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# Tracking the Sustainable Development Goals with Input-Output Analysis: A commentary and example

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**Abstract:** In September of 2015, 193 member states of the United Nations adopted the "2030 Agenda for Sustainable Development", which introduces 17 Sustainable Development Goals (SDGs) with 169 targets as the new organizing principles to direct global action towards a universal sustainable development path. Implementing mechanisms to track progress towards these global goals is still a challenge. Furthermore, the consideration of countries' "spillover effects", namely the positive or negative effect of a country's actions onto others is just being discussed and considered for national performance assessments in terms of the SDGs.

As a general research question, this article explores the applicability of Multi-Regional Input-Output analysis for tracking performance towards the SDGs, including the consideration of spillover effects. To do so, and more specifically, the article sets to a) address the question: What is the current global scenario regarding the assessment of performance towards the SDGs in which a tool such as MRIO analysis can fill a particular niche, considering both its strengths and limitations? b) address the question: To what extent relevant existing works in the Input—Output literature have examined issues matching any of the 232 SDGs-indicators proposed by the IAEG-SDG? Here, a 3-point classification scale is introduced: Class I = same as indicator, class II = relevant to indicator (could match the indicator with some modifications), class III = proxy related to the spirit of the corresponding SDG's target (but not matching any of the target's indicators); c) How can spillovers based on MRIO analysis be factored in performance evaluations and what are the implications of such country interactions? This, also considering the observation that SDGs' targets can interact positively or negatively (Nilsson *et al.,* 2016); d) develop an exercise to build on the previous points, using selected countries and socio-economic and environmental data from the Eora MRIO database. Based on all of this, some conclusions are drawn and aspects for further research are suggested.

This study combines a literature review and a MRIOA exercise using the Eora MRIO database, version 199.82, which includes more than 15,000 transactions between industrial sectors in 189 countries.

While there have been suggestions about the feasibility to connect MRIOA and the SDGs (e.g., Xiao et al., 2017), greater deliberation is appropriate and several questions and implications need further consideration. This work sets the stage for such discussion and advances the examination of the potential that this macroeconomic analytical tool has for this new and timely application for sustainable development.

*Keywords: Agenda 2030, environmental footprints, multi-regional input-output analysis, social footprints, spillover effects, SDGs.*

## 1. Introduction

### *1.1. The Sustainable Development Goals' challenge*

On September 25th, 2015, 193 member states of the United Nations adopted an agenda to direct global action towards a socially inclusive and environmentally sustainable universal development path. The term "universal" implies application in all countries. "Transforming our world: the 2030 Agenda for Sustainable Development", commonly referred to as the "2030 Agenda", consists of 17 Sustainable Development Goals (SDGs) to be met by 2030 (UN, 2015). These SDGs are thus the new organizing principles of global development cooperation, replacing and expanding the Millennium Development Goals, which ran from 2000 to 2015 (*see* Figure 1).

To operationalize these 17 global goals the 2030 Agenda decomposes them into 169 targets. It is recognized that governments will decide on how the proposed SDGs' targets can be incorporated to their national policies and strategies and/or set their own targets for the goals in accordance to their national circumstances (UN, 2015). Similarly, governments are required to implementing mechanisms to track progress towards these goals and targets, including the adoption of indicators that best fit their realities. However, to aid in this regard, the UN Statistical Commission created the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (IAEG-SDG), which developed a global indicator framework composed of 232 indicators associated to the different SDGs' targets.[1] This set of indicators was adopted by the General Assembly on July 6th, 2017 (UN, 2017), and hence it is expected that, while it should "be complemented by indicators at the regional and national levels which will be developed by Member States" (UN, 2015, p. 75), these suggested indicators will "form the core of all other sets of indicators" (ECOSOC, 2016a, p. 23).

Several are the challenges now faced by the global statistical community in order to track progress towards the SDGs. Among those challenges is the capacity to access high-quality data on such broad range of socio-economic and environmental indicators and implement these indicators in national accounts. Another challenge is the consideration of countries' "spillover effects"; namely, the positive or negative effect of a country's actions onto others, in terms of the SDGs.


**Figure 1. The Sustainable Development Goals (SDGs)**

[1] Note that the indicators listed in the global indicator framework of the IAEG-SDG adds up to 244; however, that includes 9 indicators that are cited more than once (*i.e.*, are suggested for more than one target). Hence, the total amount of individual indicators is 232 (*see* UN, 2017).

*1.2. Extended Input Output Analysis*

Multi-Regional Input—Output (MRIO) analysis is by now a well-stablished macroeconomic analytical tool, used to assess ripple effects throughout the complex 'web' of economic global interconnections. Performing environmentally extended Input—Output (IO) analysis (*e.g.*, to account for $CO_2$ emission -*see* Wiebe *et al.*, 2012- or biodiversity threats -*see* Lenzen *et al.*, 2012-) with MRIO models, as well as extending them to social issues (*e.g.*, to account for labour issues, *see* Gómez-Paredes *et al.*, 2015), has allowed for the calculation of socio-environmental implications of global production and consumption, and for the calculation of indicators commonly known as "footprints" (*e.g.* Wiedmann *et al.*, 2015).

Consequently, there have been suggestions about the feasibility to connect MRIO analysis and the SDGs (*e.g.*, Xiao *et al*., 2017); this also in light of the fact that many socio-environmental "satellite" accounts used in extended IO models have considered issues related to the indicators proposed by the IAEG-SDG. However, greater deliberation is appropriate, considering the model's strengths and weaknesses, and several questions and implications regarding its wide application for the SDGs need to be explored. This work attempts to advance the discussion and examination of the potential that this macroeconomic analytical tool has for this new and timely application for sustainable development.

## 2. Methodology

In order to explore the applicability of MRIO analysis for tracking influences and assessing national performance towards the SDGs, this study addressed three research questions:

- What is the current global scenario regarding the assessment of performance towards the SDGs in which a tool such as MRIO analysis can fill a particular niche, considering both its strengths and limitations?
- To what extent relevant existing works in the Input—Output literature have examined issues matching any of the 232 SDGs-indicators proposed by the IAEG-SDG?
- How can spillovers based on MRIO analysis be factored in performance evaluations and what are the implications of such country interactions?

The authors attempted to answer these questions via a review of relevant literature. This included documents on the SDGs from the UN and related organizations, as well as academic literature on MRIO models. For the second question, published IO studies were collected via common academic databases and search engines, using issues related to the SDGs as keywords. The themes addressed in these studies (issues evaluated through IO analysis) were then compared with each one of the 232 indicators proposed by the IAEG-SDG for the different SDGs' targets. Since the objective of this exercise was to identify whether or not a given indicator/issue has been addressed with IO analysis, data collection ended with saturation; namely, once a given IO study matched a given indicator, no other studies relevant for that same indicator were considered.

Additionally, in order to further illustrate the applicability of MRIO analysis for the SDGs and to build on previous findings, an exercise was developed using IO tables and socio-economic and environmental data from the Eora MRIO database, version 199.82, which includes more than 15,000 transactions between industrial sectors in 189 countries. For space-sake, however, results shown in this article correspond only to selected countries.

## 3. Results and discussion

### *3.1. What is the current global scenario regarding the assessment of performance towards the SDGs in which a tool such as MRIO analysis can fill a particular niche, considering both its strengths and limitations?*

Three aspects may be considered with regards to the global assessment of national performance towards the SDGs:

The relevance of the System of National Accounts (SNA): The 2030 Agenda is poised to be implemented by "all countries and all stakeholders, acting in collaborative partnership" (UN, 2015, p. 1). To such end, UN Member States need to "conduct regular and inclusive reviews of progress [towards the SDGs] at the national and subnational levels which are [to be] country-led and country-driven" (UN, 2015, p. 33). Member States are then invited to share these country-assessments as "Voluntary National Reviews" at the annual High-Level Political Forum (*see* UN, 2018a). Therefore, being able to track progress towards the different SDGs targets, primarily via the indicators proposed by the IAEG-SDG (as previously discussed), is fundamental for national review exercises. As national statistical offices set to monitor these indicators, it is recognized that -for many of them- the use and development of national accounts statistics is critical (ECOSOC, 2016b). Furthermore, it is important that these assessments are comparable; here is worth acknowledging that "the 1993 SNA or the 2008 SNA have been implemented in about 88 per cent of Member States" (ECOSOC, 2016b, p. 7), being a good base for standard assessment exercises.

The importance of assessing consumption and production: In order to advance towards the global goals and targets (particularly those related to the SDG No. 12) it is fundamental to make "changes in the way that our societies produce and consume goods and services. Governments, international organizations, the business sector and other non-State actors and individuals must contribute to changing unsustainable consumption and production patterns" (UN, 2015, p. 35). It is thus also necessary to assess how national economic structures (*i.e.*, production and consumption which takes place through complex supply chains) relate to those SDGs and their targets. In this regard, and as previously noted in Subsection 1.2., extended IO analysis is capable of accounting for direct and indirect socio-economic and environmental factors, associated to inputs/outputs of production, and allocate them to commodities, industry-sectors, domestic final demand sectors (households' consumption, government consumption, investments) and/or to foreign demand (exports); therefore allowing for the assessment of the effect of production/consumption at different scales.

The need to consider spillover effects: Since the global economy is nowadays the result of numerous flows of materials, energy, capital, information, and people, through dense multi-sector networks across countries, production and/or consumption taking place in one part of the world is often linked to socioeconomic and/or environmental transformations in another part, or effects in the global commons. Such phenomenon of "teleconnections" or "telecoupling" (Friis *et al.*, 2016), understood as the impact of an economy onto another, has traditionally been referred to as economic "spillover effects" ("externalities"), being these effects either positive (*i.e.*, desirable) or negative (*i.e.*, undesirable). The SDG Index and Dashboards 2017 Report (Sachs *et al.*, 2017) has call attention to the importance of considering international spillover effects in achieving the SDGs, within a framework of *global responsibilities*. The report recognizes that "only if such positive and negative spillovers across countries are managed carefully can the promise of Agenda 2030 be fulfilled, particularly since negative

effects tend to flow from rich to poor countries. It is therefore critical to understand spillover effects and to measure them as part of SDG monitoring" (Sachs *et al.*, 2017, p. 5).

In light of these three considerations, it is possible to reason that IO analysis can play an essential role in assessing economic influences onto the SDGs, this based on the following opportunities and strengths:

- As most countries have implemented the SNA and developed corresponding IO tables, the application IO analysis (*i.e.*, using models based on standardize conventions of national economic accounts) to the assessment of performance towards the SDGs will contribute methodological congruence and international comparability.
- The IO analysis of socio-economic and environmental factors connected to the SDGs, their targets and indicators (*e.g.*, through the compilation of relevant "satellite" accounts as part of national accounts), would allow for the assessment of the effect of production and consumption, at different scales, on the SDGs. Several studies suggest this capacity (*see* the following Subsection).
- A range of spillover effects can be evaluated through the application of MRIO analysis. That is, via the assessment of SDG-related socio/economic and environmental factors embodied in international trade. Here, again, comparability and compatibility are fundamental (*see* Subsection 3.3).

The above, however, has to be acknowledged in combination with the following limitations and weaknesses of an IO analysis approach:

- It can only apply to SDGs-issues relatable to inputs/outputs of production (*e.g.*, child labor within the workforce). Hence, a significant number of SDGs' targets, and suggested indicators seem incompatible with the IO rationale (e.g., how to relate "unsentenced detainees as a proportion of overall prison population -Indicator 16.3.2- with the activity of producing commodities?). Thus, this approach will only reflect the role of economic structures on issues related to the SDGs (*see* more in the following Subsection).
- A crucial concern should be how a given issue is associated with different industry-sectors (*e.g.*, distributed in "satellite" accounts), given that such "distribution" will ultimately be reflected on the extent to which such issue is connected with commodities, industry-sectors, domestic and/or foreign final demand (*e.g.*, allocating aggregated regional estimates of child labour into the different industry-sectors of an IO table, in order to create a "child labor satellite account", by assuming proportionality to the amount of low-skilled labor in each industry-sector –*see* Simas *et. al.*, 2014– will likely generate different than if such account is constructed from household labor surveys –*see* Gómez-Paredes *et. al.*, 2016–).
- Being a linear model, the proportionality assumption underlying demand-pull modelling may not apply for different SDGs-connected issues (*e.g.*, the amount of child labor may not vary proportionally to changes in the final demand of the commodity involving child labor). This thus limits the possibility to use IO analysis to assess how changes in final demand contribute or not to the SDGs.
- The industry-sector and commodity aggregation of IO models conveys a lack of discernibility of particular products' connection to the SDGs.

Nonetheless, these drawbacks could be overcome by:

- Using this approach to analyse SDGs-related issues that are compatible with the IO rationale, and -to the extent possible- align these to proposed indicators (*see* more in the following Subsection)
- Being transparent, careful and coherent in how "satellite" accounts are constructed
- Using this approach just to analyse (ex-post) how production and consumption relate to the SDGs, including spillover effects (through international trade relations); thus identifying aspects of economic structures that need to be addressed
- Combine it, when applicable, with Life Cycle Assessments to analyse the estimated impact particular products.

### *3.2. To what extent relevant existing works in the Input—Output literature have examined issues matching any of the 232 SDGs-indicators proposed by the IAEG-SDG?*

While there is a wealth of studies using extended IO analysis, not all cover issues related to the SDGs, and among those who do, some relate more than others. Hence, to address this questions a 3-point classification scale is introduced:

- Class I - *Same as indicator*: IO study covering issues that coincide with one of the indicators proposed by the IAEG-SDG

- Class II - *Relevant to indicator*: IO study covering issues that could match one of the indicators proposed by the IAEG-SDG with some modifications compatible with IO analysis

- Class III - *Related to target*: IO study covering issues that do not match any of the indicators proposed by the IAEG-SDG, but nonetheless are aligned with the spirit of a SDG's target

Results of this exercise (shown in Table 1) indicate that only few of the SDGs (3 out of 17) have a related IO study that matches at least one of the proposed indicators for that particular goal's targets (class I articles). For instance, the indicator No. 6.4.2 (related to the SDG No. 6's Target 6.4) corresponds to: "Level of water stress: freshwater withdrawal as a proportion of available freshwater resources", and Lenzen *et al.* (2013) have applied IO analysis to assess freshwater withdrawals as a percentage of the existing local renewable freshwater resources (see Annex 1). Such small amount of class I studies suggests that there is still work to be done in order to tackle IO analysis' potential to evaluate the relation of economic structures on the SDGs.

Fortunately, the significant amount of studies that are relevant to some of the proposed indicators (class II articles) suggests that IO analysis can already be applied to assess contributions to indicators and targets corresponding to 11 of the 17 goals. Here, efforts should be focused on in modifying the approach taken by those studies, so that their results resemble more the corresponding proposed indicators. For instance, the indicator No. 1.1.1 (related to the SDG No. 1's Target 1) corresponds to: "Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural)". Alsamawi *et al.* (2017a) have assessed the number of workers with a remuneration lower than the individual international poverty line (*i.e.*,

working poor). In order to approach the indicator, future evaluations could assess the number of workers with a remuneration lower than the individual international poverty line divided by the total number of workers

**Table 1. Existing Input—Output studies and the SDGs' targets and indicators**

| Sustainable Development Goal | CLASS I - same as indicator - | CLASS II: - relevant to indicator - | CLASS III: - related to target - |
|---|---|---|---|
| SDG 1: No poverty | | (Alsamawi *et al*., 2017a) Indicator 1.1.1 | |
| SDG 2: Zero hunger | | (Wiedmann *et al*., 2006) Indicator 2.4.1 | |
| SDG 3: Good health and wellbeing | (Gómez-Paredes *et al*., 2015) Indicator 3.8.2 | (Xiao *et al*., 2017) Indicator 3.2.1 | |
| SDG 4: Quality education | | | |
| SDG 5: Gender equality | | | (Gómez-Paredes *et al*., 2015) Target 5.1 (Xiao *et al*., 2017) Target 5.5 |
| SDG 6: Clean water and sanitation | (Lenzen *et al*., 2013) Indicator 6.4.2 | (Xiao *et al*., 2017) Indicators 6.1.2 & 6.2.1 | |
| SDG 7: Affordable and clean energy | | (Cui *et al*., 2015) Indicator 7.3.1 | |
| SDG 8: Decent work and economic growth | (Gómez-Paredes *et al*., 2016) Indicator 8.7.1 | (Wiedmann *et al*., 2012) Indicator 8.4.1 (Alsamawi *et al*., 2017c) Indicator 8.8.1 (Gómez-Paredes *et al*., 2015) Indicator 8.8.2 | (Gómez-Paredes *et al*., 2015) Target 8.8 |
| SDG 9: Industry, innovation and infrastructure | | (Davis *et al*., 2011) Indicator 9.4.1 | |
| SDG 10: Reduced inequalities | | (Alsamawi *et al*., 2017b) Indicator 10.1.1 | |
| SDG 11: Sustainable cities and communities | | (Zhao *et al*., 2015) Indicator 11.6.2 | |
| SDG 12: Responsible consumption and production | | (Wiedmann *et al*., 2012) Indicator 12.2.1 | |
| SDG 13: Climate action | | | - |
| SDG 14: Life below water | | | (Leach *et al*., 2012) Target 14.1 |
| SDG 15: Life on land | | (Lenzen *et al*., 2012) Indicator 15.5.1 | |
| SDG 16: Peace, justice and strong institutions | | | (Xiao *et al*., 2017) Targets 16.3 & 16.6 |
| SDG 17: Partnerships for the goals | | (Cao *et al*., 2014) Indicator 17.1.1 | |

Note: For further details *see* Annex I. For all indicators and SDGs Targets *see* (UN, 2017)

involved (*i.e.*, the proportion of working poor); and disaggregate this by sex, age, and (urban/rural). Similarly, the indicator No. 7.3.1 (related to the SDG No. 7's Target 7.3) reads: "Energy intensity measured in terms of primary energy and GDP". The work of Cui *et al.* (2015) is an example of the use of IO analysis to assess total energy requirements (*i.e.*, energy footprints). In this case, future evaluations could assess total energy requirements divided by total value added, so as to approach the proposed indicator.

Other modifications are somewhat more complicated. For example, the indicator No. 2.4.1 (SDG No. 2's Target 2.4) entails the: "Proportion of agricultural area under productive and sustainable agriculture". The traditional Ecological Footprint (*e.g.*, Wiedmann *et al.*, 2006) considers the total amount of cropland and pasture areas related to production/consumption. In this case, to approach the indicator it may be necessary to only use the assess amount of cropland and pasture areas and to estimate the amount of theses that are managed sustainably. Thus, this would require a new range of data based on the application of a definition of "sustainable agriculture".

Considering works cited under class I and II, there are still 5 SDGs without any related IO study. In these cases, where IO analysis seems not to be applicable to issues matching the suggested indicators, it could nonetheless be used to assess issues that align to the given SDG, and its targets. For instance, the work of Leach *et al.* (2012) evaluates the amount of reactive nitrogen associated to consumption; and while there is no proposed indicator considering nitrogen, it can be related to Target 14.1 ("by 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution") in light that nitrogen loads constitute nutrient pollution.[2]

The SDG with more IO studies related to its indicators is SDG No. 8; therefore, this should be less of a priority in the application of IO analysis to track the SDGs. On the other hand, the SDGs without any related studies are SDGs 4 and 13. The reader may think that the analysis of embodied $CO_2$ emissions trough IO analysis (*e.g.*, Wiebe *et al.*, 2012) should pertain to any of the SDG 13's targets; however, no target (and hence no proposed indicator) of the SDG No. 13 deals with $CO_2$ or GHG emissions, instead they focus on policy implementation, awareness raising, and adaptation measures (*see* UN, 2017).[3] This suggests that efforts should be targeted to identify possible ways to link IO analysis to these goals' targets or indicators. For instance, a somewhat easy approach could be to account for the amount of taxes per industry-sector that are dedicated to finance public education (in accordance to the given government's expenditure on education as a percentage total government expenditures), which would be related to Target 4.3 ("by 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university"). Then, through IO analysis such contribution to education could be allocated to different commodities and production/consumption bundles. A more elaborated (and compatible) approach could be to create a satellite account that considers the total the amount of money spent on vocational training, national education and/or scholarships per industry-sector. Similar approaches could be taken with regards to the SDG No. 13. Alternatively, a simpler approach could be to consider those countries that have adopted and implemented a national disaster risk reduction strategy in line with the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR, 2018), which would be in line with the proposed indicator No. 13.1.2. A satellite account for MRIO models could then be constructed with Boolean indicators (*i.e.*, ones "1" and zeros "0", as a dummy variable), allocating ones to those industry-sectors in countries that have adopted and implemented a national strategy, and zeros to those of countries that have not done so. In that way, exports will embody either ones or zeroes, and international production/consumption will show a greater amount when it is

[2] Note that Target 14.1 has as proposed indicator the "index of coastal eutrophication and floating plastic debris density" (indicator No. 14.1.1). However, this is a "Tier III"-type of indicator (*i.e.*, an indicator with no yet available internationally established methodology or standards, *see* UN, 2018b), and thus far concentration of chlorophyll-a is being considered as a sign of phytoplankton biomass -eutrophication-, no nitrogen load -*see* UN, 2018c).

[3] "$CO_2$ emission per unit of value added" is an indicator proposed for the SDG No. 9 (indicator 9.4.1).

the result of inputs from countries that have a national strategy, and hence relates to compliance with the SDG Target No. 13.1.

### *3.3. How can spillovers based on MRIO analysis be factored in performance evaluations and what are the implications of such country interactions?*

As previously mentioned, countries need to track their progress towards the SDGs. Thus, national profiles may be created describing their performance in each and all of the SDGs (*e.g.*, *see* Sachs *et al.*, 2017). The application of IO analysis, using compatible indicators (as the ones cited in the previous Subsection) would allow to construct similar profiles for production and consumption bundles (a "SDGs footprint"), which could be analysed at different levels: for the entire country, for industry-sectors, and/or for commodities (Figure 1).

Spillover effects, understood as socio-economic and/or environmental issues (*e.g.*, child labor and threats to biodiversity), which are linked to a country's economic activity (*i.e.*, consumption and production) but take place in other countries (*i.e.*, international externalities), can then be assessed through the application of MRIO analysis. Namely, through the calculation of "embodiments" in exports/imports, as is common in footprint-studies; thus tracking direct and indirect connections across countries, being these negative or positive in terms of progress towards the SDGs.[4] Different approaches could then be taken to factor spillover effects in national performance evaluations:

- Separate assessment: Positive and negative spillovers may be accounted/reported separately from domestic performance evaluations, complementing and contrasting the progress that countries make in their own territories with their effects elsewhere. This is akin to juxtaposing production-based accounts with consumption-based accounts (*e.g.*, *see* Peters, 2008). For instance, computing the amount of child labor taking place in the territory (*i.e.*, linked to domestic consumption + exports - imports) vs. assessing the amount of direct and indirect associated child labor (*i.e.*, linked to domestic consumption + imports - exports).

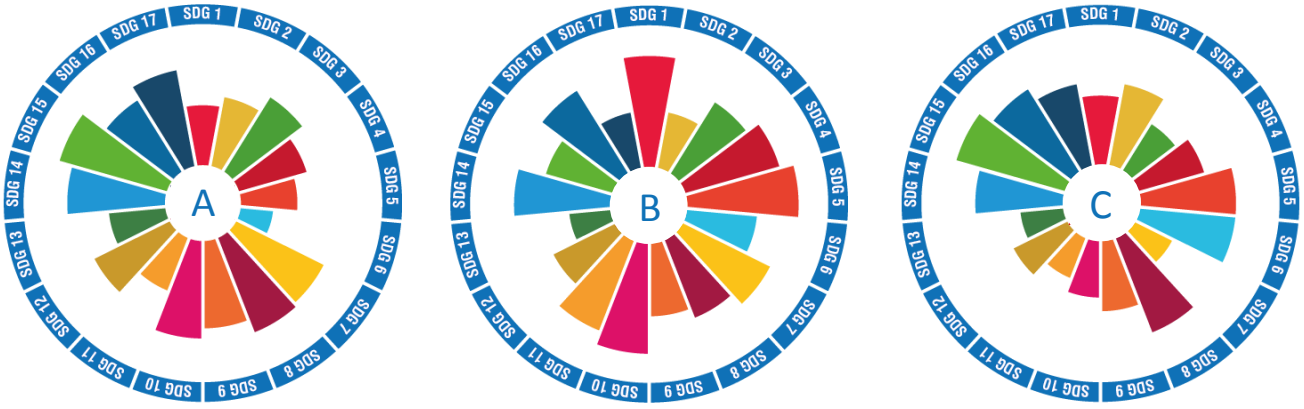


**Figure 1. Hypothetical performance towards the SDGs of A) a country, B) an Industry-sector, and C) a Commodity**

[4] Given that "footprint" accounts tend to focus on "negative" (undesirable) impacts (*e.g.*, emission of $CO_2$), the term "handprint" has been proposed for an account of "positive" (desirable) impacts (*see* Biemer *et al.*, 2013).

- Combined assessment: Spillover effects may be conjugated with territorial performance data in order to arrive to single combined performance indicators for each of the SDGs (*e.g.*, *see* Sachs *et al.*, 2017). Here, the relative "weight" conferred to these effects becomes an issue of attention.

In any case, from the consumption-based standpoint, positive spillovers should added to the country's performance in the corresponding SDG, while negative effects should be subtracted (Figure 2). In addition, and importantly, Structural Path Analysis (Wood & Lenzen, 2003) may be applied to map these spillovers from one country to another (Figure 3); allowing countries to identify who should they work with in order to make progress towards the SDGs. The further implications of accounting for such country interactions can also be seen in light of Nilsson *et al.* (2016)'s observation that actions implemented towards SDGs targets may interact, in some cases positively (*i.e.*, enabling, reinforcing, or being indivisible with one another), in others negatively (*i.e.*, constraining, counteracting, or cancelling one another).[5] With this in mind, it is possible to recognize that countries actions to move towards the SDGs domestically (*e.g.*, boosting consumption as means to "increase the annual growth rate of real GDP per capita" -Indicator 8.1.1-) may mean drawbacks in other countries progress (*e.g.* an increase in biodiversity threats, and hence an increase in the Red List Index -Indicator 15.5.1-; or an increase in hazardous waste generation -Indicator 12.4.2-). Such acknowledgment therefore calls for an appropriate international partnerships towards the goals, particularly between those countries linked by spillover effects, which entails going beyond the sharing of information, technology, and economic assistance for the SDGs, to considering and conceiving strategies to move towards these goals together. If countries act separately (just as if policymakers operate in silos) the 2030 Agenda may not be materialized. Conversely, acknowledging spillover effects in terms of the SDGs and taking close collaborative action to address them is consistent with the *global responsibly* rationale of the Agenda.

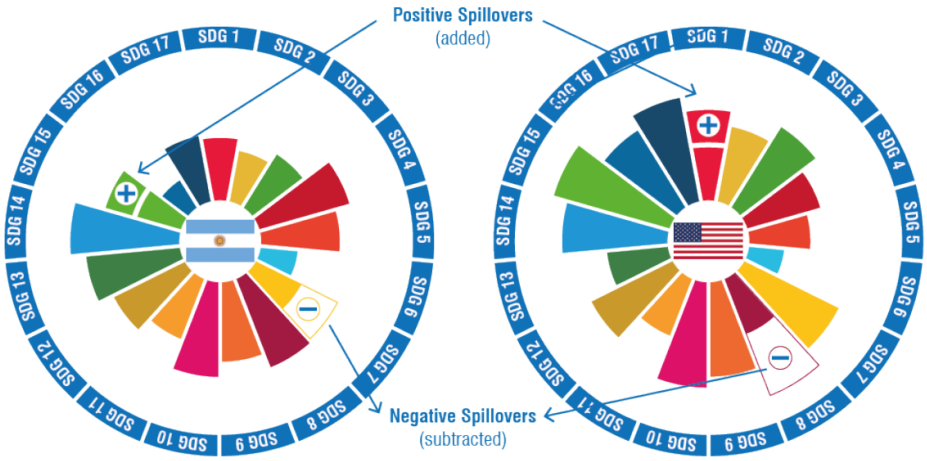


**Figure 2. Adjusted performance considering spillover effects (*e.g.*, Argentina & USA)**

[5] When there is no foreseeable interaction, the SDGs targets are said to be "consistent" with one another (*see* Nilsson *et al.*, 2016).

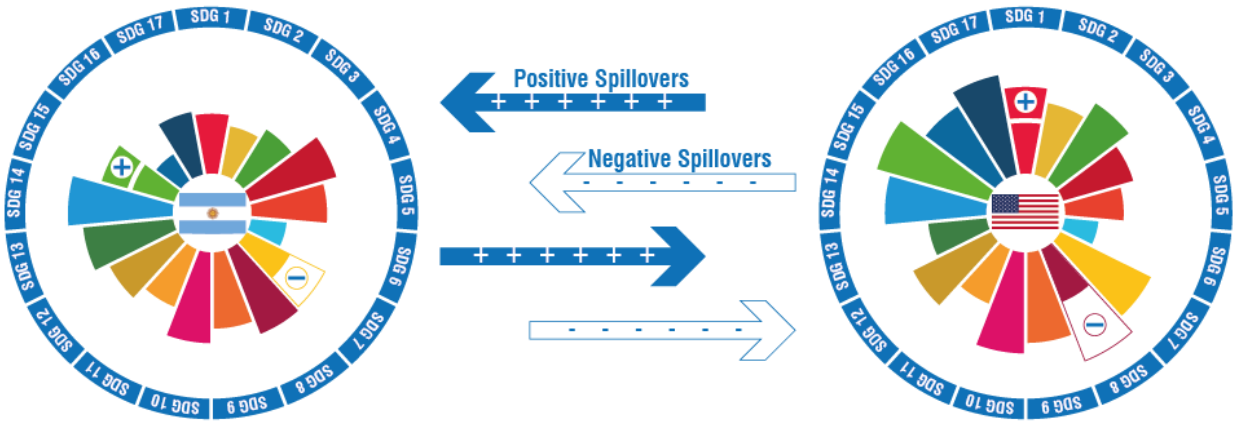


**Figure 3. Hypothetical spillover effects from one country to another (*e.g.*, Argentina ←→ USA)**

*3.4. Exercise*

In order to advance this article's commentary, and to exemplify some of the aforementioned points, this Sub-section presents a brief exercise based on an MRIO analysis of the following factors:

- Poverty: Total (direct and indirect) number of workers with a remuneration lower than the individual international poverty line of $1.25/day (*i.e.*, working poor) divided by the total number of workers (*i.e.*, the workforce) involved in the production of commodities consumed by countries. In order to reflect performance, this rate is subtracted from one ("1"), hence a result of "1" would mean no working poor, and "0" would entail the whole workforce being working poor.

- Threats to species: Number of identified threatened species (in thousands) due to the production of commodities consumed by countries. In order to reflect performance, this value is subtracted from one ("1"), hence a result of "1" would mean no identified threatened species, while a result of "0" would entail a thousand threatened species.

- Government revenue: Total (direct and indirect) amount of USD that comes from taxes on production, and which constitutes revenue for national governments, divided by total value added.

As such, these three factors relate to a social, an environmental, and an economic concern, and are relevant to indicators of the SDGs No. 1, 15, and 17, respectively (as Class II, as described in Table 1). For space-sake, results of this exercise are presented only for Argentina and the USA, and the aforementioned factors are consider only at the national level; namely, in terms of their relation to national consumption bundles (*i.e.*, a national "SDGs footprint" for the SDGs No. 1, 15, and 17). In line with the notion of footprint, these accounts link these issues to domestic consumption and net imports (imports - exports), therefore considering spillover effects through trade relations. Results are shown in Figure 4. These suggest that the amount of working poor by the total amount of workers is very small in, both, Argentina and the USA, which would convey a very high performance in terms of

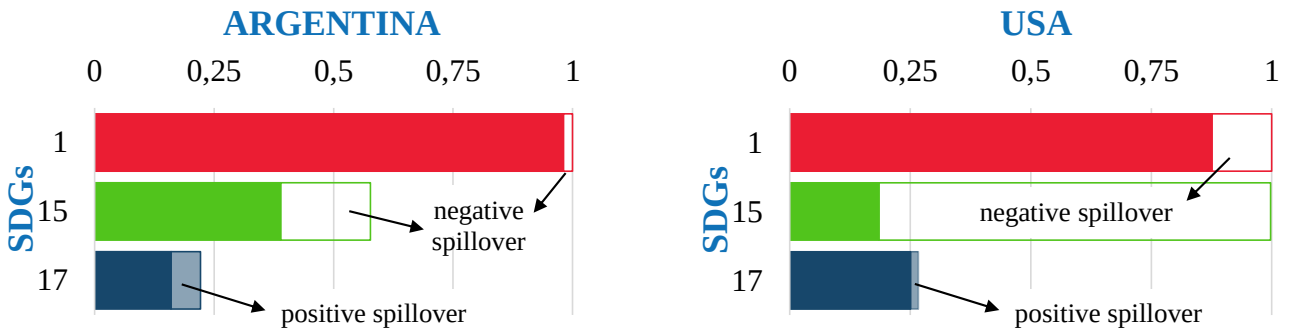


**Figure 4. Performance of Argentina and USA towards factors related to the SDGs No. 1, 15, 17**
This account includes spillover effects: For the SDG No. 1 these are working poor in other countries (other than the cited country). For the SDG No. 15 these are threats to species (in thousands) that take place in other countries (other than the cited country). For the SDG No. 17 these are government revenue (form taxes to consumption) for other governments (other than the cited country). Negative spillovers (*e.g.*, those related to the SDGs No. 1 and 15) are subtracted from the country's performance (transparent bar), while positive spillovers (*e.g.*, those related to the SDG No. 17) are added (faded bar).

the indicator related to the SDG No. 1. However, accounting for those that are working in other countries (and that are supporting the consumption of Argentina and the USA) both countries' performance is reduced, in particular that of the USA, indicating that this country has more working poor supporting its consumption. For the case of Argentina, most of these workers are in Nigeria, while for the USA most are in Tanzania. In terms of biodiversity threats, the USA would have much greater performance than Argentina if we would only account for those taking place within the country, but factoring in the related threatened species elsewhere in the world reduces significantly its performance, below that of Argentina (which is also reduced). Lastly, considering government revenue vs. value added, the USA has greater performance than Argentina. Yet, taking into account the revenue generated for other governments (exporting countries) reduced this difference, as Argentina generate more of this positive spillover.

## 4. Concluding remarks

The international community has agreed to pursue a new development agenda from 2016 to 2030. This new sustainable development agenda includes 17 global goals, decomposed in 169 targets, all of which need to be assessed in a way that reflects progress towards them. For such end the IAEG-SDG has proposed 232 individual indicators that relate to the targets. In addition to gathering data, implementing analytical tools to measure these indicators is still a challenge. Further challenges are the identification of how economic structures (*i.e.*, the complex web of production and consumption networks) contribute or affect progress towards the goals, and how countries affect others through trade relations (a form of positive and/or negative "spillover effects").

In such current global scenario, IO analysis can play an important role, considering: a) the relevance of SNA in national statistics, b) the need to analyse consumption and production, and c) the need to consider spillover effects. This rationale is based on IO analysis' corresponding strengths; namely: a) the methodological congruence and international comparability that would come from applying a model that is well-stablished and is based on standardize conventions, b) that it has shown to be applicable for the analysis of socio-economic and environmental factors connected to the SDGs, their targets and indicators, thus allowing for the calculation of "SDGs footprints" at different levels (countries, industry-sectors, commodities), and c) can account for spillover effects through the use of MRIO models. However, applying this approach should be done while taking heed of

its limitations and weaknesses, such as: a) that it can only be applied to SDGs-issues relatable to inputs/outputs of production, b) that it will heavily reflect the assumptions taken to construct "satellite" accounts, c) that they may not be applicable for forecasting exercises, and d) that the industry-sector and commodity aggregation of IO tables will limit the discernibility of particular products' connection to the SDGs. To overcome these limitations, practitioners should: a) identify issues that are compatible with IO analysis and align with the IAEG-SDG proposed indicators, b) be transparent, careful, and coherent in (and to the extent possible standardize) how satellite accounts are constructed, c) use it to analyse the (ex-post) effect of production and consumption onto the SDGs, in order to identifying important aspects of economic structures that need to be addressed d) combine it, when applicable, with Life Cycle Assessments.

With regards to the applicability of using an IO approach for the SDGs, a number of existing published works support this point. These works have applied IO analysis to evaluate issues that coincide with indicators proposed by the IAEG-SDG (class I studies), that could match the indicators with modifications (class II studies), or that do not match indicators, but are aligned to some of the SDGs' targets (class III studies). The small amount of class I studies indicates that further research should focus on assessing socio-economic and environmental issues in a way that matches the proposed indicators. Fortunately, these efforts can build on the significant body of class II studies. Yet, a few SDGs (No. 5, 14, and 16) only have class III studies, and others (No. 4 and 13) have none, thus requiring more attention.

In terms of spillover effects, MRIO analysis can be used to calculate "embodiments" in exports/imports of issues that connect positively or negatively to the SDGs. Such spillovers can be accounted/reported separately from domestic performance evaluations, complementing and contrasting such reports, and/or be combined into aggregated performance indicators (where relative weights should be considered). Whatever the case, an MRIO approach would allow to: a) add positive spillovers to countries' performance, while subtracting negative ones, b) map these country to country relations, two aspects that are crucial under the *global responsibly* rationale of the 2030 Agenda, particularly since efforts towards the SDGs' targets may interact (positively or negatively) among them (Nilsson *et al*., 2016).

A glimpse into applying this approach has shown that the performance of countries would vary significantly if positive spillovers are added and negative are subtracted. For instance, the performance of the USA would appear to be greater than that of Argentina (for factors related to the SDGs No. 1 and 15) if there was no account of working poor and threatened species happening in their exporting countries. Conversely, the performance of Argentina in terms of government revenue (factor related to the SDG NO. 17) would be much lower than that of the USA if there was no consideration of the revenue generated to exporting countries.

In this manner, this work has attempted to advance the discussion and consideration of applying IO analysis to track the SDGs. While the road towards the 17 global goals is still long and difficult, there are bases to believe that IO analysis has the potential to aid our efforts in this venturous and urgent journey.

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# ANNEX I

**Table 1.1.** Examples of existing Input—Output studies and the SDGs targets' indicators. **CLASS I** - Same as indicator: IO study covering issues that coincide with one of the indicators proposed by the IAEG-SDG

| Sustainable Development Goal | Related Target | Related Indicator | Published Study | |
|---|---|---|---|---|
| | | | Issue Analysed | Reference |
| Goal 1: End poverty in all its forms everywhere | | | | |
| Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture | | | | |
| Goal 3: Ensure healthy lives and promote well-being for all at all ages | Target 3.8: Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all | Indicator 3.8.2: Coverage of essential health services (defined as the average coverage of essential services based on tracer interventions that include reproductive, maternal, newborn and child health, infectious diseases, non-communicable diseases and service capacity and access, among the general and the most disadvantaged population) | Number of workers with social security (health coverage) | (Gómez-Paredes *et al*., 2015) |
| Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all | | | | |
| Goal 5: Achieve gender equality and empower all women and girls | | | | |
| Goal 6: Ensure availability and sustainable management of water and sanitation for all | Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity | Indicator 6.4.2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources | Amount of scarce water used (freshwater withdrawal as a percentage of the existing local renewable freshwater resources) | (Lenzen *et al*., 2013) |
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | | | | |
| Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all | Target 8.7: Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms | Indicator 8.7.1: Proportion and number of children aged 5–17 years engaged in child labour, by sex and age | Proportion and number of children in child labour, by sex and age | (Gómez-Paredes *et al*., 2016) |

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10: Reduce inequality within and among countries
Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12: Ensure sustainable consumption and production patterns
Goal 13: Take urgent action to combat climate change and its impacts
Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

**Table 1.2.** Examples of existing Input—Output studies and the SDGs targets' indicators. **CLASS II** - Relevant to indicator: IO study covering issues that could match one of the indicators proposed by the IAEG-SDG with some modifications compatible with IO analysis

| Sustainable Development Goal | Related Target | Related Indicator | Published Study | |
|---|---|---|---|---|
| | | | Issue Analysed | Reference |
| Goal 1: End poverty in all its forms everywhere | Target 1.1: By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day | Indicator 1.1.1: Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural) | Number of workers with a remuneration lower than the individual international poverty line of $1.25/day (*i.e.*, working poor) | (Alsamawi *et al*., 2017a) |
| Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture | Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality | Indicator 2.4.1: Proportion of agricultural area under productive and sustainable agriculture | Ecological Footprint (which considers the total cropland & pasture area) | (Wiedmann *et al*., 2006) |
| Goal 3: Ensure healthy lives and promote well-being for all at all ages | Target 3.2: By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births | Indicator 3.2.1: Under-5 mortality rate | *Risk of a High* Under-five Mortality Rate | (Xiao *et al*., 2017) |
| Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all | | | | |
| Goal 5: Achieve gender equality and empower all women and girls | | | | |
| Goal 6: Ensure availability and sustainable management of water and sanitation for all | Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all | Indicator 6.1.1: Proportion of population using safely managed drinking water services | *Risk of* no access to an Improved Source of Drinking Water | (Xiao *et al*., 2017) |
| | Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations | Indicator 6.2.1: Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water | *Risk of* no access to an Improved source of Sanitation | |
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | Target 7.3: By 2030, double the global rate of improvement in energy efficiency | Indicator 7.3.1: Energy intensity measured in terms of primary energy and GDP | Energy footprints | (Cui *et al*., 2015) |
| Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all | Target 8.4: Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead | Indicator 8.4.1: Material footprint, material footprint per capita, and material footprint per GDP | Material footprints | (Wiedmann *et al*., 2012) |

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| | | Indicator 8.8.1: Frequency rates of fatal and non-fatal occupational injuries, by sex and migrant status | Fatal occupational injuries incidence rate (number of fatal injuries per year by number of workers) | (Alsamawi *et al*., 2017c) |
| | Target 8.8: Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment | Indicator 8.8.2: Level of national compliance with labour rights (freedom of association and collective bargaining) based on International Labour Organization (ILO) textual sources and national legislation, by sex and migrant status | Number of workers in enterprises where there are no trade unions or other associations organization for collective bargaining | (Gómez-Paredes *et al*., 2015) |
| Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | Target 9.4: By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities | Indicator 9.4.1: $CO_2$ emission per unit of value added | Total $CO_2$ emission | (Davis *et al*., 2011) |
| Goal 10: Reduce inequality within and among countries | Target 10.1: By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average | Indicator 10.1.1: Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population | Gini index (relation between total income and total workers) | (Alsamawi *et al*., 2017b) |
| Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable | Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management | Indicator 11.6.2: Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) | PM2.5 and PM10 | (Zhao *et al*., 2015) |
| Goal 12: Ensure sustainable consumption and production patterns | Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources | Indicator 12.2.1: Material footprint, material footprint per capita, and material footprint per GDP | Material footprints | (Wiedmann *et al*., 2012) |
| Goal 13: Take urgent action to combat climate change and its impacts | | | | |
| Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development | | | | |
| Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat | Target 15.5: Take urgent and significant action to reduce the degradation of natural habitats, halt | Indicator 15.5.1: Red List Index | Number of threatened species | (Lenzen *et al.*, 2012) |

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|---|---|---|---|---|
| desertification, and halt and reverse land degradation and halt biodiversity loss | the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species | | | |
| Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels | | | | |
| Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development | Target 17.1: Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection | Indicator 17.1.1: Total government revenue as a proportion of GDP, by source | Total government revenue by sector (transportation) | (Cao *et al*., 2014) |

**Table 1.3.** Examples of existing Input—Output studies and the SDGs targets' indicators. **CLASS III** – Related to target: IO study covering issues that do not match any of the indicators proposed by the IAEG-SDG, but nonetheless are aligned with the spirit of a SDG target

| Sustainable Development Goal | Related Target | Related Indicator | Published Study | |
|---|---|---|---|---|
| | | | Issue Analysed | Reference |
| Goal 1: End poverty in all its forms everywhere | | | | |
| Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture | | | | |
| Goal 3: Ensure healthy lives and promote well-being for all at all ages | | | | |
| Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all | | | | |
| Goal 5: Achieve gender equality and empower all women and girls | Target 5.1: End all forms of discrimination against all women and girls everywhere | None | Gender pay gap (difference between male and female average earnings) | (Gómez-Paredes *et al*., 2015) |
| | | None | Female representation in the workforce | (Xiao *et al*., 2017) |
| | Target 5.5: Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life | None | Gender Gap Index | |
| Goal 6: Ensure availability and sustainable management of water and sanitation for all | | | | |
| Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all | | | | |
| Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all | Target 8.8: Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment | None | Number of workers in hazardous work (in the most hazardous sectors according to the ILO) | (Gómez-Paredes *et al*., 2015) |
| Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | | | | |
| Goal 10: Reduce inequality within and among countries | | | | |
| Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable | | | | |
| Goal 12: Ensure sustainable consumption and production patterns | | | | |
| Goal 13: Take urgent action to combat climate change and its impacts | | | | |

| | | | | |
|---|---|---|---|---|
| Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development | Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution | None | Nitrogen footprints | (Leach *et al.*, 2012) |
| Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss | | | | |
| Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels | Target 16.3: Promote the rule of law at the national and international levels and ensure equal access to justice for all<br><br>Target 16.6: Develop effective, accountable and transparent institutions at all levels | None | Characterization of World Bank Worldwide Governance Indicator (Rule of Law)<br>Characterization of World Justice Project (Rule of Law Index)<br><br>Characterization of Global Integrity Index | (Xiao *et al.*, 2017) |
| Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development | | | | |