Research

Creating Opportunities

N.º 21/02

Working Paper

Output-side GHG Emission Intensity: A consistent international indicator

Joxe Mari Barrutiabengoa
J. Julián Cubero
Rodolfo Méndez-Marcano
BBVA Research - Economics of Climate Change Cluster

March 2021

BBVA Research

Output-side GHG Emission Intensity: A consistent international indicator[a,b]

Joxe Mari Barrutiabengoa, J. Julián Cubero and Rodolfo Méndez-Marcano

BBVA Research

Abstract

This paper introduces the Output-side GHG Emission Intensity Indicator (OEI), a new, more consistent and precise indicator of the volume of greenhouse gases embedded in each representative and internationally-comparable unit of total domestic production of goods and services within each country. The paper also introduces and analyzes two international rankings, which are based, respectively, on a comprehensive version of the indicator and a restricted variant that only accounts for CO2 emissions from fossil fuel combustion and leaks. The results show remarkable differences in both rankings, especially in regard to the relative place of least developed countries and newly industrialized and oil exporting Asian economies.

Keywords: Climate change, greenhouse gases, macroeconomics, carbon price policies, transition risks.

JEL classification: E0, Q5

---

a: Thanks to Rafael Doménech for his careful revision and advise, and to the members of the Economics of Climate Change Cluster at BBVA Research for their comments and questions.
b: Data and supplementary material at http://dx.doi.org/10.13140/RG.2.2.27423.69283

Executive summary

- With climate change being one of the hot topics on the global policy agenda, **intensive action to fight global warming and its effects is expected in the future.** Economic knowledge points to a global carbon tax (or other equivalent carbon price policies) as the most effective way to meet Paris Agreement's targets on emission abatement.
- This concern has motivated the construction of internationally-comparable indicators that capture the emissions intensity by country and can be used for ranking countries according to their transition-risk-vulnerability (i.e., their vulnerability to carbon price policies).
- This working paper presents an **international ranking** based on a new indicator of the **volume of greenhouse gases (GHG) embedded in each representative and internationally-comparable unit of the total domestic production of goods and services:** the **Output-side Emission Intensity Indicator (OEI).**
- **The OEI provides a proxy of the relative vulnerability of different countries to future carbon price policies ("transition vulnerability risk"),** i.e., potentially adverse effects that could derive from the transition to a decarbonized global economy contemplated in the Paris Agreement's targets on emission abatement.
- **The new indicator is more consistent, and consequently less ambiguous in its interpretation than previous indicators,** as both greenhouse gas emissions and (internationally comparable or PPP) GDP are measured from the production or output perspective, avoiding the usual mixing of output and expenditure-side measures.
- **OEI is not a mere theoretical formality as the relative position of some countries change** in comparison to the ranking constructed with a traditional indicator (which mixes production-side emissions with expenditure-side PPP-GDP). The change is bigger for small open economies (highly sensitive to terms of trade fluctuations).
- **Two versions of the OEI are presented and mapped:** the **comprehensive version,** which captures the total greenhouse gas emissions per unit of GDP **(OEI1)**, and a **restricted variant**, which only accounts for the CO2 emissions from fossil fuel combustion and leaks per unit of GDP **(OEI2)**.
- **The OEI1 international ranking** reveals that, notwithstanding their much lower contribution to global GHG emissions, least developed countries show the highest vulnerability to carbon price policies when all GHG are considered.
- In the **OEI2** international ranking, **the poorest countries lose preeminence** and their place is occupied, mainly, by **newly industrialized and fossil fuel exporting Asian countries**. This is explained by the much lower weight of agriculture, forestry, and their associated land use changes in the emissions considered by the OEI2.
- **OEI2 provides evidence in favor of the Environmental Kuznets Curve** hypothesis, which seems to be fulfilled when OEI2 and OS-PPP-GDP per capita are taken into account. If the same analysis is performed using the expenditure-side PPP-GDP, the goodness of the fit decreases.

1. Introduction

With climate change being one of the hot topics on the global policy agenda, **intensive action to fight global warming and its effects is expected in the future.** Economic knowledge points to a global carbon tax (or other equivalent carbon price policies[1]) as one of the most effective ways to meet Paris Agreement's targets on emission abatement, and hence, the international economic landscape could be on the verge of experiencing a major disruption. In this context, transition risks, understood as the potential adverse macro-financial effects that could be derived from the introduction of carbon price policies (carbon taxes, cap-and-trade systems, etc.) required to propel the adjustment process to a lower carbon economy, are presented as a risk factor likely to create **heterogeneous effects across economic activities and consequently, countries.** That is, a link between transition risks and country profile exists, and investors, regulators and legislators need to take this new component into account when evaluating risks[2].

This concern has motivated the construction of internationally-comparable indicators that capture the emissions intensity by country and can be used for ranking countries according to their transition-risk-vulnerability (i.e., their vulnerability to carbon price policies). The present paper introduces a new variant of such indicators, the **Output-side GHG Emission Intensity Indicator (OEI), which pretends to be a better guide for anticipating international differences in the effects of transition risks.** The new indicator is more consistent, and consequently less ambiguous in its interpretation than previous indicators, as **both GHG emissions and (internationally comparable or PPP) GDP are measured from the production-perspective.** Thus, OEI avoids mixing output and expenditure-side measures[3], providing a better measurement of the relative carbon intensity associated to the domestic production of goods and services (plus domestic natural physical processes). The paper shows that **OEI is not a mere theoretical formality as the relative position of some countries change** in comparison to a ranking constructed with a traditional indicator (which mixes production-side emissions with expenditure-side PPP-GDP).The ranking difference is bigger for small open economies, which is in accordance with the economic intuition that signals that trade-open economies are expected to be the most affected. This is explained by the fact that the differences between output- and expenditure side PPP-GDP for a given country are directly related to its terms of trade fluctuations, which in turn tend to be proportional to their degree of trade openness. Therefore, **the aim of the work is to complement the existing literature by providing two international country classifications based, respectively, on a comprehensive and a restricted version of the Output-side Emission Intensity Indicator.**

The structure of this WP is as follows. Section 2 provides a detailed literature review of the economy-wide emission intensity indicators, reviewing the main historical problems at the time of constructing a consistent indicator and going over the advances made recently. Section 2 also highlights the upgrade that OEI represents and its theoretical consistency. On the other hand, section 3 provides a brief overview of the data sources and the methodology employed in the paper, while section 4 presents the results of the study. Finally, together with the main conclusions in section 5, 3 appendixes are included in the work: Appendix 1, which provides further information on the data sources, Appendix 2, which provides technical details of the indicator and Appendix 3, which presents an analysis of the ranking evolution over-time.

1: See Stavins (2019).
2: Note that for every country, complying with emission abatement pledges implies technological and infrastructure changes and demand overhauls. All in all, a transformation of the economic model.
3: For holding an informed discussion not only about the efficiency but also the fairness of alternative carbon price policies, it is of fundamental importance the proper distinction and assessment of the output-side and the expenditure-side carbon intensity. Whereas the former puts the accent on who generates current GHG emissions, the latter focuses on who is the final beneficiary of the emissions. This distinction, along with the consideration of which countries generated and profited from past emissions, it forms part of the set of unavoidable questions that need to be answered in the ongoing search for a consensus about the most efficient and fair way of deterring global warming.

BBVA Research

2. Economy-wide emission indicators

A common perspective from which looking at the challenge of global warming is the need of decoupling economic progress or welfare from GHG (or, at least, CO2) emissions, which is in fact the perspective adopted by the Sustainable Development Goal[4] No. 8 (SDG8). Thus, the emissions of a country can be decomposed into (see Herzog, Baumert and Pershing, 2006):

$$EMISSION_{i,t} = \underbrace{\left(\frac{EMISSION_{i,t}}{ECONOMY_{i,t}}\right)}_{emission\ intensity} \times ECONOMY_{i,t} = \underbrace{\left(\frac{EMISSION_{i,t}}{ENERGY_{i,t}}\right)}_{energy\ dirtiness} \times \underbrace{\left(\frac{ENERGY_{i,t}}{ECONOMY_{i,t}}\right)}_{energy\ efficiency} \times ECONOMY_{i,t}$$

where ECONOMY refers to some aggregate measure of the set of economic activities (or its outputs) of the residents of the country(denoted by *i*) and the period (denoted by *t*) under consideration, while EMISSION indicates the GHG emissions directly and/or indirectly associated with that set.

The identity above shows that from a country perspective, the reduction of GHG emissions requires either the reduction of ECONOMY (and henceforth, in the last term of collective wealth or living standards), or a "decoupling" between ECONOMY and EMISSION. The latter is equivalent to reducing the emissions intensity, either by using cleaner energy sources (i.e., reducing energy dirtiness) and/or by increasing the energy efficiency of the production processes. Not surprisingly, confronted with this dilemma, national governments have opted for the decoupling alternative, that is, focusing their environmental efforts on reducing emission intensity without sacrificing economic progress. This is one of the reasons that explain why many countries have explicitly formulated their National Determined Contributions[5] (NDC) in terms of country-wide emission intensity indicators and why these indicators play an essential role in the discussions and negotiations among countries for arriving to environmental agreements (like the Kyoto Protocol of 1997, the Paris Agreement of 2016, or the expected Glasgow Agreement of November 2021).

Consequently, the main multilateral and non-profit organizations leading or involved in the fight against global warming (World Bank, United Nations, OECD, European Union, International Energy Agency, World Resource Institute, etc.) have given great importance in the last decades to the construction, improvement and public availability of economy-wide emission intensity indicators, emphasizing their international comparability. In this sense, the decision of what specific indicators to use as the numerator (EMISSION) and the denominator (ECONOMY) of an emissions intensity ratio depends on which of the two following types of decoupling is considered: the most direct one, the production-side decoupling or, the more indirect alternative, the expenditure-side decoupling[6].

In the first case, EMISSION should be a measure of the gases emitted by the production activities realized inside the country's territory (plus some natural physical processes happened in the same space) and, consistently, ECONOMY should be an aggregate measure of the expenditure on those goods and services. In the second case, EMISSION should be a measure that captures the emissions embedded into the goods and services consumed by

4: The Sustainable Development Goals (SDGs) are the 17 goals adopted by all the United Nations Member States in 2015 in order "to shift the world on to a sustainable and resilient path" (see United Nations 2015a, 2015b, 2020) and SDG8, in particular, refers to "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all".
5: NDCs are non-binding national plans including climate related targets, policies and measures governments aim to implement in response to climate change and as a contribution to achieve the global targets set out in the Paris Agreement.
6: See footnote 3.

the residents of the country in question, that is, the gases emitted by the activities involved in the production of those goods and services (independently of being realized domestically or abroad). Accordingly, ECONOMY should be an aggregate measure of the expenditure on those goods and services.

However, due especially to data limitations, the quality and consistency of emission intensity indicators have largely evolved over time. Let's start by the numerator (GHG and CO2 emissions at the country level): until very recently, only production-side measures of CO2 emissions at the country level were available, given the high difficulty involved in the expenditure-side measurement (see Yamano and Guilhoto, 2020, and Cabernard and Pfister, 2021). On the other hand, regarding the denominator, although a consensus exists for approaching ECONOMY with the well-established concept of Gross Domestic Product[7] (GDP), a debate existed until the middle of the 2000s inside the climate-change research community regarding the international-comparability of this indicator[8] and the transformations required for guaranteeing it (see Holtsmark and Alfsen, 2004; Nordhaus, 2007 and/or Purdie, 2019).

More specifically, the debate initially focused on the old belief that international comparability could be reached just by converting GDPs from local currency to US$ by using market exchange rates. However, the idea became debunked and the focus changed to the appropriate PPP approach, which converts GDPs into really internationally-comparable units. Two alternatives are used actually for that-both based on the international price data collected by the ICP[9], the World Bank approach (see World Bank, 2020c) and the Penn World Table (PWT) approach (see Feenstra, Inklaar and Timmer, 2015).

However, although the problem of international comparability was solved, another problem persisted for years: the only reliable PPP-GDPs available for international comparisons were expenditure-side measures[10], and hence, they were more appropriate for the construction of expenditure-side emission intensity indicators than for the output-side ones. Fortunately, since 2013 (PWT 8), the Penn World Table includes a new output-side PPP-GDP (as a result of the research work done by Feenstra et.al, 2015) capable of better reflecting the differences in the domestic production of goods and services between countries than the World Bank's and other standard PPP-GDPs.

In short, it is only recently that the possibility has arisen for constructing both production-side and expenditure-side internationally-comparable measures of the aggregate emission intensity of a given country. This is explained by the fact that only recently have measures of GHG (and CO2) emissions and PPP-GDP from both perspectives become available.

In consequence, the standard emission intensity indicators employed in the literature are still inconsistent mixtures of output-side emissions and expenditure-side PPP-GDP, including the most popular among them, the World Bank's emission intensity indicator (only for CO2, it forms part of the World Development Indicators, WDI) and the

7: In contrast, in other areas (and for other purposes) of environmental research and discussion, the use of the GDP has been increasingly questioned during the last decade, given its deficiency as a measure of economic progress once environmental degradation is taking into account. In response alternative measures of (sustainable) economic progress have been proposed (see Pineda, 2012; Acosta, Pineda et.al. 2019, and Doménech, 2021).
8: Comparability that is key not only for estimating comparable intensity estimators but also for the development of the so called Integrated Assessment Models (IAMs), the workhorse tools for simulating the future interaction of the world climate and the economy as well as the effects of environmental policies on them (see Nordhaus, 2007).
9: The International Comparisons Program of the World Bank.
10: The original GDPs at local currency units and constant prices are simultaneously an output-side and expenditure-side measure for a country, but the standard PPP-adjustment only makes them internationally-comparable as measures of aggregate expenditure: it neglects the effect of the differences in the terms of trade between countries. Note that international differences in expenditure not always match international differences in domestic production, especially in the case of small open economies.

World Resource Institute's indicator (for GHG, CO_2, CH_4, N_2O and F-Gases, they form part of the Climate Analysis Indicators, CAIT).

This paper takes advantage of the new possibilities opened by the development of these complementary measures and presents the first consistent output-side GHG emission intensity indicator. Put another way, OEI is the first indicator using production-side measures for both emissions and PPP-GDP, producing a really consistent approach to output-side decoupling. In section 4.3 of the work, the OEI is compared with a standard emission intensity indicator, one which mixes production-side emissions with expenditure-side PPP-GDP, showing that for small open economies, the relative place in the international ranking experiences substantial changes (as expected given the correction in the terms of trade involved).

3. Data and methodology

In order to construct the proposed Output-side Emission Intensity Indicator (OEI), a database with annual time series for the output-side PPP-Adjusted GDP and production-side GHG and CO2 emissions (covering the period 1990-2017) was assembled. Territorial GHG and CO2 emissions data were retrieved from the CAIT Climate Data Explorer and PPP-GDP data was procured from the Penn World Table (version 10.0). See Appendix 1 for further information about the data sources and their description.

General emission intensity indicators put emissions directly or indirectly produced or consumed by a particular country (i.e., inside its territory and/or by its residents) into perspective, by comparing them to some internationally-comparable aggregate measure of economic activity (usually demand side PPP-GDP). In this context, the possibility to construct at least four possible variations of emission intensity indicators exists, as emissions, as well as PPP-GDP, can be measured both from a production or an expenditure standpoint. **OEI uses production-side PPP-GDP and produced GHG emissions, guaranteeing its consistency** (see section 4.3 for further details regarding the differences between OEI and previous indicators and their ranking differences).

Therefore, by dividing the country's produced emissions by the output-side real GDP at chained PPPs in 2017 million dollars (in what follows, OS-PPP-GDP), the corresponding OEI is obtained. The indicator facilitates international country comparisons by capturing the average carbon intensity of the country's productive activities, reflecting the structure of the economy.

Formally,

$$OEI_{i,t} = (Total\ or\ restricted\ emissions_{i,t}) \,/\, (OS - PPP - GDP_{i,t})$$

Note that $OEI_{i,t}$ reflects the Output-side Emission Intensity of country *i* at time *t*, so in order to provide a unique classification for each ranking (OEI1 and OEI2), the average ratio (from 2009 to 2017) of each country has been analyzed[11]. The difference between OEI1 and OEI2 lies on the emissions considered when calculating the ratio (different numerators): OEI1 takes all GHG emissions into account, while OEI2 only considers CO2 emissions from fossil fuel combustion and leaks.

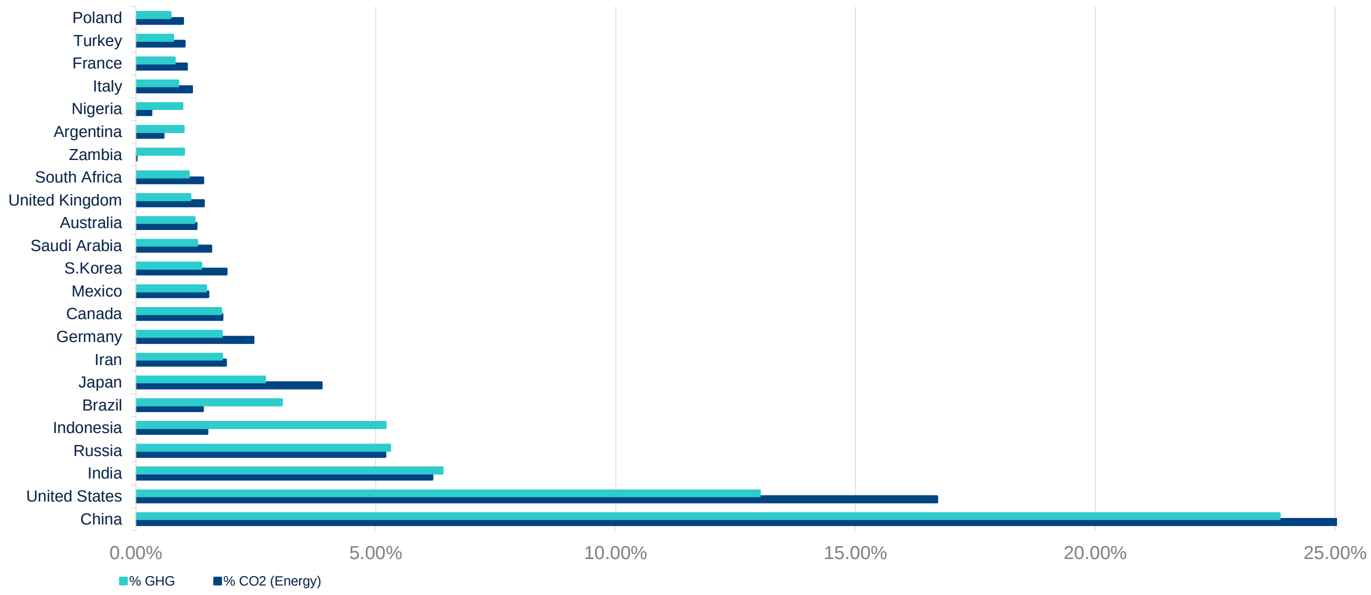
11: By taking the average, the effect of atypical years (caused by abrupt changes in GDP, especially) is contained and the ranking becomes more reliable.

4. Results

Figure 1 below shows the world's top GHG and CO2 emitters, while Figures 2 and 3 present the OEI1 and OEI2 rankings for 161 countries (all data is publicly available in http://dx.doi.org/10.13140/RG.2.2.27423.69283). Note that the higher the ratio for country *i*, the higher the carbon intensity of the economy, and that countries with **higher ratios are more exposed to the consequences of abrupt policy actions to promote climate transition.** Therefore, OEI1 and OEI2 can help gauge the scope of potential policy actions and serve as proxies of transition risk.

It is worth noting that the ranking changes depending on the numerator selected. That is, the country ranking is different if CO2 or GHG emissions are considered or if land use, land-use change and forestry (LULUCF) are incorporated or not. The two rankings considered in this paper (OEI1 and OEI2) have their own characteristics, and hence, they serve different purposes. Thus, understanding the differences among the rankings is crucial in order to select the appropriate classification (See Appendix 2 for further details regarding the differences between the indicators).

Figure 1. **World's top emitters, at least 1% of GHG or CO2** (Energy). **World percentage of GHG and CO2 from fossil fuel combustion and leaks, average 2009-17**

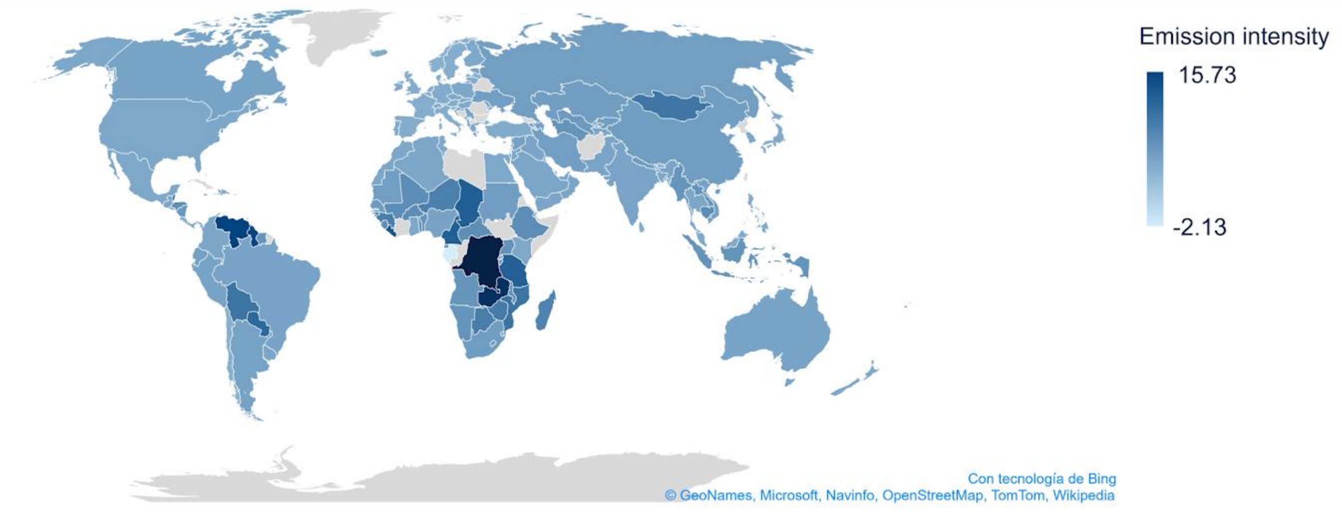


Source: BBVA Research based on CAIT Climate Data Explorer.

4.1. Output-side Total Emission Intensity Indicator (OEI1)

The Output-side Total Emission Intensity Indicator (OEI1) is an environment-linked indicator that reflects the total production-side GHG emissions needed to produce one unit of domestic real output. Note that the higher the OEI1 for a country, the higher the GHG emission associated with its OS-PPP-GDP, and hence, the greater the economic impact of future policies oriented to reduce GHG emissions, such as tighter regulation or higher GHG emissions prices. Results for the OEI1 are presented in Figure 2 below.

Figure 2. **Output-side Total Emission Intensity Indicator** (average 2009 - 2017)**, world classification**



Source: BBVA Research.

Least developed countries exhibit the greatest emission intensities with respect to their OS-PPP-GDP due to its reliance on agriculture, deforestation, mining activities and less energy efficient technologies. Thus, the results seem to indicate that the transition to a zero-emission economy might impose an additional constraint to the growth of poor countries if not accompanied by technological transfers and development aid. Although the total emission contribution of least developed countries is negligible (see Figure 1), **they are the most vulnerable in relative terms to a universal carbon tax or an emission cap scheme, as a consequence of their low real GDP and their high GHG intensity** (see Appendix 2A for further details).

Therefore, as it can be observed in the map, the African region and a few South American countries remain the most vulnerable to climate change transition risk due to their low economic development, their high dependence on natural resources for agricultural production or forestry activities, and their low technological advancement. **Note that the economic literature suggests that in the long term and above a certain level of development (proxied by the level of GDPpc) a monotonically decreasing relationship may exist between economic development and environmental quality, proxied by GHG emissions per capita or per GDP (Environmental Kuznets hypothesis).** So, in order to ensure that economic development could persist alongside improvements in environmental quality, there must be a global effort to introduce and share innovations aimed at increasing production with fewer GHG emissions in the poorest countries.[12]

Table1. **Output-side Total Emission Intensity Indicator** (average 2009 - 2017), **descriptive statistics**

St. Dev.	Mean	Median	Dispersion	Weighted aver.
1.58	0.84	0.41	1.88	0.74

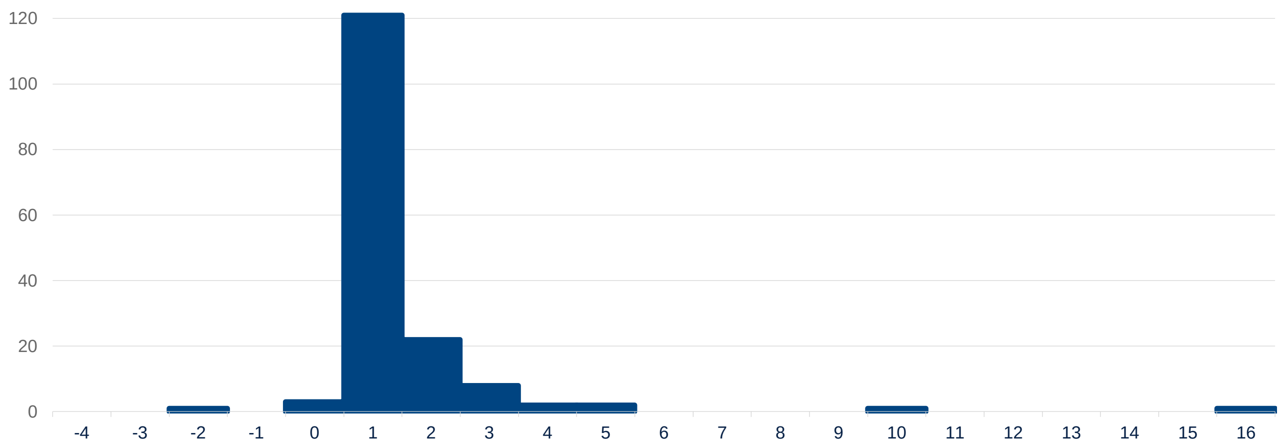
Source: BBVA Research.

12 Actually, some Nationally Determined Contributions are partially conditioned to gain access to enhanced financial resources, technology transfer or availability of market-based mechanisms among others.

Table 1 above shows the descriptive statistics of the country classification. Note that the statistics reflect the **heterogeneity in the emission intensity among countries,** with the ranking distribution being positively skewed (mean value almost doubles the median value). That is, most values are clustered around the left tail of the distribution while the right tail of the distribution is longer (see Figure 3).

In this sense, few countries have an above average OEI1 (41 out of 161), but the ones that they do exhibit really high emission intensities. As an example, China (0.68), Ukraine (0.67), Russia (0.64), Estonia (0.55) or Serbia (0.43) have higher emission intensities than the median value (0.41), but they all present OEI1s that are below the mean value (0.84), upwardly pushed by least developed countries. The weighted average emission intensity (0.74), weighted by the share of the country's GHG emissions over total GHG emissions, is also below the mean intensity, denoting that **countries with lower OEI1s than the average have a greater weight in the world's emissions than countries with bigger OEI1s than the average.**

Figure 3. **Output-side Total Emission Intensity Indicator** (average 2009 - 2017), **distribution**



Source: BBVA Research.

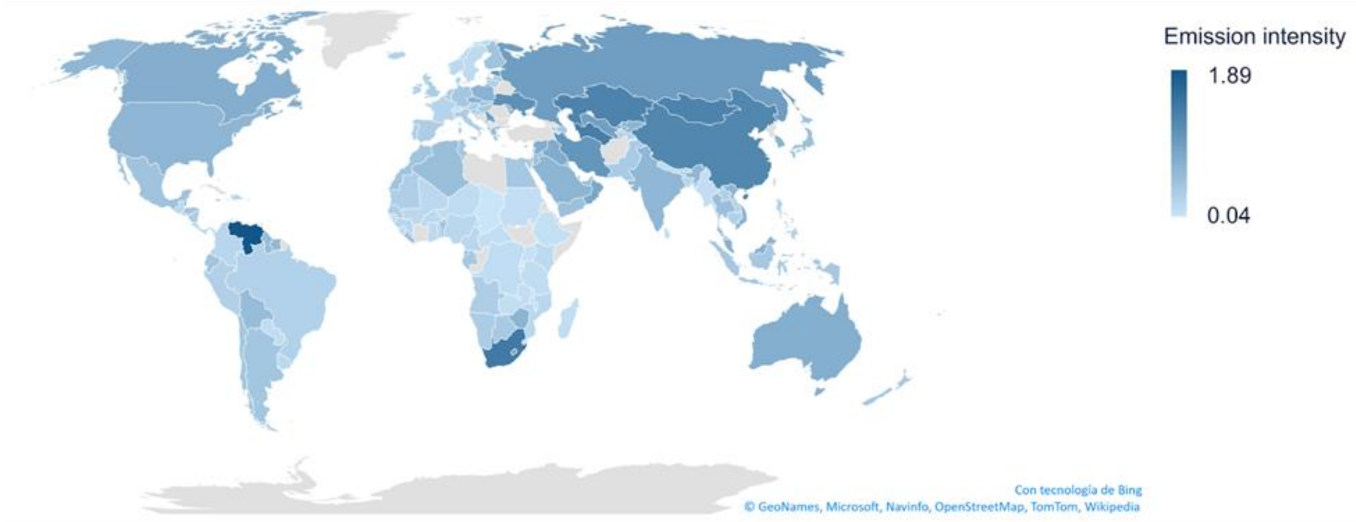
Within the top 10 GHG emitters (see Figure 1), Indonesia is the country with the highest emission intensity (1.0), followed by China (0.68), Iran (0.67), Russia (0.64), Canada (0.49), Brazil (0.46), India (0.44), USA (0.34), Japan (0.25) and Germany (0.21). Note that these countries account for 65% of the total estimated GHG emissions in the world. Finally, it is worth mentioning that **EU countries have a privileged positioning to face the transition to a low carbon-economy,** as their average OEI1 is well below any other group's ratio (0.22). The situation is even better for Northern European countries, where greenhouse gases have experienced a gradual decoupling from economic growth, justifying the pressure that the region imposes to the rest of the world to accomplish their own emission reduction targets.

4.2. Output-side Restricted Emission Intensity Indicator (OEI2)

Results for the Output-side Restricted Emission Intensity Indicator (OEI2) are presented in the map below. Note that the **OEI2 captures CO2 emission from fossil fuel combustion and leaks per unit of OS-PPP-GDP, and hence, least developed countries lose prominence on the ranking** and their place is occupied, mainly, by newly industrialized and fossil fuel exporting Asian countries. CO2 emissions from fuel combustion are affected by a range of drivers, including population growth, GDP and energy supply. Thus, as energy supply is intimately tied in with development (and the energy sources endowment), **OEI2 implicitly requires a minimum level of development to stand out in the ranking** (See Appendix 2B for further details).

As the IEA (2020) remarks, the generation of electricity and heating, together with transport, accounted for over two thirds of total CO2 emissions in 2018. In this sense, if one allocates electricity and heating emissions across final sectors, industry is the largest emitting sector, accounting for almost 40% of global emissions. Therefore, **the level of industrialization is key to understanding the position of each country in the OEI2 ranking:** economies that heavily rely on the secondary sector (manufacturing) will stand out in this alternative emission intensity ranking.

Figure 4. **Output-side Restricted Emission Intensity** (average 2009 - 2017), **world classification**



Source: BBVA Research.

Figure 4 above reflects the OEI2 ratio of 161 countries. As expected, newly-industrialized and fossil fuel exporting Asian countries exhibit the greatest emission intensities with respect to their real output-side GDP, due to its reliance on high polluting fuel extraction and industrial activities.

The expected effect of a tax on CO2 (fuel combustion and leaks) seems to be different from the effects that may derive from a global GHG tax. That is, least developed countries would be comparatively less penalized, shifting the burden to CO2-intensive Asian countries that sustain their development on manufacturing or on fossil-fuel intensive activities. Again, developed countries, which have an important share of their GDP allocated in the tertiary sector (services, commerce) are relatively less affected. Note that a **CO2 Energy tax is also easier to implement than a global GHG tax, as CO2 emissions are less uncertain than non-CO2 emissions from agriculture or GHG emissions from LULUCF.** This can be explained by the fact that the former incorporates uncertainty as both the activity level and the conversion factor need to be estimated, while the latter requires to disentangle the simultaneous natural and anthropogenic processes that determine land-related fluxes, which at the same time, are subject to variations.

Newly industrialized and fossil fuel exporting Asian countries emit more CO2 from fuel combustion and leaks than the rest to produce one unit of OS-PPP-GDP. The economic activity in these regions, with heavy investments in coal-power and oil plants could partially explain the difference. In this regard, investments in fossil fuels are declining in Asian countries as governments implement cleaner energy policies, but these regions are still laggards in terms of carbon efficiency and decarbonization of the economy. Thus, the implementation of a carbon tax would accelerate the subsidy reform in CO2-intensive Asian countries, which accounted for close to a third of global subsidies on fossil fuel consumption in the analyzed period, with expenses that were close to 2.5% of their GDP (Coady et.al., 2019).

Table2. **Output-side Restricted Emission Intensity** (average 2009 - 2017), **descriptive statistics**

St. Dev.	Mean	Median	Dispersion	Weighted aver.
0.18	0.21	0.18	0.83	0.36

Source: BBVA Research.

Table 2 above shows the descriptive statistics of the OEI2 indicator. Note that the statistics reflect a **lower heterogeneity in the emission intensity among countries than in the previous ranking,** but even so, the dispersion of the OEI2 results is considerable. The ranking distribution (see Figure 7) is again positively skewed (mean value higher than the median value) but in comparison to the OEI1 ranking, less values are clustered around the left tail of the distribution while the right tail of the distribution is smaller. This is reflected by the dispersion coefficient, which decreases from 1.88 to 0.83 (although only 59 countries have an above average OEI2). On the other hand, the OEI2 weighted average emission intensity (weighted by the CO2 energy emissions from country *i* over the total CO2 energy emissions) is above the mean, denoting that **countries with higher OEI2s than the average have a greater weight in the world's CO2 emissions than countries with OEI2s that are lower than the mean.** This is consistent with the intuition that OEI2 implicitly requires a minimum level of development to stand out in the ranking (for the same level of development, the differences in the intensity are related to the energy mix).

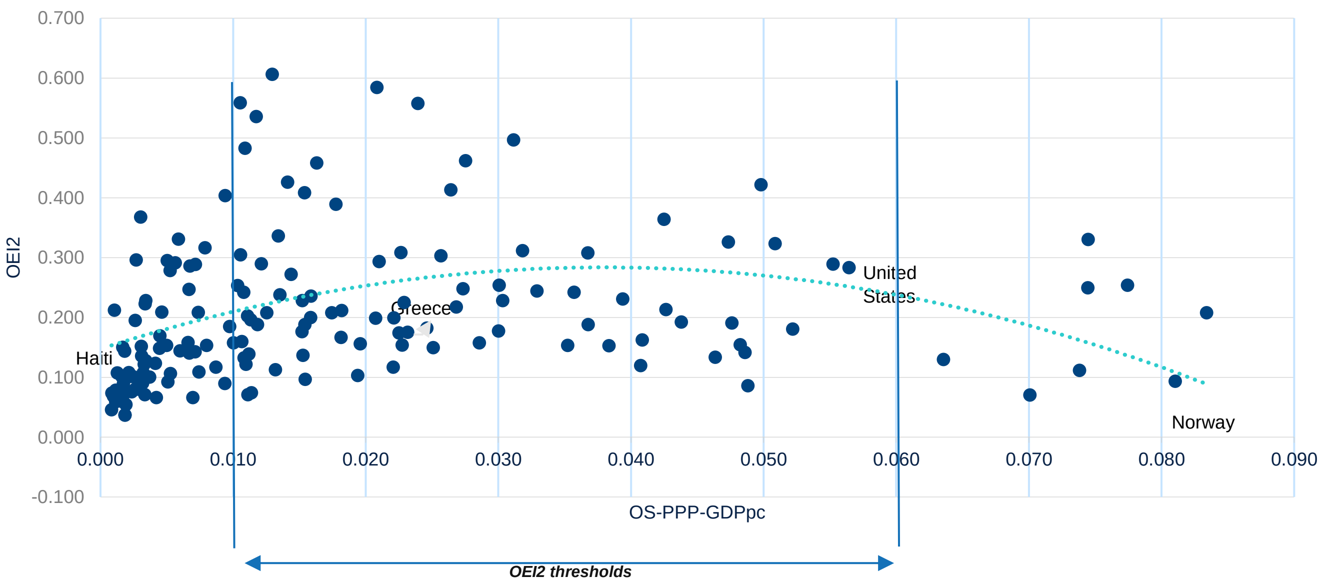
OEI2 is chaired by countries within the inflexion thresholds (see Figure 5) **of the environmental Kuznets curve, which is expressed in output-side PPP-GDP per capita terms (in general, highly and least developed countries have a lower OEI2 ratio than newly industrialized and fossil fuel exporting countries).** This can be explained by technology improvements and the growth of the service sector in developed countries, a sector that is less intensive in the use of energy, and hence, favors the fall of CO2 energy emissions. On the other hand, the exclusion of non-CO2 greenhouse gases decreases the OEI2 of least developed countries.

Thus, Figures 5 and 6 indicate that the increase in GDP per capita is compatible with a reduction in per OS-PPP-GDP emissions, fuelled by new technologies and a change in the sectoral mix. Put another way, Figures 5 and 6 provide evidence in favor of the Environmental Kuznets Curve hypothesis, which seems to be fulfilled when OEI2 and OS-PPP-GDP per capita are taken into account. Note that some studies, including Grossman and Krueger (1995) paper, use an EKC in levels and find an N-shape EKC, while Stern (2004) affirms that when using logs, the EKC takes an inverted U-shaped function of income per capita[13]. The reason behind the decision of using the natural logarithm (see Figure 6) resides in the fact that the second order polynomial provides a better fit when using logarithms than levels (Stern, 2004). In this regard, the R squared coefficient or the goodness of the fit is 0.3 when OEI and OS-PPP-GDP are transformed using the natural logarithm, a considerable coefficient in cross-country analysis. The R square signals that the output-side PPP-GDP seems to have an important role at explaining the variance in OEI2. If the same analysis is performed using the expenditure-side PPP-GDP, the R squared

13: $\ln\left(\frac{E}{P}\right)_{i,t} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{i,t} + \beta_2 \ln\left(\frac{GDP}{P}\right)^2_{i,t} + \varepsilon_{i,t}$ where E is emissions, P is population, and ln indicates natural logarithms. The first two terms are intercept parameters which vary across countries or regions *i* and years *t*.

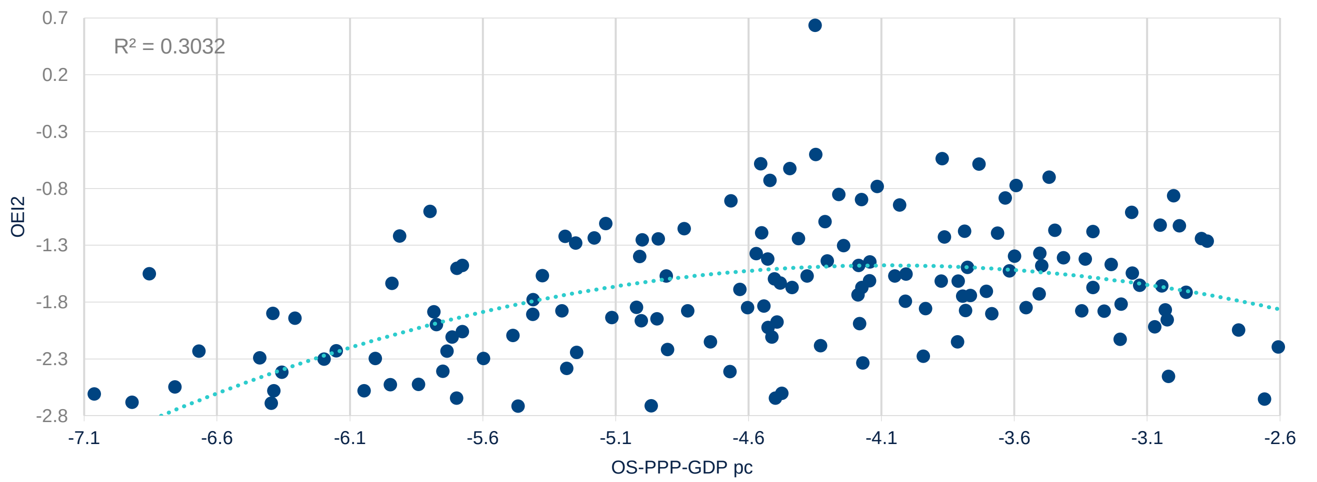
coefficient decreases to 0.266, providing an additional argument in favor of using consistent indicators as the OEI when measuring carbon intensity across countries (in comparison to traditional mixed indicators).

Figure 5. **Output-side Environmental Kuznets Curve** (OEI2 and OS-PPP-GDP per capita)



Source: BBVA Research. OEI and OS-PPP-GDP pc (average 2009-2017). Dotted line: Trend line (second order polynomial).

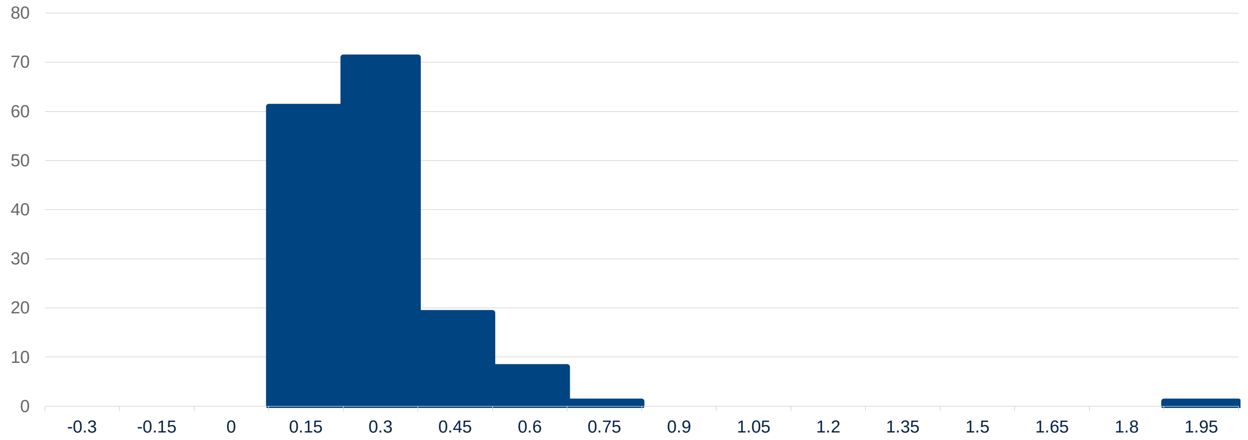
Figure 6. **Output-side Environmental Kuznets Curve** (log OEI2 and log OS-PPP-GDP per capita)



Source: BBVA Research. Both OEI2 and OS-PPP-GDP per capita have been transformed using the natural logarithm. Dotted line: Trend line (second order polynomial).

Finally, it is worth mentioning that **within the top 10 CO2 energy emitters (in absolute terms), China is the country with the highest emission intensity (0.52),** followed by Iran (0.46), Russia (0.41), Canada (0.33), South Korea (0.31), Saudi Arabia (0.29), USA (0.28), India (0.28), Japan (0.23) and Germany (0.19). Note that only these countries account for 70% of the global estimated CO2 energy emissions. Furthermore, the OEI2 ranking reaffirms the conclusion from the previous section that EU countries have a better positioning to affront the transition to a low carbon-economy, which is explained by the energy efficiency improvements of EU countries (relative decoupling of greenhouse gases from economic growth) and the moderate but constant decarbonization of their economies.

Figure 7. **Output-side Restricted Emission Intensity** (average 2009 - 2017), **distribution**



Source: BBVA Research.

4.3. Comparison with previous indicators

International GHG emission intensity indicators put GHG emissions directly or indirectly produced or consumed by a particular country (i.e., inside its territory and/or by its residents) into perspective, by comparing them to some internationally-comparable (or PPP) aggregate measure of economic activity (usually PPP-GDP). Thus, as mentioned before, there are at least four possible variations (and their corresponding interpretations) of such an indicator given that GHG emissions, as well as PPP-GDP, can be measured both from a production-perspective (production-based emissions and output-side PPP-GDP) or, alternatively, from an expenditure-perspective (consumption-based emissions and expenditure-side PPP-GDP).

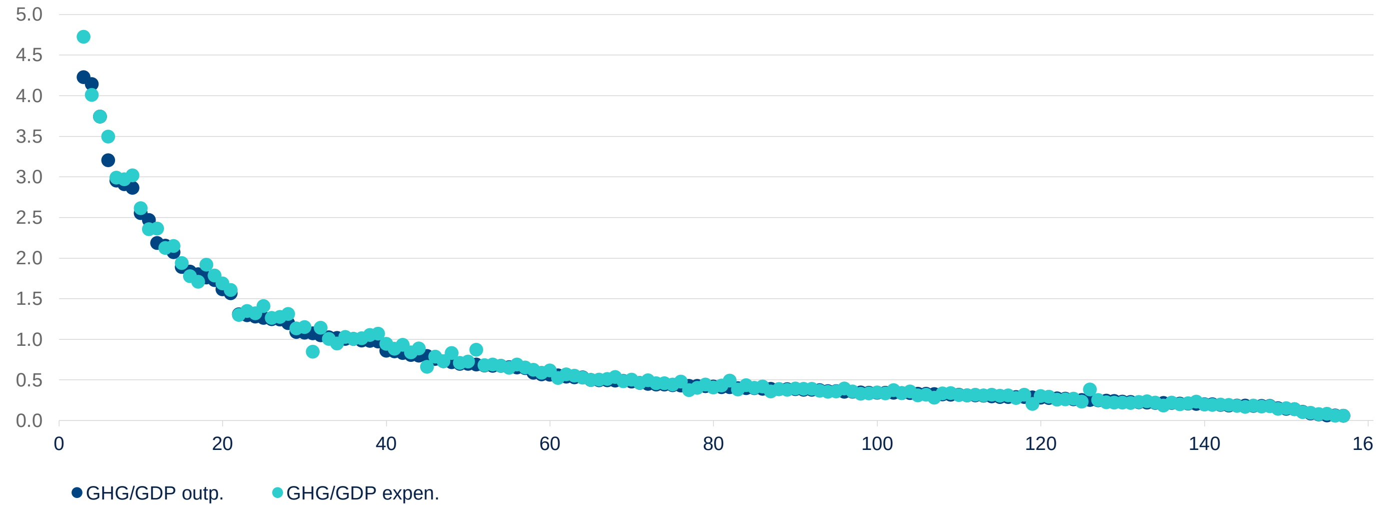
Under the production-perspective, PPP-GDP and GHG emissions are closely related, with the former summarizing the goods and services domestically produced each year and the latter comprehending the GHG emitted in the production of such GDP (and its inputs) plus any domestic physical processes. In contrast, under the expenditure-perspective, the link between PPP-GDP and GHG emissions is much looser, with the former summarizing the international purchasing power of domestic income (or, equivalently, the living standards that allows its receptors to afford) and the latter comprehending the GHG emitted for the production of goods and services purchased or consumed by national residents each year.

In this context, as it is exemplified by the most popular emission intensity indicator, the World Bank's EN.ATM.CO2E.PP.GD.KD (see World Bank, 2020), until recently emission intensity indicators were limited to the production-side GHG and expenditure-side PPP-GDP variant. In part, this is explained by the difficulty of measuring consumption-based emissions[14] and the lack of terms of trade data required for estimating the output-side PPP-GDP. Thus, these mixed indicators are difficult to interpret as, strictly speaking, they cannot be understood neither as an output-side emission intensity indicator nor as an expenditure-side one. Note that this is not a mere theoretical formality, and as we show below, some countries change their relative place in the ranking with respect to a properly computed output-side indicator.

For illustrating the potential distortion caused for not using the proper category of PPP-GDP, the OEI1 indicator is compared with a traditional style variant computed by dividing the same numerator (production-based GHG emissions) by the expenditure-side Penn World Table PPP-GDP at constant prices (instead of its output-side counterpart). Figures 8and 9 reveal that although the correlation is very high, differences exist in the positioning of some countries between the ranking based on the OEI1 indicator and the one based on the traditional indicator. Figure 10 shows that such differences are just a reflection of large differences between output-side and expenditure-side PPP-GDP for a handful of countries, which Figure 11 allows to identify as some of the top economies in a world openness ranking (see for example, The Global Economy, 2019).

Bear in mind that the traditional style variant presented below only differs itself from the OEI in the denominator (expenditure-side against output-side GDP PPP) unlike the World Bank's EN.ATM.CO2E.PP.GD.KD, which also has a different numerator (total CO2 emissions against total production-side GHG emission in OEI1 and total production-side CO2 emission from fossil fuel use and leaks in OEI2). In other words, the World Bank's indicator presents important differences with the indicators presented in the paper, and hence, an alternative traditional indicator is presented to ease comparison. If necessary, an alternative OEI can be constructed with the World Bank's emission data.

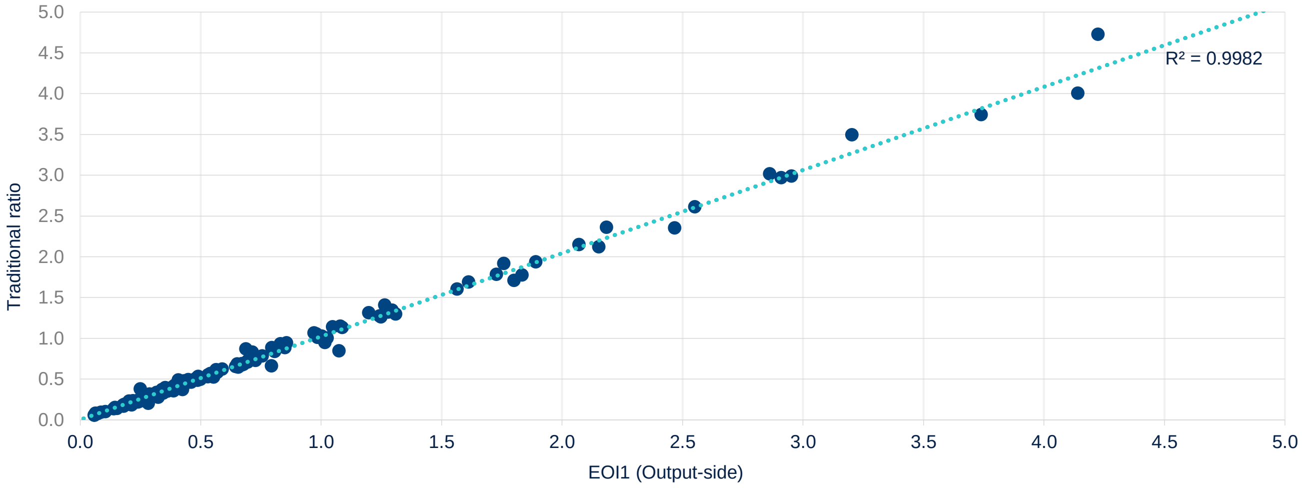
Figure 8. **OEI1** (Output-side ratio and Traditional ratio, below 5)



Source: BBVA Research.

14: See Feenstra et.al (2014) and Davis and Caldeira (2010).

Figure 9. **OEI1** (Output-side ratio and Traditional ratio, below 5)



Source: BBVA Research.

Trade-open economies are expected to be the most affected given that the differences between output- and expenditure side PPP-GDP for a given country are directly related to its terms of trade fluctuations, which in turn tend to be proportional to their degree of trade openness. In general, highly open economies with strong (weak) terms of trade, meaning higher (lower) than average prices for exports or lower (higher) than average prices for imports, have higher (lower) expenditure-side than output-side PPP-GDP and hence, a lower (higher) emission intensity when using expenditure-side PPP-GDP. Figure 11 confirms the intuition and identifies the countries with the highest ranking variations as some of the top economies in a world openness ranking.

On the other hand, as shown in Figure 10, the expenditure-output-side adjustment seems to be unrelated to the level of the traditional ratio. Note that OEI1 can be decomposed into two different parts: the traditional ratio (vertical axis, Figure 10) and a corrective element, which is simply the division of the expenditure-side and the output-side PPP-GDPs (horizontal axis, Figure 10).

Formally,

$$OEI1_{\mathrm{i,t}} = \frac{(Total\ GHG\ emissions_{i,t})}{(ES - PPP - GDP_{i,t})} * \frac{(ES - PPP - GDP_{i,t})}{(OS - PPP - GDP_{i,t})}$$

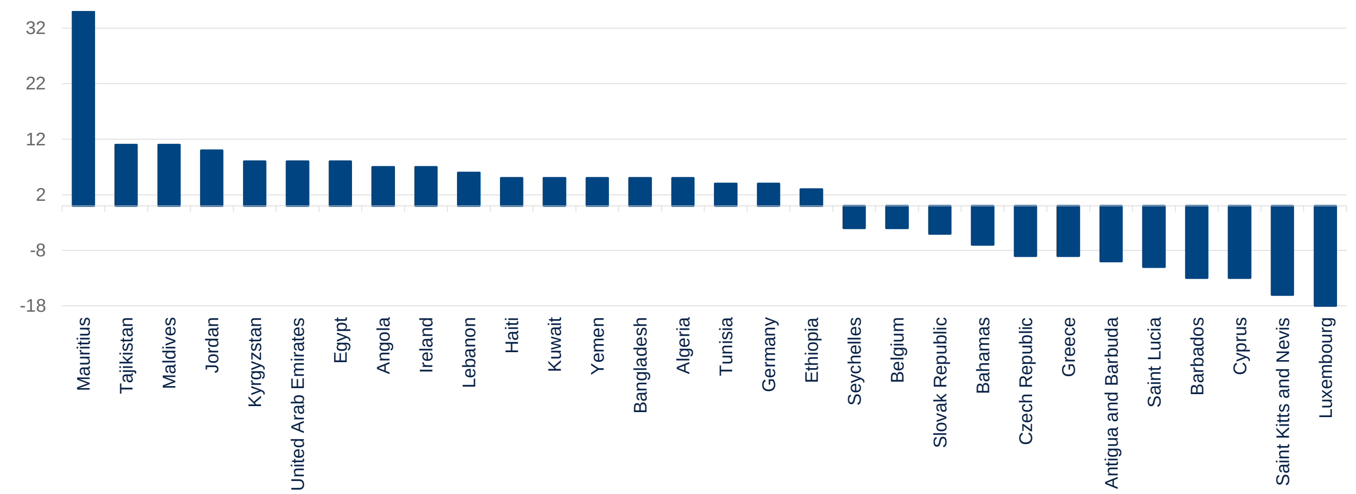
$$OEI1_{\mathrm{i,t}} = Traditional\ ratio * Corrective\ element$$

That is, no significant pattern can be observed between the traditional ratio and the corrective element: countries with the highest (lowest) traditional ratios do not have the greatest (lowest) corrective component or the highest difference between the expenditure-side and the output-side PP-GDPs. Thus, as trade-open economies are expected to be the most affected given their output and expenditure side PPP-GDP differences, it may be concluded that there is not any apparent relationship between trade-openness and emission intensities.

Figure 10. **OEI1 decomposition. Traditional ratio** (vertical axis) **and real GDP ratio, expenditure-side real GDP divided by output-side real GDP** (horizontal axis)

Source: BBVA Research.

Figure 11. **OEI1, ranking difference** (Output-side ratio - Traditional ratio)**. At least a 5 position change in the ranking**[15]



Source: BBVA Research.

15: The ranking difference between the traditional indicator and the OEI lays on a structural difference between the two indicators. That is, the difference between the two cannot be understood as an insignificant difference in statistical terms driven by measurement errors, as both indicators have differences that concord with economic logic: expenditure-side PPP-GDP will always be higher for trade-open economies with favorable trade of terms (and vice-versa).

5. Conclusions

The use of fossil fuels have dramatically increased since the industrial revolution and with that, the GHG emission into the atmosphere. If society keeps relying on non-renewable energy to the extent that it is currently doing, global warming is expected to reach 4.1°C - 4.8°C above pre-industrial by the end of the century[16]. Quite likely, an increase in temperature this high will provoke all sorts of economic, political, social and geophysical problems. In this context, transition risks, understood as the potential adverse macro-financial effects that could be derived from the introduction of carbon price policies (carbon taxes, cap-and-trade systems, etc.), must be studied as their effects could be considerable and definitely heterogeneous across countries, sectors and even companies.

Assessing the first layer of heterogeneity, this note has shown that one way of evaluating country exposure to transition risks is to construct an appropriate environment-linked indicator. The concept of the Output-side Emission Intensity Indicator, with its two variants, the Output-side Total Emission Intensity Indicator and the Output-side Restricted Emission Intensity Indicator, helps in this regard. OEI1 measures the total production-side GHG emissions associated with the production of one unit of output (as measured by OS-PPP-GDP), while OEI2 captures the production-side CO_2 emissions from fossil fuel combustion associated with the production of one unit of output.

In general, OEI provides a proxy of the relative vulnerability of different countries to carbon pricing policies, and at the same time, it is more consistent than previously available indicators, as both, greenhouse gas emissions and (internationally comparable or PPP) GDP are measured from the production or output perspective. Thus, OEI avoids the usual mixing of output and expenditure-side measures.

Regarding the international results, the OEI1 ranking shows that least developed countries exhibit the greatest emission intensities with respect to their OS-PPP-GDP, due to its reliance on agriculture, deforestation, mining activities and less energy efficient technologies. Thus, the results seem to indicate that the transition to a zero-emission economy imposes an additional constraint to the growth of poor countries if not accompanied by technological transfers and development aids. Note that although the total emission contribution of least developed countries is negligible, they are the most vulnerable to a universal carbon tax or an emission cap-schemes in relative terms.

On the other hand, OEI2 implicitly requires a minimum level of industrialization to stand out in the ranking. Consequently, newly industrialized and fossil fuel exporting Asian countries exhibit the greatest emission intensities with respect to their OS-PPP-GDP, with least developed countries being less penalized. Again, developed countries, with a great share of GDP allocated in the tertiary sector, are relatively less affected. Furthermore, the analysis conducted provides evidence in favor of the Environmental Kuznets Curve hypothesis, which seems to be fulfilled when OEI2 and OS-PPP-GDP per capita are taken into account.

Finally, the comparison between the OEI and the standard emission intensity indicator shows that for small open economies, the relative place in the international ranking experiences substantial changes, as expected given the correction in the terms of trade involved. Note that trade-open economies are expected to be the most affected given that the differences between output- and expenditure side PPP-GDP for a given country are directly related to its terms of trade fluctuations, which in turn tend to be proportional to their degree of trade openness.

16: See Climate Action Tracker (2020).

Appendix 1: Data sources and description

In order to construct the Output-side Emission Intensity proxy, PPP-Adjusted Gross Domestic Product (GDP), Carbon dioxide (CO2) and Greenhouse Gases (GHG) data were obtained for 161 countries, from 1990 to 2017. GHG and CO2 emissions data were retrieved from the CAIT Climate Data Explorer and PPP-GDP data was procured from the Penn World Table (version 10.0). Similar indexes have been created by the World Economic Forum or the World Bank (2020).

The Climate Analysis Indicators Tool (CAIT), developed by the World Resources Institute (WRI) is a data and analysis tool designed to help inform policy discussions and decisions under the United Nations Framework Convention on Climate Change (UNFCCC), which can be defined as the treaty that enables the publication of the national greenhouse gas inventories. Put another way, WRI compiles data from a variety of non-governmental sources, not to replace those data reported by countries to the UNFCCC, but to complement them (providing a wider geographical scope and longer emissions time series). WRI data sources are chosen based on criteria such as completeness and relative accuracy and country datasets are produced by applying a consistent methodology. GHG and CO2 territorial emissions data are expressed in Mt CO2 equivalents, thousands.

On the other hand, the Penn World Table (2021) is a database with information on relative levels of income, output and productivity, which covers 183 countries between 1950 and 2019. In order to perform the analysis, data of the output-side real GDP at chained PPPs (in mil. 2017US$) was used. Note that the output-side real PPP-GDP allows a comparison of the productive capacity across countries, in contrast to the expenditure-side real PPP-GDP, which allows making comparisons of differences in the living standards.

Output-side real PPP-GDPs were previously not feasible because of data availability constraints. Their computation requires not only relative prices of consumption and investments but also of export and imports. In this sense, incorporating such data was challenging due to the fact that there was not any cross-country survey that collected prices for traded goods of comparable quality across countries (Feenstra et.al., 2015). Thus, academics initially worked with the unit values of traded goods, which can now be corrected for quality, thereby obtaining quality-adjusted prices across countries (Feenstra and Romalis, 2014). The decision to work with the output-side real PPP-GDP was based on the nature of the OEI ratio, which intends to measure the internationally-comparable average production-side emissions that the country needs to emit for producing one additional unit of value added. Note that results are presented in Mt CO2 equivalents (thousands) per million (2017US$) output-side PPP-GDP, but for simplification purposes, OEI may be defined as production emissions per unit of output-side PPP-GDP (one only needs to rescale the ratio). Although data from 1990 to 2009 has been ignored for the purpose of this analysis, it could be interesting to expand it in the future, as the possibility of analyzing ranking changes exists with the available dataset (see Appendix 3).

Appendix 2: Technical details

Output-side Total Emission Intensity Indicator (OEI1)

The Output-side Total Emission Intensity indicator (OEI1) is an environment-linked indicator that reflects the total output-side GHG emissions needed to produce one unit of output-side real Gross Domestic Product. OEI1 is obtained by dividing the country's total GHG emissions by the OS-PPP-GDP of each country, and for the purpose of this analysis, GHG refers to the sum of the six different gases included in the Kyoto Protocol as directly related with climate change: Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Chlorofluorocarbons (CFCs), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur Hexafluoride (SF_6).

Note that apart from CO2, which accounts for about 70 percent of the total releases in the world, OEI1 also includes other less common gases. As an example, Methane and Nitrous oxide, which arise essentially from agriculture and land use, contributes 16 and 6 percent of GHG emissions. Put another way, OEI1 can be understood as a comprehensive ratio that is in line with the Paris agreement targets in the extent that it takes all GHG into account. Note that countries with low OS-PPP-GDP are in general non-industrialized countries with a great dependence on extensive agriculture, and therefore, the inclusion of non-CO2 emissions coming from agriculture severely increases their carbon intensity.

Bear in mind that although 65% of GHG emissions come from just 10 countries, and the 100 least-emitting economies contributed less than 3% to the world's total, OEI1 captures the relative dependence on GHG emissions (in accordance to each country's OS-PPP-GDP) or the GHG emissions per dollar of output. That is, the carbon intensity of a country is not directly affected by the total emission quantity, but the emission amount relative to the size of its economy. Furthermore, OEI1 also includes emissions coming from land use, land-use change and forestry activities (LULUCF), which can be defined as the GHG inventory sector that covers emissions and removals of GHG resulting from direct human-induced land use such as settlements and commercial uses, land-use change, and forestry activities. In its overall assessment of GHG, Watson et al. (2000) mentioned that land use, land-use change and forestry were responsible for 20 to 25% of global greenhouse gas emissions. What is more, according to a recent study (Lutfalla et al., 2019), the conversion of forests to soils rich in organic carbon generates a CO2 flux from soils to the atmosphere corresponding to 10% of emissions.

Developing or least developed countries are also the ones with more emissions originating from LULUCF, as deforestation is especially prevalent in these countries. The reasons for this deforestation repeat themselves from one country to the next: agriculture, deforestation and mining activities that leads farmers to clear new ones (Climate Chance, 2018). As an example, Palo & Lehto (2003) mentioned that deforestation on the African continent is the fastest growing in the World, faster than in the Amazon rainforest due to the adoption of low-risk, low-yield farming and income-generation strategies. In consequence, it seems reasonable to expect the OEI1 to provide a classification where poor African and South American countries occupied the first positions, as their low OS-PPP-GDP is extremely penalized when emissions from agriculture and LULUCF are included. That is, countries with low value added-high carbon intensive products would be the ones with higher transition risks when all GHGs are taken into account.

B. Output-side Restricted Emission Intensity Indicator (OEI2)

The Output-side Restricted Emission Intensity (OEI2) an environment-linked indicator that reflects the total output-side CO2 emissions from fuel combustion and leaks needed to produce one unit of output-side real GDP.

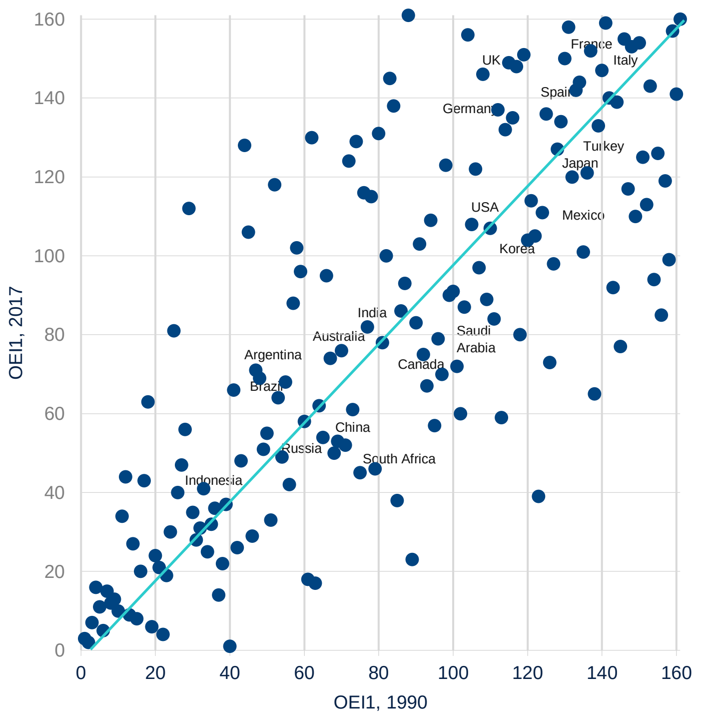
The weight of fuel combustion in the energy supply is closely related with the endowment of energy sources of the country and its development. Put another way, OEI2 is affected by three main factors: Real GDP or development of the country, structural or sectoral mix of the economy and energy efficiency or technological blooming. In such a case, least developed countries, who heavily depend on deforestation and extensive agriculture benefit from a decrease in their carbon intensities in the OEI2 ranking, with CO2-intensive newly industrialized and fossil fuel exporting countries taking the lead.

In this sense, it seems reasonable to find newly industrialized and fossil fuel exporting countries in the first positions of the ranking. Highly developed nations, with an important share of GDP originating from the tertiary sector, and least developed countries, which lay their bases on agriculture, are expected to be found on the last positions of the ranking (note that the majority of emissions from agriculture and LULUCF are non-CO2 greenhouse gas emissions).

Appendix 3: EOI1, ranking evolution over-time.

Although the annual evolution of emissions has been ignored in the core analysis of this work, it could be interesting to expand the scope in the future, as the possibility of extensively analyzing efficiency and decarbonization gains exists. This work has focused on the average emission intensity between 2009 and 2017, ignoring country by country annual evolution. However, the research conducted offers the possibility of analyzing the ranking variations over-time, in order to see which countries have improved their ranking position in the last 27 years (1990 against 2017) and which countries are relatively more carbon intensive now.

Figure 12. **OEI1, ranking position over-time. 2017 (vertical axis) and 1990 (horizontal axis)**



Source: BBVA Research.G20 countries and Spain have been highlighted.

Figure 12 above shows the OEI1 raking in 1990 (horizontal axis) and 2017 (vertical axis) for all the dataset countries. By construction, the ranking changes are a zero-sum game and hence, broad conclusions about efficiency improvements and decarbonization cannot be made. Note that the further up and to the left of the graph, the greater the raking improvements of the countries in the ranking. Put another way, all the countries located in the left-hand-side of the line have improved their position, while countries in the right-hand-side of the line are now

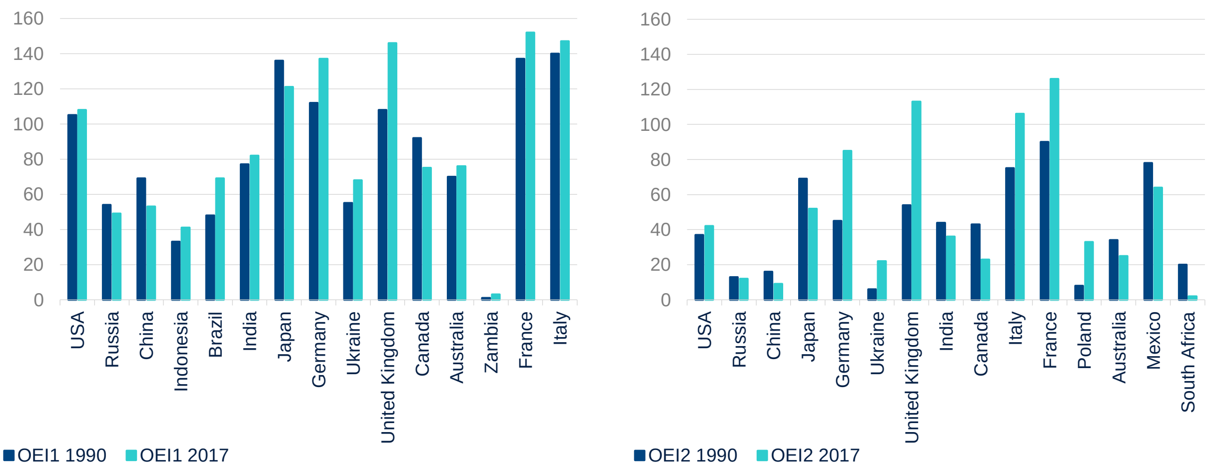
BBVA Research

relatively more carbon intensive than in 1990. Note that the main European economies, in the upper-right-hand-side of the graph, have improved their relative carbon intensity, a result that is consistent with previous findings of the research. Regarding the countries that have improved their position, but still remain relatively carbon intensive (left-hand-side of the graph, above the diagonal line) no easy pattern can be found, but the group is mainly composed of countries that have gone through PPP-GDP yearly-growths that exceed their GHG emission yearly-growth rates. However, the group is very heterogeneous (i.e. Bolivia, Liberia, Cambodia, Myanmar, Angola or Indonesia) and further research is needed in order to reach any clarifying conclusion.

On the other hand, fossil fuel exporters or countries that have based their economic growth on carbon intensive sectors are now relatively worse off than in 1990 with respect to the analyzed 161 countries (see South Africa, Canada, China, Mexico or Saudi Arabia for example). Furthermore, countries that were already relatively intensive back in 1990 and have suffered from great political instability since, also have seen their ranking deteriorated (see for example Venezuela, Chad, Congo or Iran). However, further research is needed in order to understand the key reasons behind these changes.

Finally, Figure 13below shows how the OEI1 and OEI2 rankings of the Top 15 emitters have evolved in the last 27 years. Note that in this case, the countries classified as top emitters are the ones that emitted more GHG and CO2 (energy) emissions in 1990 (in absolute terms). Again, European countries exhibit the greatest improvements in the ranking, with the USA showing a much less positive evolution and with Russia, Japan and China being relatively worse-off. No specific pattern can be detected in the figure, but is undeniable that countries with the highest emission shares have not enjoyed the greatest improvements in their carbon intensity ranking.

Figure 13. **OEI1 and OEI2, ranking position over-time. Top 15 emitters for GHG and CO2 (energy). 1990 and 2017**



Source: BBVA Research.

References

Acosta, L., Pineda J; Galotto, L; Maharjan, P and Sheng, F.(2019): Assessment of complementarities between GGGI's Green Growth Index and UNEP's Green Economy Progress Index, *GGGI Technical Report No. 10*, Green Growth Performance Measurement (GGPM) Program, Global Green Growth Institute.

Baumert, K; Herzog, T. and Pershing, J. (2005): Navigating the numbers: Greenhouse gas data and international climate policy. World Resources Institute.

Cabernard, L. and Pfister S. (2021): A highly resolved MRIO database for analyzing environmental footprints and Green Economy Progress. Science of the Total Environment, 755 (2021).

Climate Action Tracker (2020): Temperatures. Retrieved February 5, 2021, from https://climateactiontracker.org/global/temperatures/

Climate Change (2018): LULUCF emissions and the disappearance of the forests: A situation as dramatic as ever. Retrieved 24 February 2021, from https://www.climate-chance.org/wp-content/uploads/2019/02/lulucf.pdf

Climate Watch Data (2021): Historical GHG Emissions. Retrieved February, 17, 2021, from https://www.climatewatchdata.org/ghg-emissions?end_year=2017&start_year=1990

Coady, D., Parry, I., Le, N., & Shang, B. (2019): Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates. IMF Working Papers, 19(89), 1. doi: 10.5089/9781484393178.001

Davis, Steven J. and Caldeira, Ken (2010): Consumption based accounting of CO2 emissions. Proceedings of the National Academy of Sciences of the United States of America, 107(12).

Doménech, R., & Andrés, J. (2020): Cambio Climático y Crecimiento Económico. Revista de Geoeconomía.

Doménech, R. (2021): Beyond GDP: welfare and social and environmental sustainability. English summary and spanish presentation available at https://www.bbvaresearch.com/en/publicaciones/global-beyond-gdp-welfare-and-social-and-environmental-sustainability/?cid=eml:oem:oth:----47953--:::lnkpubl:::20210122::oth:instant:

Feenstra, R., & Romalis, J. (2014): International Prices and Endogenous Quality*. The Quarterly Journal of Economics, 129(2), 477-527. doi: 10.1093/qje/qju001

Feenstra, R., Inklaar, R., and Timmer, M. (2015): The Next Generation of the Penn World Table. American Economic Review, 105(10), 3150-3182. doi: 10.1257/aer.20130954

Grossman, G.M., & Krueger A.B. (1995). Economic Growth and the Environment. Quarterly Journal of Economics, 2: 353-375.

Herzog, T., Baumert, K and Pershing, J. (2006): Target: intensity. An Analysis of Greenhouse gas intensity targets. World Resources Institute.

Holtsmark, B. J. and Alfsen,K.H. (2004): The use of PPP or MER in the construction of emission scenarios is more than a question of 'metrics'. *Climate Policy*, 4(2). Working paper version available at https://pub.cicero.oslo.no/cicero-xmlui/bitstream/handle/11250/191792/CICERO_Policy_Note_2004-03.pdf?sequence=1

IEA (2020): CO2 Emissions from Fuel Combustion: Overview – Analysis. Retrieved February, 17, 2021, from https://www.iea.org/reports/co2-emissions-from-fuel-combustion-overview

Lutfalla, S., Ehrhardt, F., Rosenstock, T., Lamanna, C., and Havlík, P. et al. (2019): Matching policy and science: Rationale for the '4 per 1000 - soils for food security and climate' initiative. Soil & Tillage Research, 188, 3-15. doi: 10.1016/j.still.2017.12.002

Nordhaus, W. (2007): Alternative measures of output in global economic-environmental models: Purchasing power parity or market exchanges rates. *Energy Economics* 29 (2007).

Nordhaus, W. (2007): CO2 emissions embodied in international trade and domestic final demand: Methodology and results using OECD inter-country Input-Output database. *OECD Science, Technology and Industry Working Papers 2020/11*.

Palo, M. and Lehto, E. (2003): African deforestation: causes and scenarios. RetrievedFebruary,10, 2021, from http://www.fao.org/3/XII/0542-B1.htm

Penn World Table version 10.0. (2021): Retrieved February, 9, 2021, from https://www.rug.nl/ggdc/productivity/pwt/?lang=en

Pineda, J. (2012): Sustainability and human development: A proposal for a sustainability adjusted HDI human development index. *Theoretical and Practical Research in the Economic Fields (TPREF)*, III(6).

Purdie, E. (2019): Purchasing power parities: an essential tool in climate monitoring. ICP Blog Series. World Bank. Retrieve May, 29, 2019 from https://blogs.worldbank.org/opendata/purchasing-power-parities-essential-tool-climate-monitoring.

R. T. Watson, R. Noble, B. Bolin, and N. H. Ravindranath, et al. (2000): IPCC Special Report (Land Use, Land Use Change and Forestry). Cambridge University Press, 375.

Stavins, Robert (2019): The future of U.S. carbon-pricing policy. NBER Working Paper 25912.

Stern, D. (2004): The rise and fall of the environmental Kuznets curve. *World Development*, 32(8).

The Global Economy (2019): Country rankings: Trade - openness. Retrieved March, 2, 2021, from https://www.theglobaleconomy.com/rankings/trade_openness/

United Nations (2015a): Resolution 70/1: Transforming our World: the 2030 Agenda for Sustainable Development.

United Nations (2015b): Annual Report 2015", United Nations Environment Program (UNEP).

United Nations (2020): "The 17 goals". Sustainable Development Goals (SDG) website. Retrieved March 15, 2021, from https://sdgs.un.org/goals

World Bank (2020): CO2 emissions (kg per 2017 PPP $ of GDP) | Data. Retrieved February 7, 2021, from https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD.KD

World Bank (2020c): International Comparison Program. Retrieved March, 17, 2021, from https://www.worldbank.org/en/programs/icp.

Yamano, N. and Guilhoto J. (2020): CO2 emissions embodied in international trade and domestic final demand: Methodology and results using OECD inter-country Input-Output database. *OECD Science, Technology and Industry Working Papers 2020/11*.

Working Papers

2021

21/02 **Joxe Mari Barrutiabengoa, J. Julián Cubero and Rodolfo Méndez-Marcano:** Output-side GHG Emission Intensity: A consistent international indicator.

21/01 **Ángel de la Fuente y Pep Ruiz:** Series largas de VAB y empleo regional por sectores, 1955-2019 Actualización de *RegData-Sect* hasta 2019.

2020

20/17 **Amparo Castelló-Climent and R. Doménech:** Human Capital and Income Inequality Revisited.

20/16 **J.E. Boscá, R. Doménech, J. Ferri, J.R. García and C. Ulloa:** The Stabilizing Effects of Economic Policies in Spain in Times of COVID-19.

20/15 **Ángel de la Fuente:** La evolución de la financiación de las comunidades autónomas de régimen común, 2002-2018.

20/14 **Ángel de la Fuente:** El impacto de la crisis del Covid sobre el PIB de las CCAA en 2020: una primera aproximación.

20/13 **Ali B. Barlas, Seda Guler Mert, Álvaro Ortiz and Tomasa Rodrigo:** Investment in Real Time and High Definition: A Big Data Approach.

20/12 **Félix Lores, Pep Ruiz, Angie Suárez y Alfonso Ugarte:** Modelo de precios de la vivienda en España. Una perspectiva regional.

20/11 **Ángel de la Fuente:** Series largas de algunos agregados económicos y demográficos regionales: Actualización de RegData hasta 2019.

20/10 **Ángel de la Fuente:** La liquidación de 2018 del sistema de financiación de las comunidades autónomas de régimen común.

20/09 **Lucía Pacheco Rodríguez and Pablo Urbiola Ortún:** From FinTech to BigTech: an evolving regulatory response.

20/08 **Federico D. Forte:** Network Topology of the Argentine Interbank Money Market.

20/07 **Ángel de la Fuente:** Las finanzas autonómicas en 2019 y entre 2003 y 2019.

20/06 **Vasco M. Carvalho, Juan R. Garcia, Stephen Hansen, Álvaro Ortiz, Tomasa Rodrigo, José V. Rodríguez Mora and Pep Ruiz:** Tracking the COVID-19 Crisis with High-Resolution Transaction Data.

20/05 **Jinyue Dong and Le Xia:** Forecasting modeling for China's inflation.

20/04 **Le Xia:** Lessons from China's past banking bailouts.

20/03 **Ángel de la Fuente y Pep Ruiz:** Series largas de VAB y empleo regional por sectores, 1955-2018. RegData_Sect FEDEA-BBVA (v5.0_1955-2018).

Creating Opportunities

20/02 **Luis Antonio Espinosa y Juan José Li Ng:**

ESP/ El riesgo del sargazo para la economía y turismo de Quintana Roo y México.

ING / The risk of sargassum to the economy and tourism of Quintana Roo and Mexico.

20/01 **Ángel de la Fuente:** La dinámica territorial de la renta en España, 1955-2018. Los determinantes directos de la renta relativa: productividad, ocupación y demografía.

CLICK HERE TO ACCESS THE WORKING DOCUMENTS PUBLISHED IN

Spanish and English

ENQUIRIES TO:
BBVA Research: Azul Street. 4. La Vela Building – 4th and 5th floor. 28050 Madrid (Spain).
Tel.:+34 91 374 60 00 y +34 91 537 70 00 / Fax:+34 91 374 30 25
bbvaresearch@bbva.com www.bbvaresearch.com