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The Inclusive and Sustainable Industrial Development Index: A Data Envelopment Analysis approach

by

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By Charles Fang Chin Cheng and Nicola Cantore

The Inclusive and Sustainable Industrial Development Index: A Data Envelopment Analysis approach[1]

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Abstract

Inclusive and Sustainable Industrial Development (ISID) calls for the full engagement and commitment of policymakers in industrializing countries to minimize the environmental footprint and enhance social inclusion. This study investigates the progress of 118 countries towards ISID (2005-2015) through an input-oriented CCR (Charnes, Cooper and Rhodes) slack-based (data envelopment analysis) DEA model. The efficiency analyses have been carried out using two approaches: i) the ISID approach represents countries' ambition to promote industrialization and to sustain economic growth by reducing the negative environmental and social effects that become manifest in the economy; ii) the ISIDsdg9 approach considers the same aspects of ISID but only focusses on indicators related to the industrial sector. We develop an analytical tool to measure ISID using these two different approaches. This study finds that Denmark, Sweden and Switzerland top the ranking when applying the ISID approach, and that Czechia and Switzerland rank highest when we apply the ISIDsdg9 approach. We could not detect any signs of catching up between developed and developing countries in terms of progress towards ISID and ISIDsdg9 between 2005 and 2013.

Keywords: Slack-based model (SBM), Inclusive and Sustainable Industrial Development (ISID), data envelopment analysis (DEA), United Nations Sustainable Development Goals (UN SDGs)

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1 Introduction

The United Nations Sustainable Development Goal (SDG) 9 aims at building resilient infrastructure, promoting inclusive and sustainable industrial development (ISID), and at fostering innovation (UNIDO, 2019)[2]. Industrialization generates new challenges: fossil fuel and industrial processes alone account for 65 per cent of global greenhouse gas emissions, and the social system and unprecedented effects disproportionately burden the poorest and the most vulnerable (Intergovernmental Panel on Climate Change, 2014; UNCTAD, 2019). Urgent action is needed not only to minimize the environmental degradation caused by industrial pollution and its impacts, but also to advance decent work and equitable social welfare as the foundation for sustained, inclusive and sustainable economic growth.

ISID calls for minimizing environmental damage and social inequality while promoting industrialization. Although economic growth increases the resources available for consumption in an economy as a whole, it is often accompanied by rising inequality in the distribution of resources among individuals [3] (Kuznets, 1955). Moreover, industrializing countries often experience a deterioration of environmental conditions and an increase in inequality before reaching higher levels of development. ISID builds on the notions that: i) countries need industrialization, as manufacturing is an engine of growth (Kaldor, 1960), and ii) the way in which countries industrialize matters, as it shapes their middle and late stages of development.

Manufacturing value added (MVA) is the most common indicator of the level of industrialization achieved by a country (UNIDO, 2013, 2018, 2020). It signifies an economy's capacity to produce goods to meet society's needs. The post-2030 Agenda (UN SDGs) calls for complementing economic indicators with environmental and social ones. ISID integrates all three dimensions of sustainable development for industrialization, namely economic, social and environmental. Despite the relevance of the ISID concept for the post-2030 Agenda, the measurement of countries' performance in the three dimensions of industrialization remains a challenge.

The present study develops an ISID and ISIDsdg9 monitoring tool for policymakers to evaluate countries' progress towards achieving UN SDG9, and presents two approaches to measure ISID: macro-economic (ISID) and industry-specific (ISIDsdg9) indicators. ISID is achieved when countries maximize their manufacturing performance (and, indirectly, GDP growth) by minimizing total CO_2 emissions and inequality in the country. The underlying approach is to measure the extent to which industrialization affects the environmental and social performance of the overall economy. The underlying notion of this approach is that manufacturing is an engine of economic growth that spreads positive spillovers to all other economic sectors. An ISID index

[2] On 2 December 2013, at the 15th session of UNIDO's General Conference, UNIDO member states endorsed the Lima Declaration: Towards inclusive and sustainable industrial development. The declaration highlights the relevance of inclusive and sustainable industrial development as the basis for sustained economic growth and, while respecting the processes established by the UN General Assembly, encourages appropriate consideration of the issue in the elaboration of the post-2015 development agenda.

[3] In Kuznets' (1955) model, waves of economic growth do not sweep over society as a whole at the same time. Growth is instead initially confined to narrow segments of the economy, leading to an increase in labour productivity and a rising dispersion of wages within these segments, so that income inequality in the economy as a whole increases.

should therefore aim to identify to what extent economic growth fuelled by manufacturing comes at the expense of environmental and social degradation. In contrast to ISID, ISIDsdg9 focusses exclusively on economic, social and environmental indicators of the manufacturing sector. The underlying notion is that ISID is achieved when a country's manufacturing sector grows without worsening the sector's environmental and social performance. According to this measurement approach, ISID is achieved when industrialization is promoted simultaneously with green industry and with social improvements that are strictly and directly related to the manufacturing sector.

As demonstrated by good international practices, the principles of the post-2030 Agenda are being mainstreamed in national policies, plans and strategies to address the social and environmental challenges countries face. In 2019 alone, 47 countries conducted voluntary national reviews[4] at the High-Level Political Forum (HLPF) of the United Nations. Even though the concept of ISID is important for policymaking in sustainable development, the underlying mechanism to quantify the trade-off mechanism among its three pillars, i.e. economic growth, social inclusion and environmental sustainability, can be complicated. The literature proposes the use of composite indices for evidence-based policymaking (see, among others, Saltelli, 2007; Nardo et al., 2008), but the composite index is often constructed based on the equal weight approach in which each component is accorded equal weight in the final index. This principle does not explain the choice of weights and implies perfect substitutability between economic, environmental and social indicators. According to Munda (2012), the perfect substitutability principle for measuring composite indices may not be ideal structural characteristics, and the relevance of indicators may not be uniform across countries. Alternative mathematical aggregation rules and compensatory approaches in practice are thus needed. Data envelopment analysis (DEA) can be used to concretely and objectively measure the progress economic actors have made towards achieving ISID and mitigate the equal weights and the perfect substitutability bias[5] (Atkinson et al., 2002).

This study aims to develop a DEA based on ISID and ISIDsdg9 rankings of 118 countries. To the best of our knowledge, this is the first study to rank world countries based on their performance in terms of economic, environmental and social indicators related to UN SDG9 using a DEA approach. The following section reviews the relevant literature. Section 3 presents the methodology used to elaborate an aggregate index that measures countries' performance in terms of economic, environmental and social indicators. Section 4 analyses the rankings and our findings. The section also includes considerations based on "the reality check", which compares

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[4] As part of the 2030 Agenda's follow-up and review mechanisms, its agenda for sustainable development encourages countries to conduct regular and inclusive reviews of progress at the national and sub-national levels (paragraph 79, Sustainable Development, 2019). These national reviews are expected to serve as a basis for the regular reviews by the high-level political forum (HLPF), meeting under the auspices of ECOSOC. As stipulated in paragraph 84 of the 2030 Agenda, regular reviews by the HLPF are to be voluntary, state-led, undertaken by both developed and developing countries, and shall provide a platform for partnerships, including through the participation of major groups and other relevant stakeholders.

[5] An example is provided by Atkinson et al. (2002), who, in the context of the EU social inclusion policy claim: "in the context of the EU, there are evident difficulties in reaching agreement on such weights, given that each member state has its own national specificity".

the DEA's aggregate performance of countries with performances in each individual economic, social and environmental indicator to demonstrate that the aggregated performance fully reflects the performance achieved in the individual indicators. Section 5 discusses the policy implications that we draw from our analysis.

2 Literature review

DEA was developed by Charnes, Cooper and Rhodes (1978) and is characterized by linear programming conducted with no predetermined assumptions about the objective function and weights. The base models can be categorized as follows: slack-based undesirable output model, radial and non-radial measures, range-adjusted measure and directional distance function. The slack-based undesirable output model has been receiving increased attention in evaluating the performances of countries and regions on resource allocation efficiency due to its capability to account for undesirable output in the optimization process (Wei, Ni and Shen, 2009; Li et al., 2013). This model framework is particularly suitable for the present study, which aims to capture the undesirable outputs of industrialization such as negative environmental or social impacts. We also adopt the non-radial approach (e.g. Färe and Lovell, 1978) as the unrealism of equiproportional target reductions to improve the overall ISID performance implied by the radial approach.

A thorough literature review on energy and the environment was carried out by Sueyoshi, Yuan and Goto (2017), who categorize 693 DEA studies. They start from the acknowledgment that industrialization is necessary to increase the level of a country's prosperity, but that it generates pollution and health problems. To analyse these trade-offs, they emphasize that "DEA is one of the methodologies to examine the level of sustainability" (Goto 2017, p. 104). They find that an increasing number of DEA studies in energy and the environment, particularly after 2000, has been conducted. They further conclude that the DEA methodology has some drawbacks: i) it is an imperfect modelling treatment of technology; ii) it lacks statistical inference; iii) greater attention must be paid to China (Yuan et al., 2019) conducted a study with a focus on China). None of the studies reviewed by Sueyoshi, Yuam and Goto specifically analyse the performance of world countries in SDG9 indicators.

Zhou, Ang and Han (2010), Arazmuradov (2011), and Kounetas (2015) review the trade-offs among energy, environmental and economic performance for over 30 countries and monitor and evaluate the possible effect of adopted international agreements and regulations, such as the Kyoto Protocol[6], on countries' environmental efficiency. Their work is relevant for the present study as a strong link exists with the international energy and environmental policy debate, which is one of our areas of investigation.

[6] The Kyoto Protocol is linked to the United Nations Framework Convention on Climate Change.

3 Methodology

This study follows the DEA approach for measuring countries' economic, social and environmental performance introduced by Zhou, Poh and Ang (2016, p. 32) based on the notion of minimizing undesirable or negative outputs (by-products of desirable outputs such as carbon dioxide emissions) to achieve the same level of desirable or positive outputs (beneficial outputs such as production outputs), i.e. it is an input-oriented approach. One strand of literature considers CO_2 emissions to be one of the inputs in the production function (see Gollop and Swinand, 1998; Pittman, 1983). If emissions are treated as inputs, they serve as a proxy for the use of the environment in the form of its assimilative capacity. An increase (decrease) in the quantity of emissions represents an increase (decrease) in the use of the environment's purification services (Färe, Grosskopf and Whittaker, 2007). Pittman (1981), Cropper and Oates (1992) and Reinhard, Lovell and Thijssen (2000) follow this approach and treat emissions as inputs.

In the context of ISID, manufacturing performance is the "good" countries seek to maximize; carbon emissions and social inequality are the "bad" they aim to minimize. Based on Tone (2001), we develop a constant returns-to-scale slack-based input model as follows (Cooper, Heron and Heward, 2007, p. 368):

$$\rho_{Input}{}^{*} = min_{\lambda,s^{-},s^{+}}\ [1 - \left(\frac{1}{m}\right) \sum_{i=1}^{m} \frac{s_i{}^{-}}{x_{i0}}] \tag{1}$$

Subject to

$$x_{i0} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i{}^{-} (i = 1\ , \dots , m) \tag{2}$$

$$y_{r0} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r{}^{+} (i = 1\ , \dots , s) \tag{3}$$

$$\lambda_j \geq 0 (\forall j), s_i{}^{-} \geq 0 (\forall i), s_r{}^{+} \geq 0 (\forall r) \tag{4}$$

where x_{i0} denotes input vectors, y_{r0} represents desirable output vectors; λ_j is an intensity vector; $s_i{}^{-}$ signifies the surpluses in the inputs, and $s_r{}^{+}$ the deficiencies in desirable outputs. The target value $\rho_{Input}{}^{*}$, is between 0 and 1. $\lambda_j{}^{*}, s_i{}^{-*}, s_r{}^{+*}$ represents optimal solution values. If the decision-making unit evaluated is efficient, it is taken as: $\rho_{Input}{}^{*} = 1$, $s_i{}^{-*} = 0$, and $s_r{}^{+*} = 0$; if it is not efficient, it is taken as: $\rho_{Input}{}^{*} < 1$. It is worth highlighting that the SBM model is designed to meet the following two conditions: unit variant and monotone. The measurement is not affected by the units of data and the input slack is monotone decreasing.

3.1 Dual formulations of Inclusive and Sustainable Industrial Development (ISID) indicators

The mathematical optimization does not solve another problem that characterize ISID indices: the choice of indicators for the final ISID index. Our approach is to offer two formulations of ISID and ISIDsdg9: ISID represents countries' ambition to promote industrialization and consequently, to sustain growth by reducing the adverse environmental and social effects that manifest in the economy. ISIDsdg9 evaluates the same aspects as ISID, but limits the externalities to the industrial sector and to indicators that are universally recognized as playing an important role in monitoring SDG9.

3.2 Data

A list of three indicators from Table 1 are used to quantify the three dimensions of ISID, where MVApc is manufacturing value added per capita (United Nations Industrial Development Organization, 2018), $\mathrm{CO2pc}$ is CO_2 emissions per capita (The World Bank, 2018) and GINI is an inequality index (the Gini net index applied to incomes net of taxes from SWIID, Standardized World Income Inequality Database, 2018).

Table 1. ISID indicators

Dimensions	**ISID**		**ISIDsdg9**	
Manufacturing development	MVApc	Manufacturing value added per capita	MVApc	Manufacturing value added per capita
Social inclusion	GINI	Inequality index expressing inequality in the distribution of income within the country	MEMPGAP	The gap between each region and the best performer in terms of share of industrial employment in total employment
Environmental sustainability	CO2pc	Total CO_2 emission per capita	MCO2INT	Manufacturing CO_2 emission intensity (KG per value added USD)

Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (Solt, 2018)

The difference between ISID and ISIDsdg9 are the environmental and social indicators. ISIDsdg9 includes manufacturing CO_2 emission intensity (CO_2 emission, kt per value added USD) as an environmental indicator. Furthermore, inspired by the global indicator framework[7], namely Indicators 9.2.1, 9.2.2 and 9.4.1 (UNSD, 2018[8]), ISIDsdg9 includes the manufacturing employment gap as a social indicator (the gap between a country's share of manufacturing employment and that of the country with the highest share of manufacturing employment in the world). The ISID approach, on the other hand, includes non-manufacturing-specific environmental and social indicators such as total CO_2 emissions per capita and the Gini index of inequality. It also captures

[7] https://unstats.un.org/sdgs/metadata/?Text=&Goal=9&Target=
[8] https://unstats.un.org/sdgs/metadata/

the impacts of industrialization on environmental and social aspects related to the economy as a whole, whereas the ISIDsdg9 approach specifically captures variables related to manufacturing.

One of the best ways to ensure that there is "not much imbalance in the datasets is to have them at the same or similar magnitude" (Sarkis, 2007, p. 4). One way of ensuring that the data is of the same or similar magnitude across and within datasets is to min-max normalize the data. This process of min-max normalization requires two simple steps. The first step is to identify the minimum and maximum values of each indicator by year. The second step is to divide each input or output by the range of min-max for that specific factor.

4 Main findings and discussions

The DEA approach is the one that is most likely to capture the essence of the ISID concept: traditional composite indices reflect the capacity of countries to increase their performance in all dimensions of sustainability simultaneously. The DEA approach calculates to what extent countries minimize trade-offs across different dimensions of sustainability.

We test the ISID specifications for the period 2005 – 2013 for 50 countries and the ISIDsdg9 specifications for 118 countries for the period 2005 – 2015[9]. The DEA algorithm generates the following five top and bottom rankings (Table 2).

Table 2: ISID ranking

Top 5 ISID 2013	Bottom 5 ISID 2013
Switzerland	Chile
Denmark	Serbia
Norway	Bulgaria
Sweden	North Macedonia
Belgium	Georgia

Table 3: ISIDsdg9 ranking

Top 5 ISIDsdg9 2015	Bottom 5 ISIDsdg9 2015
Czechia	Kyrgyzstan
Switzerland	Iraq
Germany	Ethiopia
Japan	Nepal
Ireland	Syria

A first insight that emerges from the ranking in Table 2 is that industrialized countries are, in relative terms, more efficient in generating manufacturing value added by minimizing the

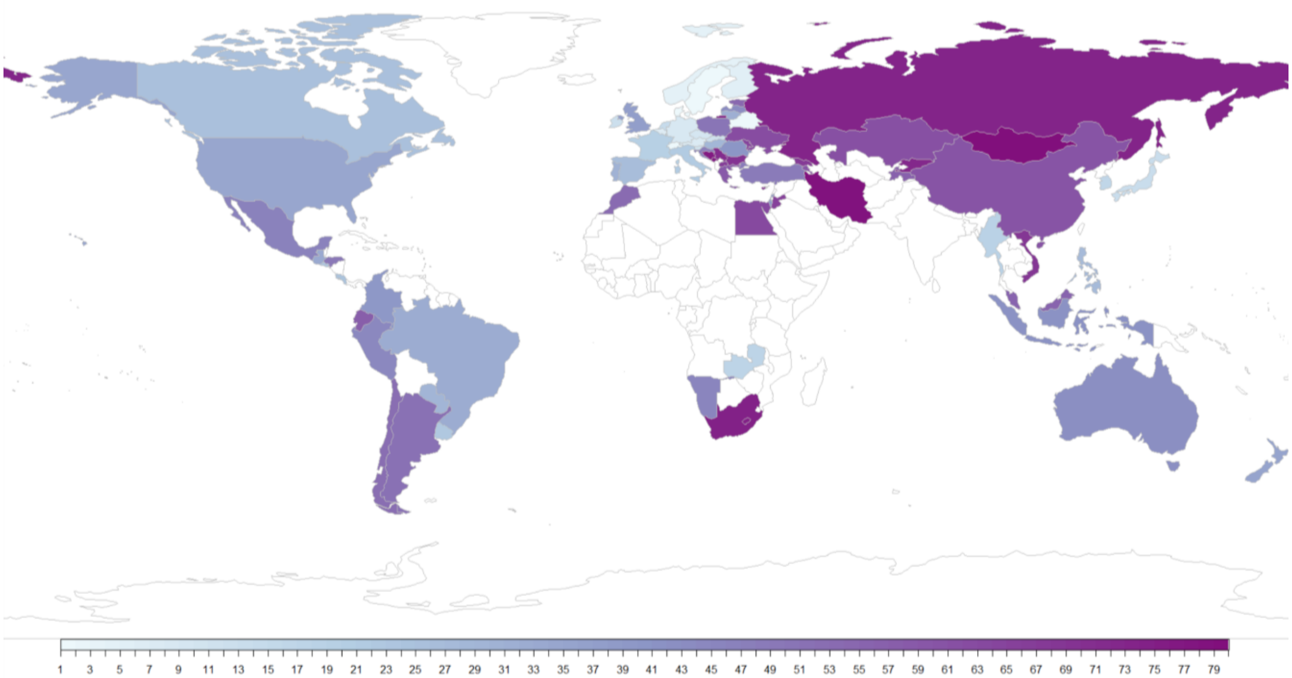
[9] We used a narrower dataset in terms of country coverage and time periods to maintain a balanced dataset across countries. In the Appendix, we include the final ranking of the indices for 50 countries in 2013 (ISID index) and for 118 countries in 2015 (ISIDsdg9 index).

environmental footprint and social inequality. Eastern European countries tend to concentrate at the bottom of the ranking. An exception of a developed country included in the bottom of the list is Chile, which showed a low share of manufacturing employment in the ISID formulation.

4.1 ISID approach

Figure 1 presents the main results of the ISID efficiency scores: the scale of colours represents the level of integration efficiency among countries. The lower the efficiency score, the deeper the purple colour. It is worth noting that Northern European countries like Sweden, Switzerland, Norway and Denmark (integrated efficiency score: 1) are the best performers in terms of the ISID indicators. These countries constitute the benchmark of ISID mainstreaming (see Appendix 1 for the complete ISID ranking). We also find that Central Asian countries are less efficient in the ISID context. Insufficient data is available for those countries that are not coloured.

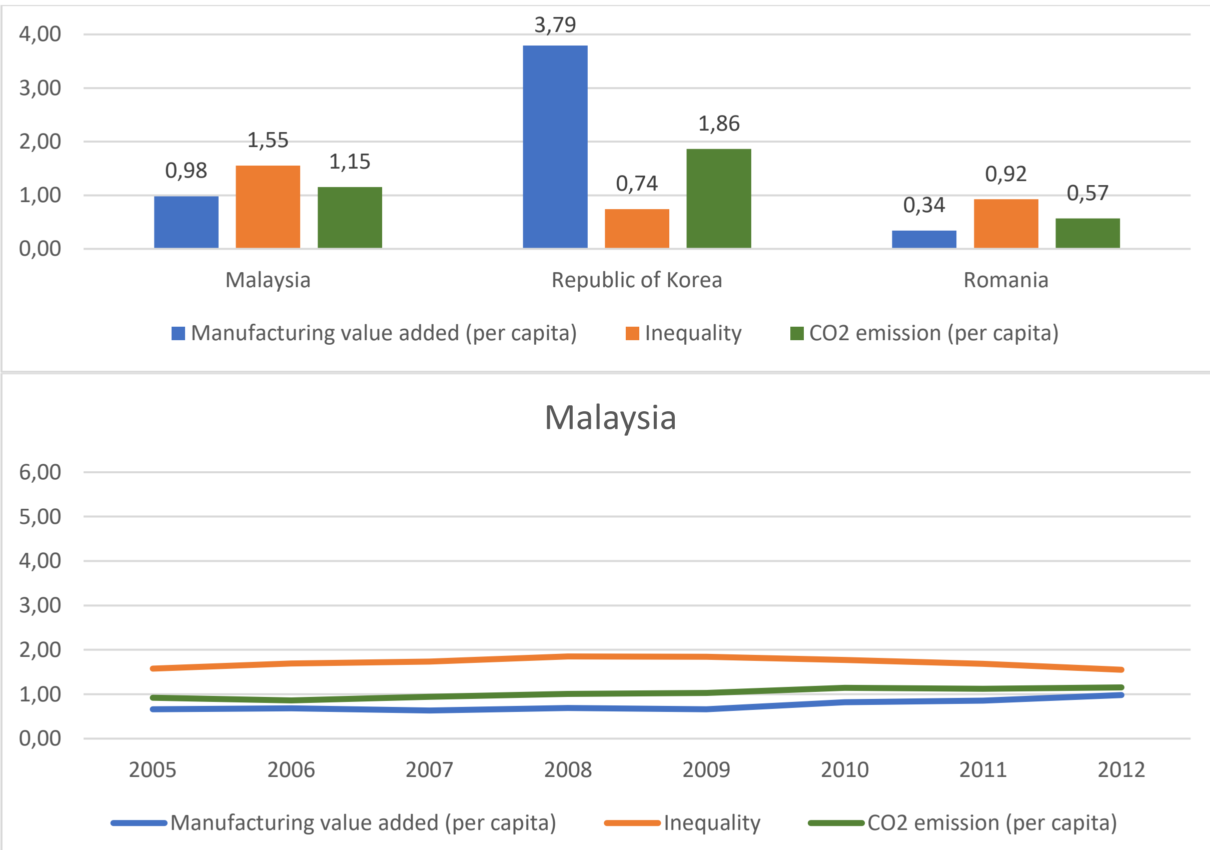
Figure 1. ISID ranking (2013)

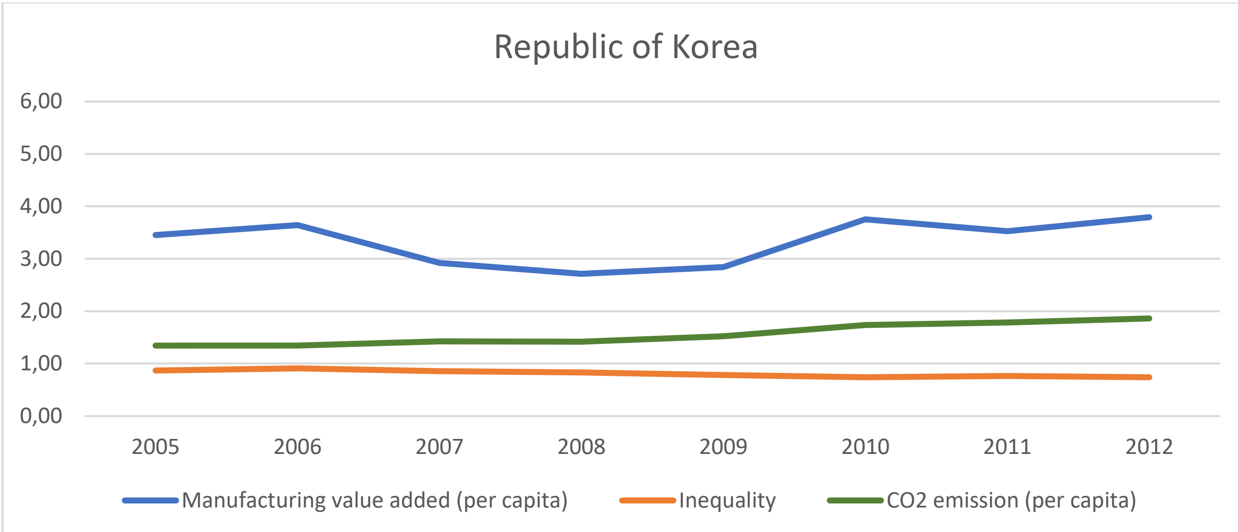


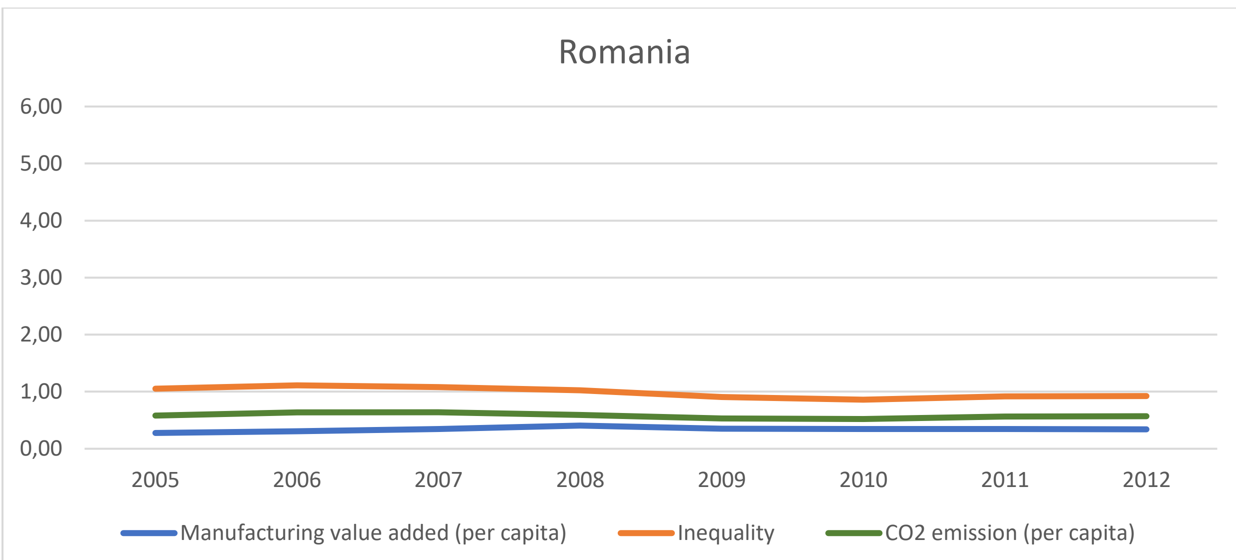
Source: Authors' elaboration based on the input-oriented DEA CCR SBM model

Figure 2 (upper panel) illustrates the extent to which a country performs better or worse according to the DEA methodology. The Republic of Korea outperforms the other countries because it produces (relative to the indicators' median value) a high level of manufacturing value added per capita (blue bar) with relatively low levels of inequality (orange bar) and CO_2 emissions per capita (green bar). While Malaysia and Romania have similar levels of CO_2 emissions per capita and inequality as the Republic of Korea's, the two countries' level of manufacturing value added is far below the median level. In other words, these countries are less efficient in generating manufacturing value added because they pay "higher toll rates" in terms of carbon emissions and social inequality. The difference between the Republic of Korea, on the one hand, and Romania and Malaysia, on the other, is evident when looking at the time series graphs (Figure 2, lower panel). The Republic of Korea shows a very strong performance in terms of manufacturing value added (relative to CO_2 emissions per capita and inequality), whereas Romania and Malaysia's performance is weaker. Figure 2 sheds some light on the overall ranking of Romania (45th) and Malaysia (37th), which is the result of their poor performance in social equality.

Figure 2: ISID index components analysis for 2013, Republic of Korea (10th in the ISID ranking), Malaysia (37th in the ISID ranking) and Romania (45th in the ISID ranking)







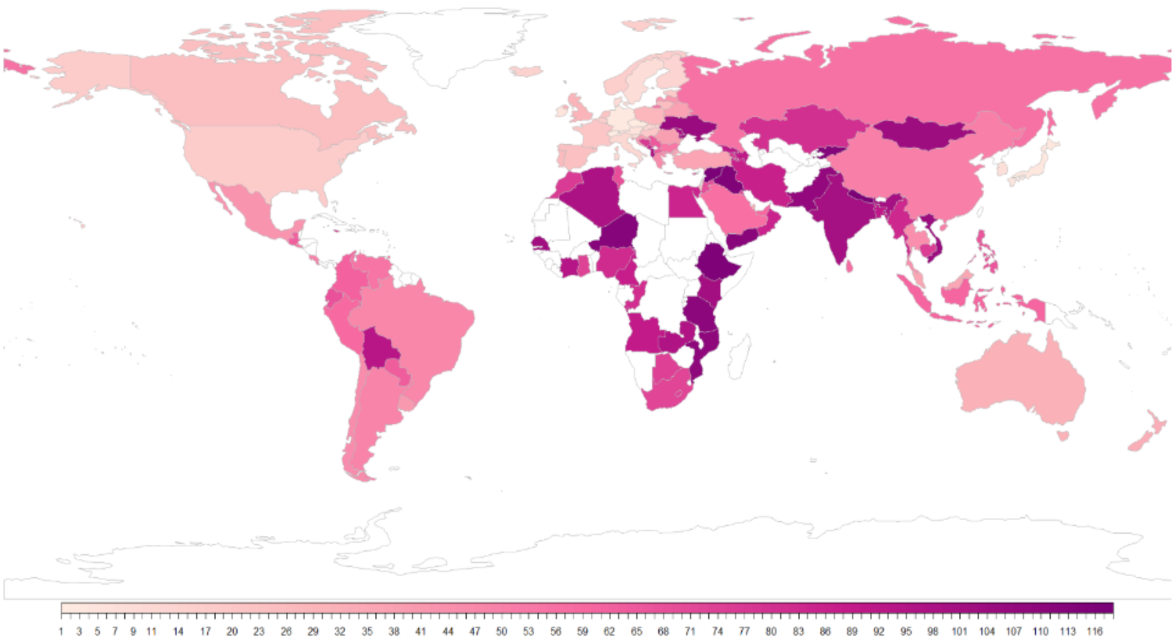
Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (2018)

Note: The median value of the sample normalizes the variables.

4.2 ISIDsdg9 approach

In the ISIDsdg9 approach, we only focus on indicators related to UN SDG9 (i.e. approved as international indicators), specifically the manufacturing sector. Based on the dataset of 118 countries in 2015, Figure 3 presents the global ranking of ISIDsdg9 with Czechia and Switzerland positioned at the efficiency frontier (integrated efficiency score equal to 1). Both Czechia and Switzerland have a low CO_2 emission intensity and a high share of manufacturing employment. By reviewing the ranking of countries across regions, we find that countries in Africa and in the South Asia regions generally perform below average.

Figure 3: ISIDsdg9 ranking for 2015

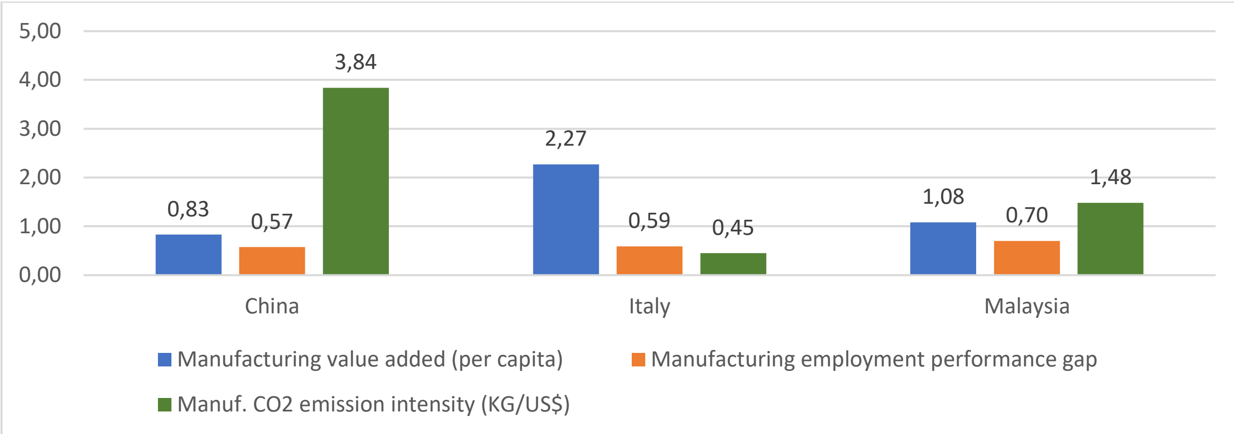


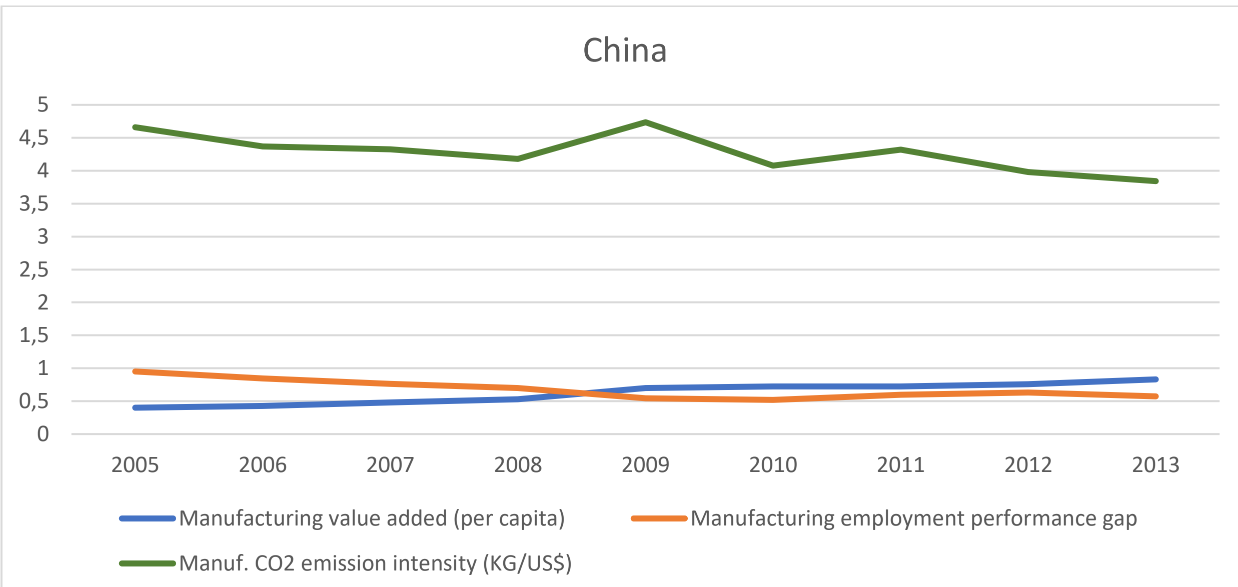
Source: Authors' elaboration based on the input-oriented DEA CCR SBM model

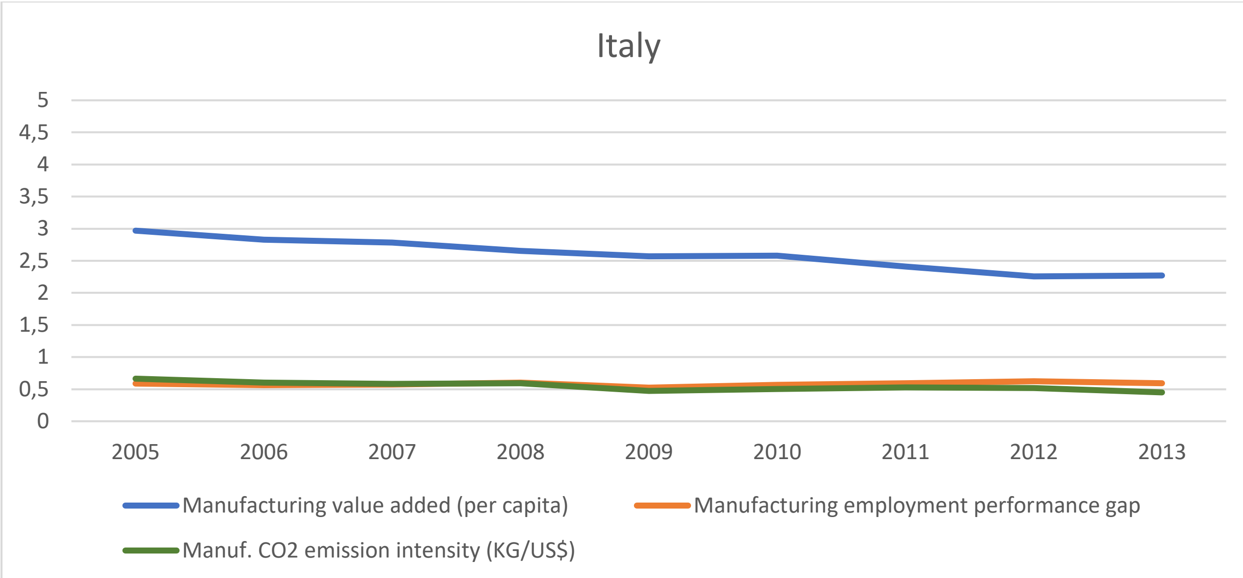
Figure 4 (upper section) shows that Italy has a very high level of MVA per capita (blue bar) relative to its manufacturing sector's low level of CO_2 emission intensity and the gap between the best performer in terms of share of manufacturing employment in total employment (orange and green lines). China and Malaysia's MVA per capita is particularly weak with a high level of CO_2 emission intensity. Figure 4 (lower panel) illustrates a declining trend of Italy's efficiency score, suggesting that the country's capability to generate manufacturing value added has been gradually decreasing over time with a relatively stable trajectory of emission intensity and inequality. Italy is an example of a country that is experiencing rapid deindustrialization, accelerated by the global financial crisis.

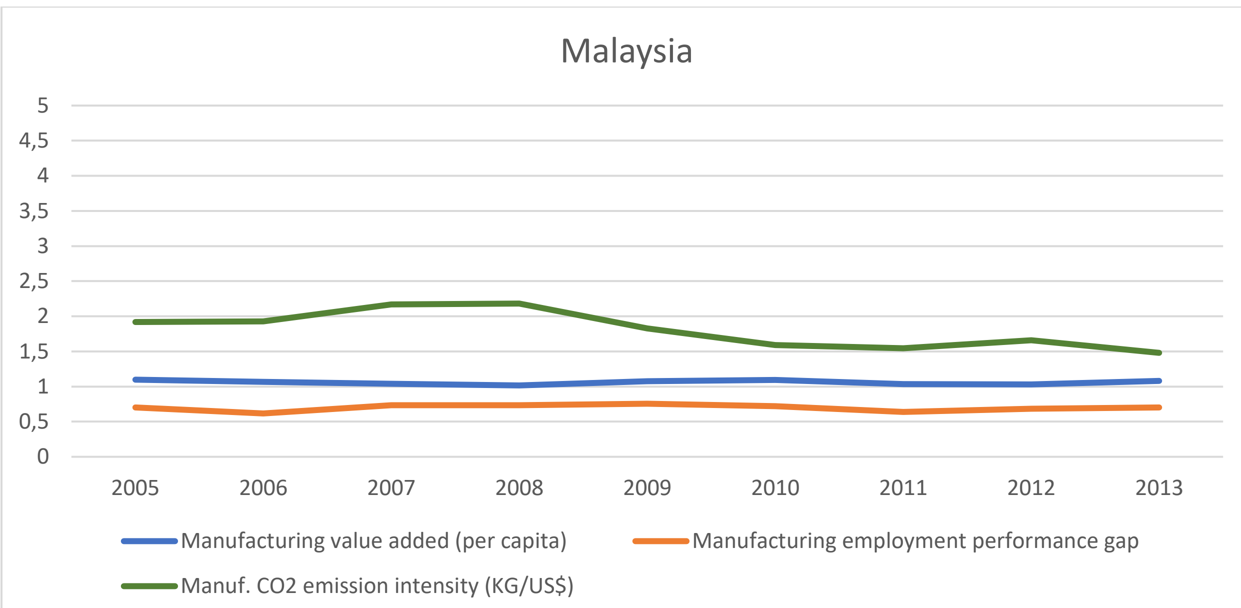
Italy dropped by one position since 2005 (10^{th} in 2015) as a result of declining MVA performance. In many developed countries, the value of industrial-led growth for society as a whole has come into question due to increasing inequality. In developing countries, record decreases in poverty and growing manufacturing activities have fuelled higher demand for transport and energy; these demands have given rise to environmental challenges that most developing countries face. The CO_2 intensity of China's manufacturing sector is around 3.8 times higher than the global average.

Figure 4: ISID SDG9 components analysis for 2013, Republic of Korea (10th in ISID ranking), Malaysia (37th in ISID ranking) and Romania (45th in ISID ranking)









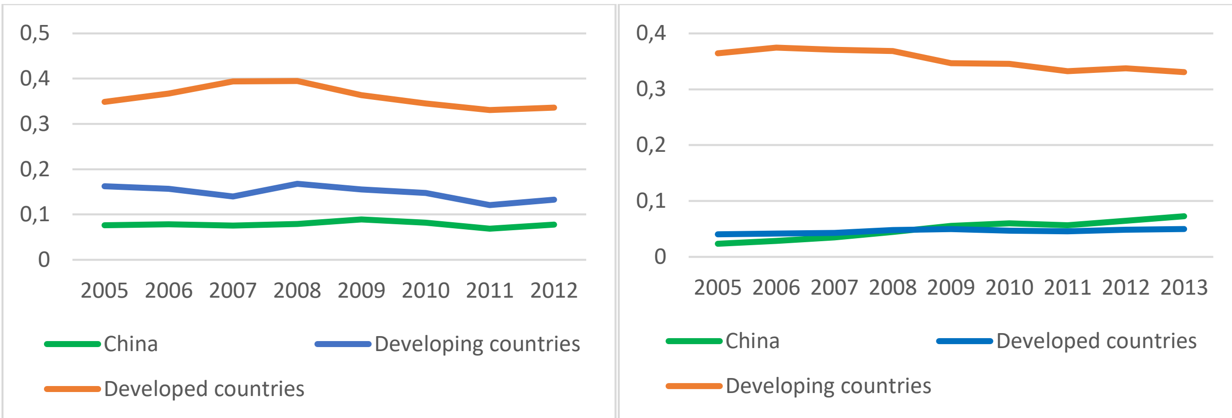
Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (Solt, 2018)

Note: The median value of the sample normalizes the variables. The assumption underlying this figure is that value added is scaled at the same level for all countries included.

The evidence presented above is supported by the average efficiency scores of ISID and ISIDsdg9 for developed and developing countries. Developed countries are the most efficient, as the analysis in the previous section shows. Over the period 2005–2012, there is no sign of catching up between developed and developing countries (for both ISID and ISIDsdg9). China's performance in the ISID model is weak; its performance is even lower than the average score of other developing countries.

4.3 Aggregate results of developed and developing countries

Figure 5: Efficiency score of ISID model (2005 – 2012); ISIDsdg9 (2005-2013)



Source (left): INDSTAT2 (UNIDO, 2017), World Development Indicators (The World Bank, 2017), SWIID (Solt, 2017); Source (right): SDG 9 Indicators (UNIDO, 2018);

Income classification: GINI per capita in US$ (Atlas methodology) (The World Bank, 2013)

5 Policy section

Policymakers face the challenge of addressing different environmental, social and economic goals simultaneously. These challenges are associated with the core dimensions of ISID, which feature strongly in the 2030 Agenda for Sustainable Development[10]. All countries have the potential to promote ISID, and policymakers are encouraged to continue reviewing best practices to accelerate their progress and pave the path for ISID. There is an urgent need to develop an objective and comprehensive ISID policy tool to rationalize the trade-offs between the multidimensional principles of ISID and to monitor and evaluate the progress of countries towards ISID.

An immediate question arises in this regard: how can this study support policymakers in formulating an effective monitoring and evaluation system and evidence-based policy interventions to achieve ISID? This study puts forward a policy tool based on the input-oriented DEA-CCR-SBM model to identify and benchmark the country with the best practice in ISID. There are two guiding principles for ISID benchmarking: (i) to identify best practice "role model" countries in ISID; (ii) to conduct an assessment of countries' reduction potential. One drawback of this policy tool is that it neither establishes a definitive policy tool, nor does it introduce a one-size-fit-all solution, as country conditions differ considerably. Our approach identifies countries' role model in terms of best practice in ISID and assesses the efforts necessary to reach the target. The modalities for achieving the target require a more in-depth policy analysis of the specific enablers of ISID.

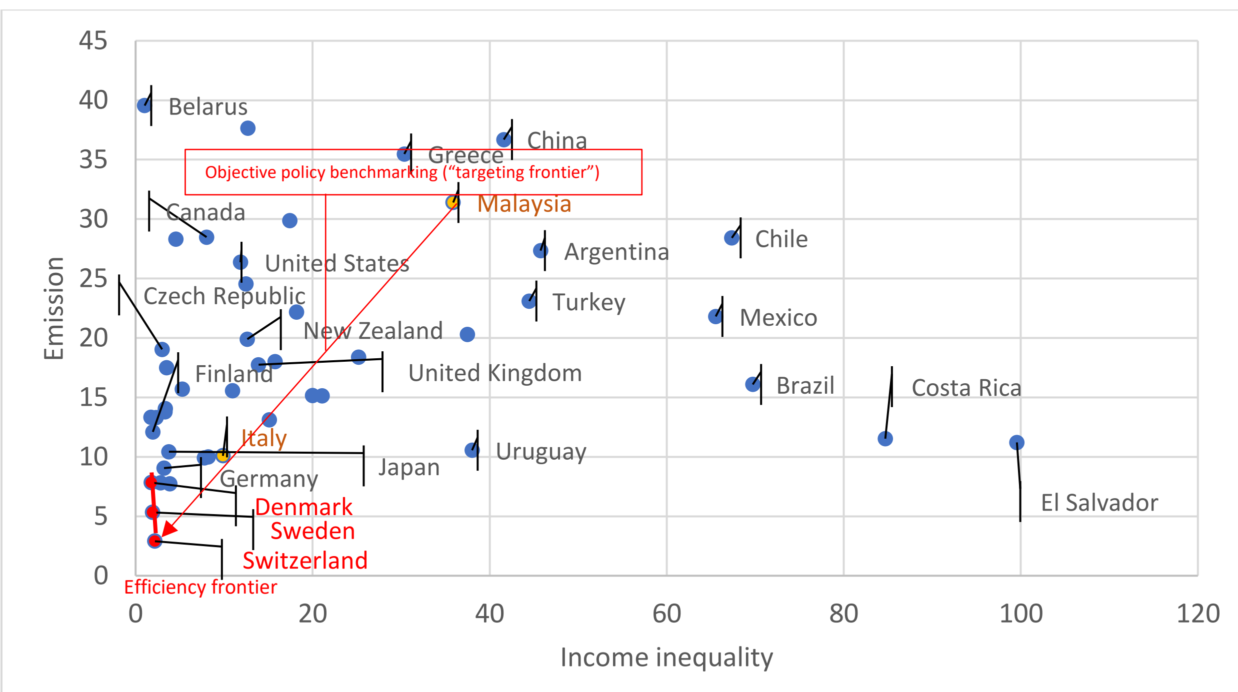
Figure 6 presents a two-dimensional figure on the trade-offs between social equality and environmental sustainability for 50 countries to achieve similar levels of manufacturing

[10] https://www.unido.org/inclusive-and-sustainable-industrial-development

development in 2013. The input-oriented DEA-CCR-SBM model suggests that Norway, Denmark, Sweden and Switzerland represent the efficiency frontier (red curve). They are the most efficient countries in terms of accelerating the growth of their manufacturing sector while minimizing the negative externalities of carbon emission (CO_2 emission per capita) and social inequality (GINI) at the same time.

In the ISIDsdg9 approach, we limit the externalities of ISID within the manufacturing sector. Figure 7 presents the performance of 118 countries in terms of CO_2 emission intensity (CO_2 emission per value added) and the manufacturing employment gap (distance to the country with the highest share of manufacturing employment), assuming that these countries achieve a similar level of manufacturing development. A general observation that holds for both the ISID and ISIDsdg9 approaches is that OECD countries are the most efficient and are clustered towards the origin of the diagram. As illustrated in Figures 6 and 7, developing countries are generally located furthest from the efficiency frontier (red curve). In the ISIDsdg9 approach, Czechia and Switzerland were the most efficient countries in terms of generating manufacturing value added in 2015 (Figure 7) and were the most successful in minimizing their manufacturing CO_2 emission intensity and the gap to the best performer as regards the share of manufacturing employment in total employment. It is worth noting that Czechia has the highest share of manufacturing employment in total employment and shares the frontier status with Switzerland, which had the lowest carbon emission intensity that same year.

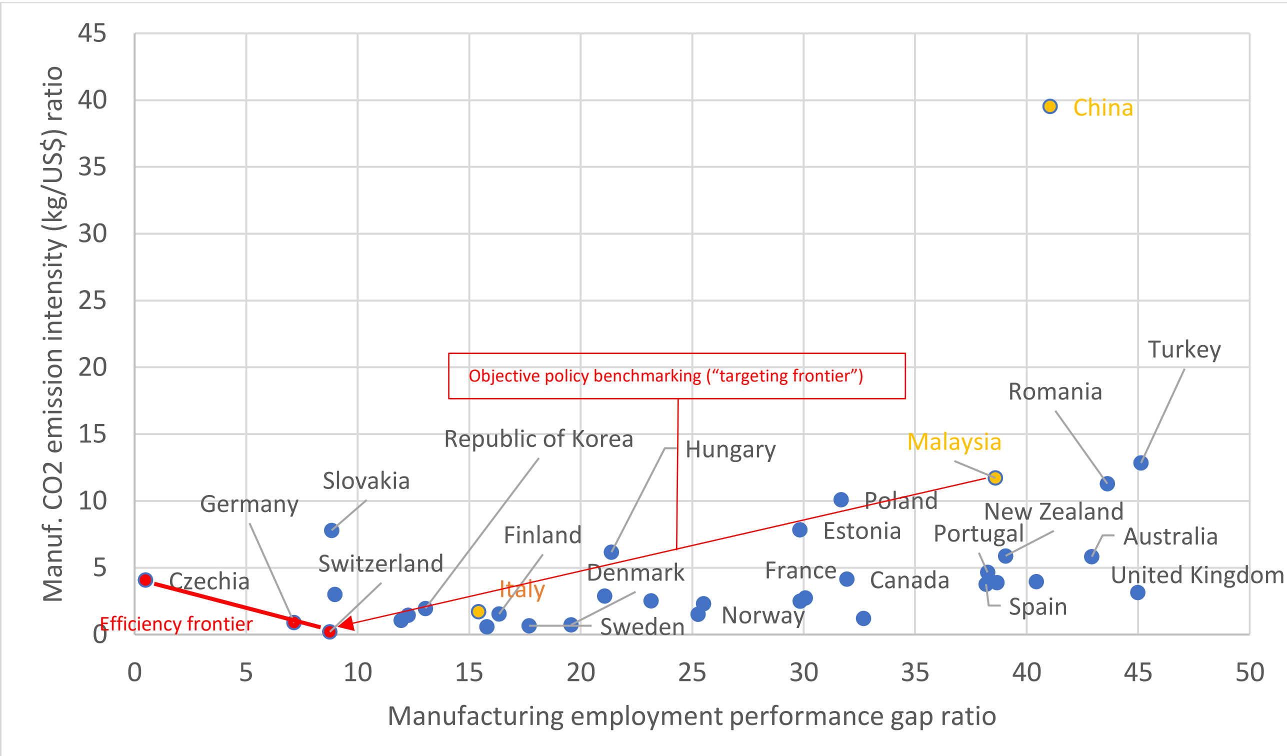
Figure 6: Efficiency analysis for the full sample of 50 countries for 2013: ISID model



Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (2018)

Note: The assumption underlying this figure is that value added is scaled at the same level for all countries included

Figure 7: Efficiency analysis for the full sample of 118 countries for 2015: ISIDsdg9 model



Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (2018)

Note: The assumption underlying this figure is that value added is scaled at the same level for all the included countries

For Malaysia, for example, we can establish a radiate line (from origin to DMU) in Figure 6, which reaches the target role model countries (countries at the efficiency frontier: Switzerland, Sweden and Denmark) or a comparator country (on the radiate line and closer to the frontier: Italy) when we conduct ISID benchmarking. We can also identify a country's reduction potential compared to the role model or a comparator country for countries that could achieve a similar level of manufacturing development as Malaysia, albeit with a lower carbon footprint and a higher degree of social inclusion.

Similarly, in Figure 7, the benchmarking analysis can be applied to ISIDsdg9 for manufacturing-specific policymaking. As discussed earlier, Czechia and Switzerland are the countries at the efficiency frontier that serve as role models for ISIDsdg9. As the ISIDsdg9 indicator focusses on employment within the manufacturing sector, it is assumed that the model penalizes advanced countries that are experiencing deindustrialization, such as Australia and New Zealand, which are characterized by a low share of manufacturing employment (high gap ratio to the best performer). A more developed country, like Italy, with a strong manufacturing base and a relatively low CO_2 emission intensity could be a suitable comparator for Malaysia.

Table 4: Efficiency analysis for the full sample of 50 countries for 2013: ISID model

Country	Manufacturing value added per capita (US$)	CO_2 emission (kt) per capita	GINI (disposable income)	Ranking	Efficiency score	Targeted CO_2 emission (after slack adjustment)	Targeted GINI (after slack adjustment)
Switzerland	14049	0.004312	29.2	1	1.00	0.004312	29.20
Denmark	7184	0.005936	25.4	1	1.00	0.005936	25.40
Sweden	7922	0.004478	25.9	1	1.00	0.004478	25.90
Austria	8356	0.006874	27.7	8	0.68	0.004707	26.08
Germany	9388	0.008889	29.1	9	0.60	0.005342	26.49
Republic of Korea	7052	0.011570	30.6	17	0.36	0.004254	25.52
Italy	**4918**	**0.005271**	**33.1**	**22**	**0.29**	**0.001599**	**24.27**
Malaysia	**2391**	**0.008033**	**41.4**	**56**	**0.09**	**0.000849**	**23.20**
China	1905	0.007544	40.1	61	0.08	0.000704	23.10

Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (Solt, 2018)

Table 5: Efficiency analysis for the full sample of 118 countries for 2015: ISIDsdg9 model

Country	Manufacturing value added per capita (US$)	CO_2 emission (kt) per value added (US$)	Manufacturing employment gap	Ranking	Efficiency score	Targeted CO_2 emission (after slack adjustment)	Targeted manufacturing employment gap (after slack adjustment)
Czechia	4929.24	0.22	27.30	1	1.00	0.22	27.30
Switzerland	13773.69	0.04	12.58	1	1.00	0.04	12.58
Germany	9485.02	0.12	19.30	3	0.98	0.12	19.13
Austria	8460.94	0.13	15.96	6	0.66	0.09	12.02
Republic of Korea	7118.54	0.22	17.29	8	0.53	0.12	12.44
Italy	**4980.94**	**0.12**	**18.34**	**12**	**0.48**	**0.06**	**13.55**
Malaysia	**2467.67**	**0.38**	**16.51**	**36**	**0.14**	**0.06**	**7.02**
China	2016.38	0.95	18.36	51	0.07	0.08	9.81

Source: INDSTAT2 Rev.3 (United Nations Industrial Development Organization, 2018); World Development Indicators (The World Bank, 2018); Standardized World Income Inequality Database (Solt, 2018)

From a policy perspective, it is also useful to assess the trade-offs between the externalities generates by industrialization. Table 4 presents the indicator-specific efficiency values of nine countries. According to the input-oriented DEA-CCR-SBM model, it is possible to measure a country's reduction potential to reach the efficiency frontier. For example, Malaysia has to reduce its CO_2 emissions to 0.00085 (CO_2 emissions kt, per capita) and maintain its level of social equality at 23.2 (in GINI) based on its current manufacturing performance. The country would then be able to achieve a higher level of ISID by reducing its carbon emissions, which implies the adoption of technologies and practices that decouple natural resource use and environmental impacts from economic growth.

Table 5 presents the gap between Malaysia's actual and targeted manufacturing CO_2 emission intensity and share of manufacturing employment for the ISIDsdg9 formulation. Based on 2015 data, a country like Malaysia could become efficient in ISIDsdg9 by reducing its CO_2 intensity by

0.32 (CO_2 emissions kt, per value added US$) and minimizing the employment gap by about 9.5 per cent.

For a country like Malaysia, the binding constraint to achieving higher levels of ISID and ISIDsdg9 is the country's carbon emission. Mainstreaming ISID and ISIDsdg9 into national policies can have far-reaching impacts on communities at all levels. When environmental safeguards and social inclusion criteria are adequately taken into account, as promoted by ISID, the industrial sector proves to be a powerful driver of prosperity and collective well-being.

6 Conclusions

ISID requires the full engagement of policymakers in industrializing countries to minimize the environmental footprint and negative social impacts. Although a vast consensus on this approach exists in the international community, as reflected in the approval of SDG9 on industrialization, social inclusion and environmental sustainability, from an operational point of view, it is quite difficult to monitor and evaluate countries' progress and the benchmarks set. Many attempts to express ISID through composite indexes, including economic, environmental and social indicators, are not always useful for policymakers and practitioners. The major practical problem is that composite indices assume equal weight (the economic, environmental and social indicators have the same importance at every level of income per capita) and are characterized by perfect substitutability (the rate of substitution across indicators to maintain the same level of ISID is constant over time). The data envelopment analysis addresses these technical problems (which implies a substantial challenge for interpreting ISID correctly) by an optimization algorithm calculating optimal weights putting countries in the most favourable position in the final ranking based on the underlying economic structure. The present study applies the data envelopment analysis using two formulations: the first one focusses on manufacturing value added per capita by minimizing total CO_2 emissions per capita and inequality in the distribution of income. This formulation construes ISID as industrialization achieved by minimizing the adverse externalities of industrialization on the overall economy.

The formulation for ISIDsdg9 construes ISID as industrialization achieved by minimizing the manufacturing sector's detrimental environmental and social impacts. In both formulations, we find that industrialized countries tend to perform better than emerging countries, but interesting distinctions emerge as well. New and more appropriate formulations could emerge from further discussions and research, but a general finding that arises from our study is that methodologies should be developed that are able to fully capture the extent of trade-offs between economic indicators and negative social and environmental indicators.

Annex 1. ISID ranking of 50 countries for 2013

Case: ISID (Normal)

Year: 2013

Data: UNIDO INDSTAT, IEA, SWIID

Data: MVA per capita (US$), CO_2 emission per capita (Kt per capita), GINI net

Country	Year	Rank	Theta
Switzerland	2013	1	1
Denmark	2013	1	1
Norway	2013	1	1
Sweden	2013	1	1
Belgium	2013	5	0.7684605
Finland	2013	6	0.6679813
Austria	2013	7	0.4916249
Czechia	2013	8	0.4776648
Germany	2013	9	0.4733471
Netherlands	2013	10	0.4714312
Republic of Korea	2013	11	0.460112
France	2013	12	0.3918104
Slovenia	2013	13	0.3756631
Costa Rica	2013	14	0.3629705
Sri Lanka	2013	15	0.3315724
Brazil	2013	16	0.3228744
Slovakia	2013	17	0.2853143
Luxembourg	2013	18	0.2835943
Singapore	2013	19	0.2739699
Italy	2013	20	0.2524402
Canada	2013	21	0.2425811
Peru	2013	22	0.2174224
United States	2013	23	0.2118069
New Zealand	2013	24	0.2017948
Hungary	2013	25	0.1982384
Colombia	2013	26	0.1847103
United Kingdom	2013	27	0.1729781
Spain	2013	28	0.1726647
Australia	2013	29	0.164318
Portugal	2013	30	0.1636461
Israel	2013	31	0.1435971
Latvia	2013	32	0.119324
Croatia	2013	33	0.1139362
Indonesia	2013	34	0.105093

Lithuania	2013	35	0.0988915
Mexico	2013	36	0.098214
Poland	2013	37	0.0937966
China	2013	38	0.0902135
Estonia	2013	39	0.0852262
Turkey	2013	40	0.085142
Romania	2013	41	0.0809949
Ecuador	2013	42	0.0785311
Russian Federation	2013	43	0.0699482
Greece	2013	44	0.0611174
Cyprus	2013	45	0.0587147
Chile	2013	46	0.0540018
Serbia	2013	47	0.0499389
Bulgaria	2013	48	0.0490355
TFYR of Macedonia	2013	49	0.0409122
Georgia	2013	50	0.0371048

Annex 2: ISIDsdg9 ranking of 118 countries for 2015

Data: UNIDO SDG indicators (internal source), imputed data

Data: MVA per capita (2010 US$), CO_2 emission per value added (KG/US$), share of manufacturing employment (gap to top performer)

Country	Year	Rank	Theta
Czechia	2015	1	1
Switzerland	2015	1	1
Germany	2015	3	0.98001
Japan	2015	4	0.673286
Ireland	2015	5	0.661336
Austria	2015	6	0.660782
Slovenia	2015	7	0.605382
South Korea	2015	8	0.527366
Sweden	2015	9	0.502005
Denmark	2015	10	0.497102
Singapore	2015	11	0.491595
Italy	2015	12	0.480457
Slovakia	2015	13	0.475114
Finland	2015	14	0.418749
Iceland	2015	15	0.34522
Belgium	2015	16	0.345103
Norway	2015	17	0.329242
USA	2015	18	0.314011

Estonia	2015	19	0.289053
Hungary	2015	20	0.286789
France	2015	21	0.278469
Israel	2015	22	0.271913
Netherlands	2015	23	0.269019
Spain	2015	24	0.242109
Canada	2015	25	0.234541
Lithuania	2015	26	0.219128
Portugal	2015	27	0.208753
Luxembourg	2015	28	0.208368
Poland	2015	29	0.197634
Brunei	2015	30	0.191579
UK	2015	31	0.18421
Australia	2015	32	0.171908
New Zealand	2015	33	0.17042
Qatar	2015	34	0.169978
Bahrain	2015	35	0.143606
Malaysia	2015	36	0.142312
Turkey	2015	37	0.135244
Belarus	2015	38	0.124852
Romania	2015	39	0.120008
Croatia	2015	40	0.119708
Uruguay	2015	41	0.109163
Latvia	2015	42	0.10478
Mexico	2015	43	0.102243
Mauritius	2015	44	0.088464
Thailand	2015	45	0.085496
Chile	2015	46	0.07923
Greece	2015	47	0.077569
Brazil	2015	48	0.074148
Argentina	2015	49	0.073585
Costa Rica	2015	50	0.073369
China	2015	51	0.071922
Trinidad and Tobago	2015	52	0.065895
El Salvador	2015	53	0.05989
Bulgaria	2015	54	0.059814
Venezuela	2015	55	0.058152
Russia	2015	56	0.055794
Saudi Arabia	2015	57	0.052327
Sri Lanka	2015	58	0.050648
Peru	2015	59	0.049021
United Arab Emirates	2015	60	0.048325

Indonesia	2015	61	0.043846
Colombia	2015	62	0.042744
Guatemala	2015	63	0.037914
Paraguay	2015	64	0.036621
Macedonia	2015	65	0.03585
Serbia	2015	66	0.034467
Philippines	2015	67	0.032553
Ecuador	2015	68	0.032395
Tunisia	2015	69	0.032193
Jordan	2015	70	0.031639
Cyprus	2015	71	0.031495
Kuwait	2015	72	0.029865
South Africa	2015	73	0.029165
Honduras	2015	74	0.025562
Botswana	2015	75	0.025414
Cambodia	2015	76	0.024649
Morocco	2015	77	0.024432
Bosnia and Herzegovina	2015	78	0.023286
Armenia	2015	79	0.022444
Jamaica	2015	80	0.018002
Kazakhstan	2015	81	0.017889
Congo	2015	82	0.017386
Nigeria	2015	83	0.017357
Myanmar	2015	84	0.017348
Egypt	2015	85	0.017277
Oman	2015	86	0.01719
Iran	2015	87	0.016918
Cameroon	2015	88	0.01631
Montenegro	2015	89	0.0148
Angola	2015	90	0.013884
Azerbaijan	2015	91	0.013698
Bangladesh	2015	92	0.013035
Georgia	2015	93	0.012805
Bolivia	2015	94	0.012336
Côte d'Ivoire	2015	95	0.010294
China, Hong Kong Special Administrative Region	2015	96	0.010181
Zambia	2015	97	0.009609
Algeria	2015	98	0.009408
Albania	2015	99	0.009091
Moldova	2015	100	0.008946
India	2015	101	0.008745

Kenya	2015	102	0.008499
Senegal	2015	103	0.007519
Mongolia	2015	104	0.007032
Viet Nam	2015	105	0.006292
Ukraine	2015	106	0.006227
Ghana	2015	107	0.006065
Pakistan	2015	108	0.005962
Haiti	2015	109	0.005539
Mozambique	2015	110	0.005475
Tanzania	2015	111	0.005249
Yemen	2015	112	0.005041
Niger	2015	113	0.004837
Kyrgyzstan	2015	114	0.004221
Iraq	2015	115	0.00296
Ethiopia	2015	116	0.002793
Nepal	2015	117	0.002331
Syria	2015	118	0.001855

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