus the leading economy worldwide in green manufacturing value added per capita (USD 2,482.83 in 2019), share of green manufacturing value added (17.81 per cent) and share of green manufacturing employment (21.34 per cent), while Denmark tops the rank of European economies in terms of the role of green manufacturing, i.e. green manufactured exports per capita (US$ 2,571.74) and share of green manufactured exports (17.97%). It is worth mentioning that Switzerland has traditionally emphasized the importance of sustainable development and the green economy. Decoupling economic productivity from resource and energy use was at the core of the Swiss Fourth Sustainable Development Strategy for 2012–2015 (Federal Council 2012) while national efforts on consumption and production patterns, raw material and waste, the Cleantech Master Plan and greening the tax system featured prominently in its Green Economy Plan of 2013 (FOE, 2013) and its extension for 2016–2019 (BAFU 2016).
Table 5  GIP ranks: Global, regional and by each dimension, Europe (2019)

| Regional rank | Economy   | Global rank | Rank in the first dimension | Rank in the second dimension | Rank in the third dimension | Absolute change compared to 2014 |
|---------------|-----------|-------------|-----------------------------|-----------------------------|-------------------------------|----------------------------------|
| 1             | Switzerland | 1           | 1                           | 10                          | 1                            | 0                                |
| 2             | Denmark    | 2           | 4                           | 1                           | 3                            | 1                                |
| 3             | Germany    | 3           | 2                           | 2                           | 2                            | -1                               |
| 4             | Czechia    | 4           | 6                           | 3                           | 5                            | 0                                |
| 5             | Austria    | 5           | 5                           | 4                           | 8                            | 0                                |
| 6             | Slovenia   | 6           | 7                           | 12                          | 11                           | 5                                |
| 7             | Finland    | 9           | 11                          | 18                          | 9                            | 3                                |
| 8             | Italy      | 10          | 13                          | 7                           | 14                           | 0                                |
| 9             | Sweden     | 11          | 9                           | 27                          | 17                           | -3                               |
| 10            | Slovakia   | 13          | 14                          | 17                          | 10                           | 2                                |
| 11            | Hungary    | 14          | 16                          | 11                          | 18                           | -8                               |
| 12            | Belgium    | 16          | 10                          | 42                          | 35                           | 1                                |
| 13            | Netherlands | 17         | 12                          | 47                          | 23                           | 7                                |
| 14            | United Kingdom | 18      | 24                          | 16                          | 13                           | 2                                |
| 15            | Poland     | 20          | 28                          | 15                          | 19                           | 3                                |
| 16            | Estonia    | 21          | 22                          | 29                          | 26                           | 5                                |
| 17            | Norway     | 23          | 23                          | 32                          | 28                           | -1                               |
| 18            | Lithuania  | 24          | 26                          | 25                          | 38                           | 3                                |
| 19            | Spain      | 26          | 30                          | 28                          | 20                           | -1                               |
| 20            | France     | 27          | 25                          | 36                          | 31                           | -6                               |
| 21            | Portugal   | 28          | 32                          | 22                          | 32                           | 1                                |
| 22            | Croatia    | 30          | 37                          | 21                          | 24                           | 0                                |
Table 5 (continued)

| Regional rank | Economy                | Global rank | Rank in the first dimension | Rank in the second dimension | Rank in the third dimension | Absolute change compared to 2014 |
|---------------|------------------------|-------------|-----------------------------|------------------------------|------------------------------|---------------------------------|
| 23            | Serbia                 | 31          | 45                          | 5                            | 16                           | 3                               |
| 24            | Romania                | 32          | 40                          | 14                           | 34                           | 7                               |
| 25            | Latvia                 | 33          | 36                          | 35                           | 40                           | 3                               |
| 26            | Luxembourg             | 35          | 19                          | 58                           | 85                           | -4                              |
| 27            | Bulgaria               | 37          | 43                          | 30                           | 39                           | 6                               |
| 28            | Belarus                | 40          | 47                          | 41                           | 4                            | 8                               |
| 29            | Malta                  | 46          | 42                          | 65                           | 69                           | 36                              |
| 30            | Iceland                | 47          | 35                          | 82                           | 54                           | 57                              |
| 31            | Bosnia and Herzegovina | 48          | 53                          | 34                           | 66                           | 8                               |
| 32            | Greece                 | 50          | 50                          | 57                           | 50                           | 0                               |
| 33            | Russian Federation     | 60          | 59                          | 69                           | 36                           | -3                              |
| 34            | Ireland                | 61          | 34                          | 100                          | 77                           | -21                             |
| 35            | Republic of Moldova    | 76          | 81                          | 60                           | 81                           | 0                               |
| 36            | Montenegro             | 81          | 83                          | 79                           | 84                           | 2                               |
| 37            | Albania                | 94          | 90                          | 97                           | 102                          | 3                               |
| 38            | Ukraine                | 105         | 64                          | 37                           | 114                          | -2                              |

Source: Authors’ elaboration based on UNIDO (2022b)
Despite overall stability in this geographical group, one can find significant changes in the performance of some countries during 2014–2019. Ireland lost 21 positions despite being the fourth best global performer in terms of CO2 emissions with 0.0325 kg per unit of manufacturing value-added, and Hungary lost 8 positions despite being the seventh best performer in terms of green manufactured exports with US$ 1,451.66 compared to the improvement of Iceland (+57) and Malta (+36) in their global rankings.

We conclude that Europe displays a comparatively strong capacity to produce and export green manufactured products with a median score of 0.123 even if lower than that of Northern America (0.1717) and Eastern Asia (0.1329) (see Table 3). Such differences might be explained, at least partly, by the varying performance of European countries in this dimension, even though the world leaders belong to this region, with Switzerland, Denmark and Germany outperforming the other countries. Europe’s performance in terms of the role of green manufacturing and social and environmental aspects of green manufacturing is comparatively stronger with Europe ranking second with a median score of 0.576 only behind Northern America whose median score is 0.6759 similarly to what happens with the role of manufacturing where Europe is also strong with a median score of 0.311, driven by the strong performance of such economies as Denmark, Germany, Czechia and Austria, only after Northern America with 0.3580. We present the score distributions of Europe’s economies in Figure 7.

4 Conclusions and recommendations

This paper contributes to the ongoing debate on conciliating the various dimensions of development by filling an existing gap in the literature through the introduction of a robust and improved tool to measure and benchmark the green industrial performance of the world’s economies. This paper is thus instrumental to refine the methodology behind the Green Industrial Performance (GIP) index. The six indicators included in the GIP are quantitative and use exclusively comparable data produced by reputed international data sources. Our analysis illustrates how the indicators are selected, data processed, the coverage of the indicators, and how we fill in missing data and deal with outliers, using normalization and aggregation. This paper makes an additional contribution to improve the methodological approach behind the GIP index by reviewing and enlarging the list of ‘green’ products that we use to compute green industrial production and exports. The paper uses the expanded list of green products to quantify the green performance of the manufacturing sector. The expanded list covers 280 products identified from the lists of environmental products of the APEC and the OECD.

After constructing a novel database of the revised GIP index for 116 economies from 2000 to 2019, the paper first looks at green industrial performance of those economies. We find that Switzerland, Denmark, Germany, Czechia and Austria, all European industrialized economies held the top five positions in 2019. Even if several economies experienced significant changes in their GIP index over time, we find that most economies need time to move significantly in terms of the GIP.
index ranking, as proven by the stability of the GIP’s top quintile, which remained unchanged during 2016–2019 with the exception of Poland and Estonia that moved into this group during that period. The GIP index also offers opportunities to conduct analyses using different groupings of economies. For the first time ever, this paper analyzes the GIP performance of eight geographical regions as per UNIDO’s definition and presents, due to length limitations, the results of Europe and Eastern Asia. The paper concludes that both regions perform well in terms of the various facets of green industrial performance contained in the GIP index, i.e. production and trade of green industrial products as well as green manufacturing social and environmental dimensions. Overall, we find that Europe, Eastern Asia and Northern America did significantly better than the other country groupings in terms of green industrial performance. The detailed analyses conducted on Europe and Eastern Asia serve to highlight that even within such green industrial performance leading country groupings economies displayed large differences.

The paper is also instrumental to spell out several methodological limitations that might guide future research. The limited data coverage, particularly in Africa, reduced the number of countries for which we can compute the GIP index to 116 in 2019 constraining comparability. We noticed that the coverage of industrial production data is lower than international trade data, and some countries do not report on employment and CO2 emissions data. While looking for alternative sources to impute missing data, particularly using multiple imputations might help alleviate this problem, enhancing national capacity to produce the above data would be of outmost importance to enable benchmarking the green industrial performance of all world’s economies. It is also worth reminding that several green products (as HS subheadings) fall outside manufacturing (Group C in ISIC Revision 4), which would call for using alternative datasets to improve our coverage.

The improved GIP index introduced in this paper provides policymakers with a novel tool to measure and benchmark the green industrial performance of economies and regions. It can support the efforts to monitor and steer their industrial and environmental policies. Our analysis finds significant differences in terms of green industrial performance regardless the level of industrial development or the geographical groupings, which might imply that the move towards green industry is yet to be fully achieved. Moreover, such differences might also constitute an indication of the different levels of investments channeled to support the move towards a green economy in the various economies of the world.

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