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Are we measuring natural resource wealth correctly?

A reconceptualization of natural resource value in the era of climate change

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Abstract: Underlying the management of revenues from natural resource extraction is a set of assumptions about how abundant and how valuable these resources are. Nevertheless, existing approaches to measuring the value of extractive resources are seriously flawed. This paper proposes two avenues for improving them. It explains how a multidimensional approach to measuring resource wealth can be used to identify the policy challenges that a country might face as it sets out its strategy for managing extractive revenues. It also provides a rethinking of the valuation of extractive wealth by integrating environmental considerations. Extractive activities can at times incur a great loss of (renewable) opportunity income, either directly or indirectly, because of their environmental impact. By analysing a range of examples from across the globe, this paper extracts key lessons on the true value of extractives and why it matters for policy makers, civil society, and international donors today.

Key words: natural resource, valuation of extractive wealth, environmental impact, extractive activities

JEL classification: O13, Q2, Q3, Q5

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1 Introduction

> It is impossible to escape the impression that people commonly use false standards of measurement.—Sigmund Freud, *Civilization and Its Discontents* (1930)

The economic decline of Nauru, a small island-country located in the Central Pacific, can be considered as a development economics horror story.[1] Nauru possessed the highest gross domestic product (GDP) per capita in the world in the 1970s due to the rents generated by the extraction of its rich phosphate deposits (Trumbull 1982).[2] Nevertheless, a few decades later, the country was on the brink of economic collapse, as a result of the exhaustion of its phosphate deposits but also because phosphate extraction activities had eroded the island's arable land and effectively destroyed the country's agricultural potential.[3] In this context, what was the *true* value of Nauru's natural resource wealth? Can we argue that Nauru's phosphate reserves had a negative value in the long term considering its considerable opportunity costs? Should we discount the lost agricultural and environmental value from extractive rents? Why does this matter to policy makers today?

Existing approaches to measuring extractives wealth have been historically flawed and relatively narrow. The limitations of existing measurements are worth discussing because resource wealth measurements can influence decisions to extract natural resources as well as the way in which resource revenues are mobilized to foster economic development. Understanding the complexity of conceptualizing and measuring natural resource wealth, therefore, is of central importance to development policy, especially in the age of climate change. The prices of West Texas Intermediate crude oil hitting negative values for the first time in history in April 2020 is yet another evidence that a world in which extractive wealth has a negative value is not unthinkable. Therefore, rethinking the measurements of extractive wealth is timely.

This paper discusses two ways forward to improve resource measurements. The first one is to adopt a multidimensional approach to resource measurements, as reflected by the recent development of multidimensional indices of resource wealth and dependence (see Hailu and Kipgen 2017; ICMM 2020; Lebdioui 2019). Existing measurements have mostly relied on resource measurements in isolation to one another, which is problematic because there is no objective all-encompassing single measurement for resource abundance. The combination of several indicators of resource wealth (such as resource production, exports, rents, and government revenues) can offer useful insights that single indicators cannot grasp on their own (Lebdioui 2019).

The second way forward is the integration of environmental considerations in resource measurements. Extractive deposits can be commercially viable but may incur a far greater income loss (and therefore a greater long-run socio-economic cost) because of the carbon footprint of extractive activities. By analysing a range of examples, from Algeria to Bolivia and Ecuador, this paper extracts key lessons that can be learnt on the dilemmas that policy makers face when deciding to extract commodities, and their implications for assessing the worth of extractive wealth.

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[1] Thanks to Reda Cherif and Fuad Hasanov for bringing my attention to the case of Nauru.

[2] In the 1970s and early 1980s, the government of Nauru's annual income from the sale of phosphate used to represent more than USD 27,000 per capita (Trumbull 1982).

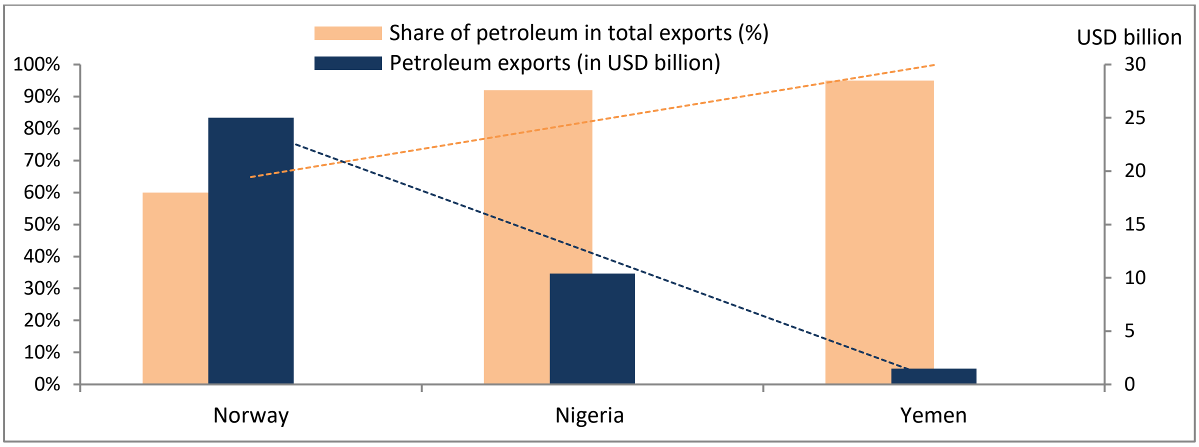
[3] In the early 2000s, a controversial Australian refugee processing centre had to be established on the island to avoid bankruptcy.

This paper is structured as follows. In Section 2, the flaws of existing approaches to conceptualizing and measuring resource wealth are identified. This section also discusses the implications of different measurements for policy making and economic theory. Section 3 proposes ways to improve resource measurements in the context of the multidimensionality of resource wealth and in the context of climate change. Also, a decision tree is proposed to help policy makers, academics, and civil society make more informed decisions about the value of resource extraction. Section 4 lays out the concluding remarks of this paper and identifies areas where further research is needed.

2 Existing measurements and their limitations

Extractive wealth, which includes both mining and fossil fuel resources, has been historically measured in many ways, which have great implications for policy making and economic theory.[4] For instance, much of the resource curse theory relies on the negative correlation between natural resource wealth and economic growth and development found in influential studies (such as Sachs and Warner 1997). Nevertheless, such studies have relied on measurements of the share of resource output/exports out of total output/exports, which is misleading because it reflects resource dependence rather than resource abundance. There are important implications of choosing indicators of resource dependence over resource abundance. For instance, the investigation on the impact of oil wealth on democracy in Ross (2001) also uses indicators of oil reliance rather than oil abundance, and finds that Nigeria ranks 4th and precedes Yemen (ranked 7th) and Norway (ranked 16th) in terms of oil reliance in 1995. However, the relative position of these three countries is almost reversed by using an indicator of oil abundance in absolute terms (such as oil exports in US dollars) rather than oil reliance (see Figure 1). Norway's oil exports were in fact 17 times higher than Yemen's in 1995, despite Yemen featuring higher levels of oil dependence than Norway.

Figure 1: Oil reliance and abundance in selected countries in 1995



Source: author's elaboration based on UN Comtrade (2020) data.

Such divergence raises important questions on how the impact of natural resources on various indicators of development (such as growth or democracy) has been estimated in the scientific literature to date. Several studies (such as Brunnschweiler and Bulte 2008; Di John 2011; Gelb

[4] Extractive wealth has often been distinguished from other types of natural resources because of the specific political and economic circumstances associated with it and the fact that it is non-renewable.

2010) have pointed out the endogeneity between resource dependence and growth, which suggests that the poor economic performance in many least developed countries is more likely to be due to resource dependence than abundance. This explains why studies that focus on resource abundance tend to find a positive relationship with economic growth, and those focusing on resource dependence tend to find a negative relationship (Gelb 2010).

What is more, the conflation between resource dependence and resource abundance leads to a misclassification as 'resource-wealthy' countries that are in fact resource-poor but export little else than the few commodities they have (e.g., Chad and Mali) (Gylfason 2011), but also a misclassification of diversified resource-rich countries as 'resource-poor'.[5]

There are further concerns that arise when defining and measuring resource dependence. Should we distinguish mono-resource exporters from multi-resource exporters? In other words, should we consider countries that depend on several types of natural resources [such as the Democratic Republic of the Congo (DRC) or South Africa, for instance] to be as resource-dependent as mono-resource exporters (Algeria or Angola) only on the basis of the total share of natural resources in their revenues/export basket? In such a scenario, if the prices of the different natural resources that a country is endowed with are uncorrelated, one could regard such a country to be less dependent than a mono-resource exporting country as the former is likely to experience less commodity price fluctuation-induced macroeconomic vulnerability than the latter.

Given the complexity of measuring resource dependence, and its endogeneity with developmental outcomes, should we instead use indicators of resource exports in absolute terms as an indicator of resource wealth? Resource exports by country is also an imperfect indicator of resource wealth for at least three reasons.

First, such a variable does not distinguish countries that are genuine resource exporters from countries that are resource-poor but re-export commodities (after some basic degrees of processing or after they have been illegally smuggled into the country). For instance, resource-poor countries such as Germany, Switzerland, Hong Kong, or Singapore often rank among the top resource exporters in the world.

Second, resource exports do not necessarily accurately represent the true value of resource wealth because of the variations in the cost of production of natural resources. The cost of production can vary across geographies even for the same commodity. For instance, the total costs for producing an oil barrel in recent years has been about USD 9 in Iran and Saudi Arabia, in comparison to USD 44 in the United Kingdom, USD 29 in Nigeria, and USD 28 in Venezuela (*Wall Street Journal* 2016). Could we therefore legitimately consider that such countries are equally resource-rich if the value of their oil exports is comparable? Such considerations also mean that if commodity prices go below the value of the commodity production costs in a given country, and this gap persists, then this country's resource wealth has in effect become a stranded asset (and should therefore be valued differently). Naturally, the costs of production of a given commodity are not static over time and depend on technological progress. Nevertheless, the way in which we value a country's resource wealth over time should reflect such considerations, which is further discussed in Section 3.2 of this paper.

[5] Several now-industrialized resource-rich countries, such as the United States, Canada, the Netherlands, and Malaysia, began as resource-based economies but have managed to add value to their natural resources and diversify their economy. Despite being resource-rich, such countries do not qualify as 'resource-dependent' any more (Lebdioui 2019).

Third, the fact that two countries are producing or exporting the same volume of minerals does not mean that they are equally resource-rich, as their resulting wealth will depend on the cost of extraction but also on how many people will share the benefits of such wealth (Lahn and Stevens 2018). It makes little sense to consider that a country such as Nigeria is more resource-rich than Norway based on the national value of resource rents generated in a given year, because such rents have to be shared between 190 million people in Nigeria and only 5 million in Norway. By adjusting resource rents to population size, Norway's resource rents per capita in 2016 are 40 times higher than Nigeria's. From that perspective, Lederman and Maloney (2007) measured resource abundance by using *net resource exports per capita* and concluded that Norway, New Zealand, Canada, Finland, and Australia ranked as the most resource-intensive economies rather than economies such as the DRC and Papua New Guinea in the study by Sachs and Warner (1995). This measurement appears to be a much better reflection of resource abundance than the share of natural resources in GDP/exports. Nevertheless, it remains imperfect for the first two reasons discussed.

Resource abundance can be measured in terms of exports as well as in terms of the value of production (see Leamer 1984; Moroney 1975), the size of resource revenues (see IMF 2012; Matsen and Torvik 2005), or the size of resource rents (see Cammett et al. 2015; Chang and Lebdioui 2020; Collier and Hoeffler 2009; Chauvet and Collier 2008; IMF 2012). It can be argued that resource rents, which are defined as unit price minus the cost of production times the quantity produced (World Bank 2019), are a more accurate indicator of resource wealth available given that such measurement considers the difference between the value of commodity production at world prices and total costs of production.[6] Nevertheless, it can be argued that resource rents remain poor indicators of resource wealth because they fail to include the potential loss of opportunity income through extraction, as further discussed in Section 3.2.

Other studies have measured resource abundance by using indicators of physical resource endowment, by comparing resource reserves or deposits per square kilometre across regions (see Collier 2011; Arezki et al. 2016; World Bank 2010). The World Bank has also developed a measure of natural capital that includes estimates for subsoil assets. Using this measure, Brunnschweiler and Bulte (2008) find that the most resource-rich countries are Australia, Canada, New Zealand, and Norway. Despite its usefulness, resource reserves data face important limitations.

First, the data availability on extractives reserves by country is related to a country's technological level. Relying on this indicator alone could give uneven weighting to the resource wealth of more advanced economies where far more geological explorations have been conducted. Several studies have highlighted that there has been far less geological exploration in Sub-Saharan Africa than in the rest of the world (Collier 2011; Gelb et al. 2012), which is why the Wealth of Nations database (World Bank 2010) shows that the value of known subsoil assets per square kilometre of Sub-Saharan Africa is barely one-fourth of that for high-income countries.

Second, it is important to distinguish extractable from non-extractable resource reserves. In contrast to most studies within political science and economics, geologists generally do not consider endowments as the value of current production and tend to focus on geological abundance as well as quality, and technical considerations such as extractability of metal from ore (Davis 2010). The United Nations even has its own definitions that distinguish resource deposits

[6] Gelb et al. (2012) raise the interesting question of how much it costs to find new reserves relative to the value of discoveries and bring together estimates of the value of imputed discovery and of the cost of exploration, which has implications for how natural resource wealth and discoveries should be valued. The World Bank's resource rents data impute the cost of exploration.

on extractability grounds: reserves are more certain geologically and more likely to be economic to extract, whereas resources are less geologically certain and may never be economically extracted.

While many indicators have been used to measure resource abundance, both absolute terms and relative terms (as share of GDP or total exports, for instance), there are great implications of relying on one measurement over another. Table 1 ranks the top 12 countries across six indicators of both resource abundance and dependence. Only three countries (namely, Brunei, Kuwait, and Saudi Arabia) feature in the top 12 ranking for each of the six indicators. This shows that using different indicators may have great influence on study results.

Table 1: Country rankings across various indicators of extractive abundance and dependence

	Extractive exports	Extractive exports	Extractive reserves	Extractive rents	Extractive revenues	Extractive revenues
Ranking/ Units	*USD per capita*	*%*	*USD per capita*	*USD per capita*	*USD per capita*	*%*
1	Qatar	Angola	Venezuela	Qatar	Kuwait*	Iraq
2	Kuwait*	Venezuela	Kuwait*	Kuwait*	Brunei*	Brunei*
3	Brunei*	Algeria	Botswana	United Arab Emirates (UAE)	Qatar	Equatorial Guinea
4	Norway	Qatar	Saudi Arabia*	Saudi Arabia*	UAE	Saudi Arabia*
5	Singapore	Kuwait*	Australia	Brunei*	Libya	Kuwait*
6	UAE	Azerbaijan	Brunei*	Oman	Norway	Timor-Leste
7	Oman	Brunei*	Canada	Norway	Saudi Arabia*	Angola
8	Saudi Arabia*	Botswana	South Africa	Equatorial Guinea	Oman	Republic of Congo
9	Australia	Nigeria	Iran	Australia	Bahrain	Azerbaijan
10	Canada	Kazakhstan	UAE	Iraq	Equatorial Guinea	UAE
11	Kazakhstan	Saudi Arabia*	Guyana	Trinidad and Tobago	Trinidad and Tobago	Nigeria
12	Botswana	Zambia	Norway	Libya	Iraq	Yemen

Source: author's compilation based on the MINDEX dataset.

3 Ways forward

This paper suggests some conceptual and practical ways to improve future measurements of extractives wealth. The first issue discussed in this paper concerns the multidimensionality of resource measurements. The second issue relates to the valuation of extractive resources in light of the environmental impact and opportunity costs associated with their extraction.

3.1 Towards a multidimensional approach to extractives measurements

Existing resource measurements have mostly relied on indicators in isolation to one another, which is problematic because there is no objective all-encompassing single measurement for resource abundance. The combination of several indicators of resource wealth (such as resource production, exports, rents, and revenues) can offer useful insights that single indicators cannot grasp on their own. There have been recently emerging efforts to capture the multidimensionality of resource wealth. For instance, the Mining Contribution Index (MCI), developed by the

International Council on Mining and Metals (ICMM 2020), synthesized into a single number as the share of the mining sector's contribution to exports and GDP. The Extractive Dependence Index, developed in Hailu and Kipgen (2017) includes indicators of natural resources as a share of export earnings, share of fiscal revenues, and share of GDP. Such methods represent laudable efforts to capture the several dimensions of resource dependence. Another recent indicator, the Multidimensional Indicator for Extractives-based Development (MINDEX), initially developed in Lebdioui (2019),[7] takes one step further by (i) including variables of resource abundance in absolute terms (rather than in relative terms alone); (ii) including all types of extractive resources (rather than mining alone as in the MCI, although the type of commodity can be further isolated); and (iii) visualizing the data into radar charts in order to avoid the synthetization into single numbers, which may shadow important variation in the distribution of value across different variables. As a result, the MINDEX may be the most comprehensive effort so far to capture the multidimensionality of resource abundance and dependence.

The MINDEX consists in weighting six different indicators of resource abundance and resource dependence on a scale of 0 to 1. These indicators represent different dimensions of extractive activities. Some indicators (such as government extractives revenues) relate to the fiscal linkages arising out of commodities, while others relate to resource availability (and exhaustibility), resource exports, and resource rents (to account for the costs of production). The six indicators reflect the different steps of the resource revenue management policy chain to translate extracted commodities into developmental assets. Such steps are common across various policy frameworks of natural resource management (such as Chang 2017; Collier and Laroche 2015; Henstridge and Roe 2018; NRGI 2014; and the Extractive Industries Transparency Initiative framework: EITI 2019), according to which the conversion of extractive resources into developmental outcomes follows a sequence of steps, which includes the discovery of natural resources, their production, the appropriation of extractives revenues, and the investment of such revenues for developmental purposes.

Therefore, the MINDEX can serve as a diagnostic tool to assess the performance of a given country across the series of steps of the resource management policy chain (whether it is limited production compared with proven reserves, poor appropriation of revenues, or an insufficiently diversified economy reflecting the poor investments of resource revenues for structural transformation). Table 2 illustrates how the MINDEX can help identify the policy challenges that a given country might face at a given time by categorizing countries into seven case scenarios.

I will not dwell here on explaining the methodology choices (such as the MINDEX's scoring system and benchmarks used for each indicator, as well as data sources and comparability concerns) behind the MINDEX, which are explained in Lebdioui (2019).[8] Instead, I will focus on the main findings from the initial application of the MINDEX that it is possible to match each country with at least one of the seven case scenarios identified in Table 2, which confirms the notion that extractive resource wealth and dependence are multifaceted. For instance, the MINDEX of countries such as Algeria and Ecuador corresponds to Case 1, Malaysia features a Case 6, Singapore features a Case 7, while Chad and Nigeria feature a Case 5 (see Figure 2).

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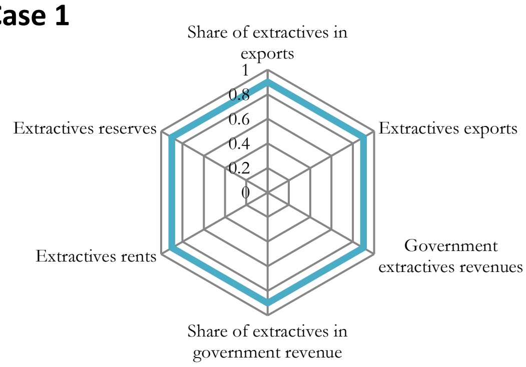
[7] The MINDEX dataset, although mainly based on Lebdioui (2019), has been extended and updated since the time of writing this paper.

[8] The value of extractives exports, rents, reserves, and revenues are all expressed in US dollars and in per capita terms. Per capita measurements are a better reflection of resource abundance than national ones, as discussed earlier in Section 2.

Table 2: Seven case scenarios and ‘shapes’ of resource endowment

Case scenario	Description and interpretations

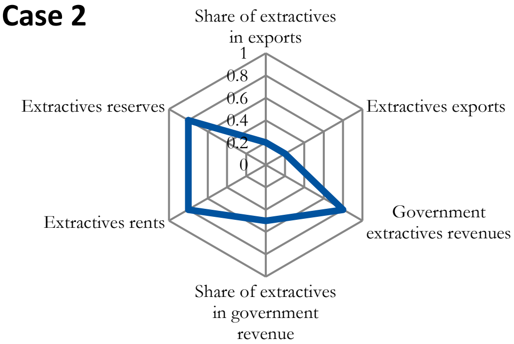
Case 1



All six indicators are high.

The country is both resource-abundant and resource-dependent.

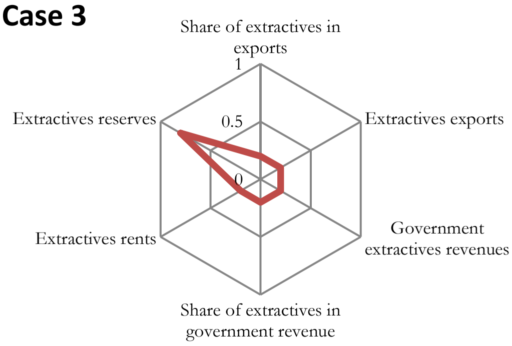
Case 2



Resource production is high but exports are low.

High domestic consumption of that mineral as a finished product (consumption of oil for electricity generation in Saudi Arabia) or as inputs for value-added activities (e.g., oil used for petrochemical production in the United States) or illegal smuggling of commodities.

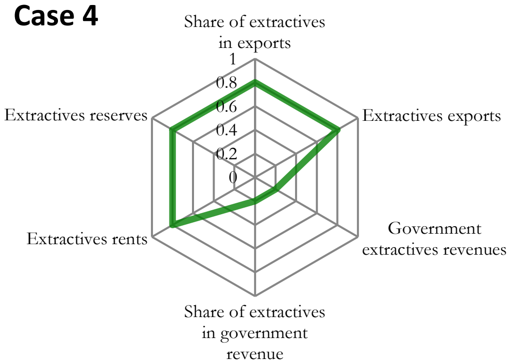
Case 3



Resource reserves are high but production/rents are low.

Issue of investment attractiveness in resource activities (due to a poor business climate); limited domestic infrastructure and capabilities to extract minerals; political issues such as an embargo (as in oil-rich Iran and manganese-rich Cuba); or local conflict (e.g., Libya) restraining resource production and exports.

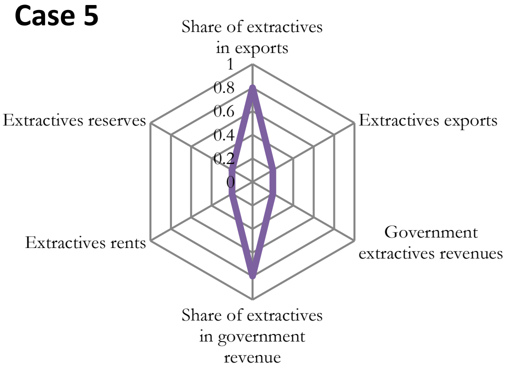
Case 4



High levels of resource production (or resource rents) but low government revenues from resource exploitation.

The country faces issues of appropriation of resource revenues and possible insufficient taxation on mineral production/exports.

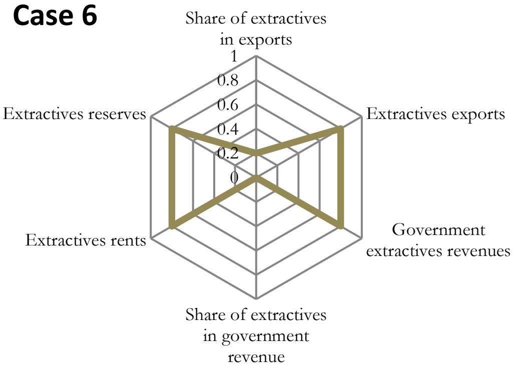
Case 5



Resource production, exports, and reserves are low but the share of minerals in total exports and government revenues are high (vertical stretch).

The country is resource-poor but is highly resource-dependent.

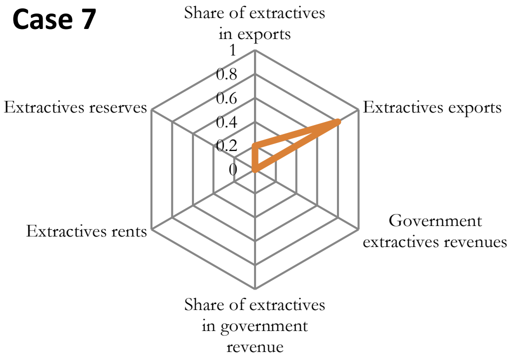
Case 6



In contrast to Case 4, mineral production, exports, and reserves are high but the share of minerals in total exports and government revenues are low (horizontal stretch).

The country is resource-rich but has a diversified economy.

Case 7



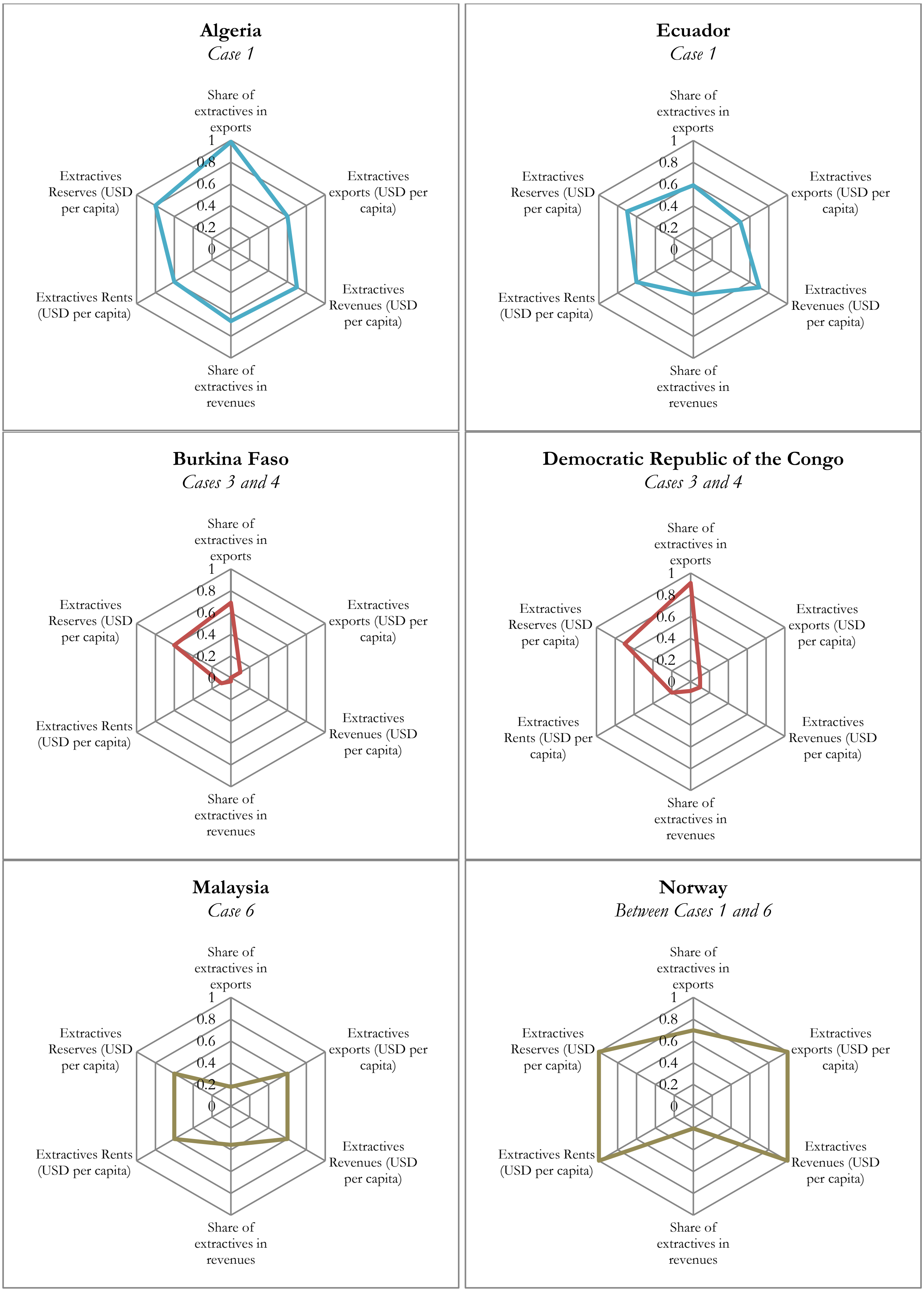
The 'Swiss paradox': Extractives exports are high, but mineral rents and reserves are low.

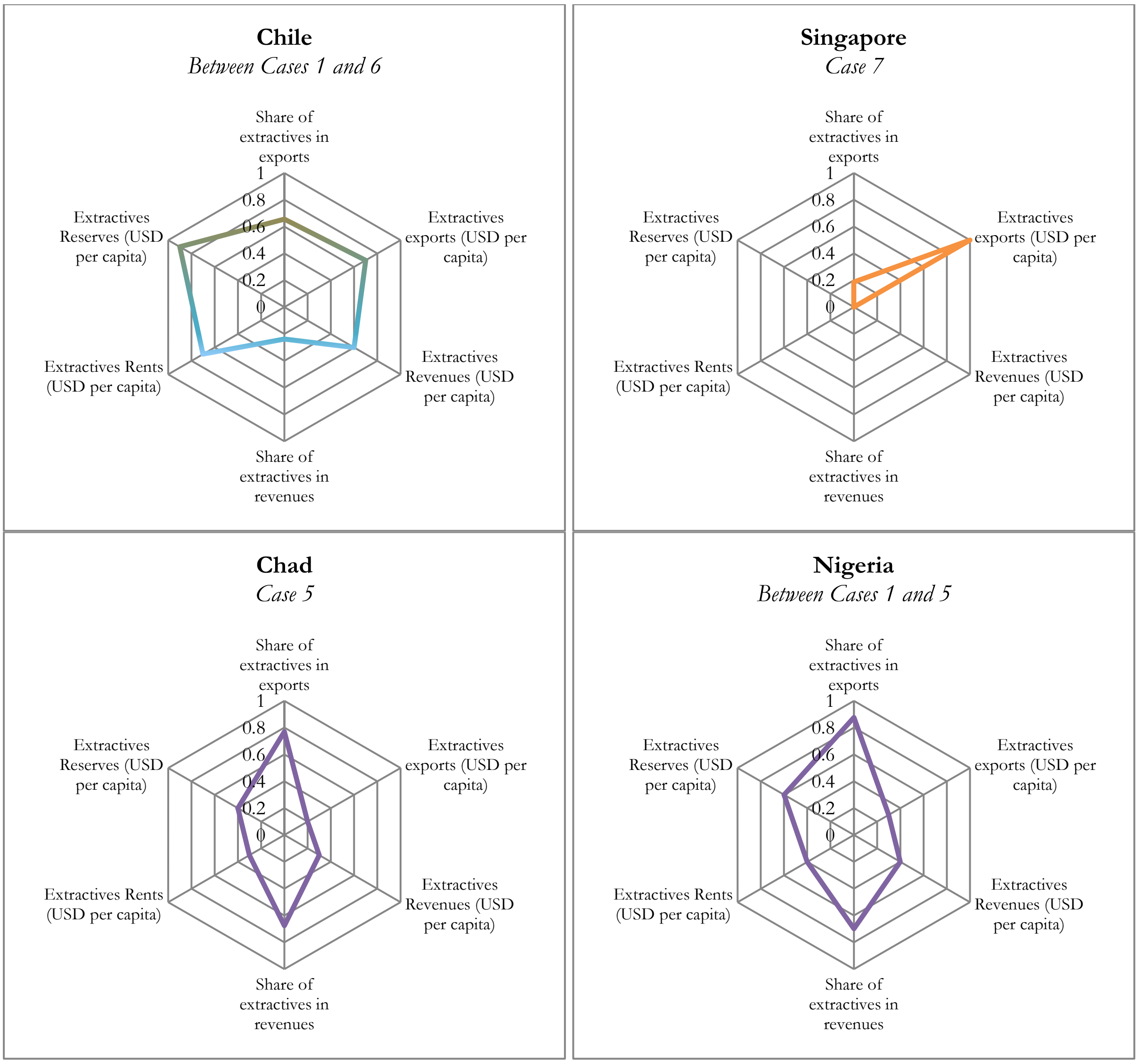
The country is resource-poor but is a re-exporter of commodities after some processing (India and Israel with diamonds; Switzerland and UAE with gold; Singapore with fuel); or after the illegal smuggling of commodities into the country (e.g., Republic of Congo or Liberia with diamonds smuggled from DRC and Sierra Leone, respectively).

Source: author's compilation based on the MINDEX (see Lebdioui 2019).

It is also interesting to note that some of the cases are hybrids, either because they simultaneously feature several case scenarios (e.g., DRC) or because they are in the transition between two cases (e.g., United Arab Emirates, UAE). For instance, the MINDEX for both the DRC and Burkina Faso corresponds to a hybrid between Cases 3 and 4, due to the small size of government resource revenues and resource exports despite the country's reliance on mining exports and the availability of resource deposits. Such a result reveals a lack of capabilities to extract minerals (due to a lack of investments or the presence of conflicts) but also potentially the illegal smuggling of commodities, which would explain why so little government revenues, exports and rents have been recorded in these two countries. Such assessment is confirmed by existing accounts [see EITI (2016) on illegal commodity smuggling in Burkina Faso; see Di John (2010), on the insufficient mining taxation in DRC].

Figure 2: Application of the MINDEX to selected countries (year 2010)





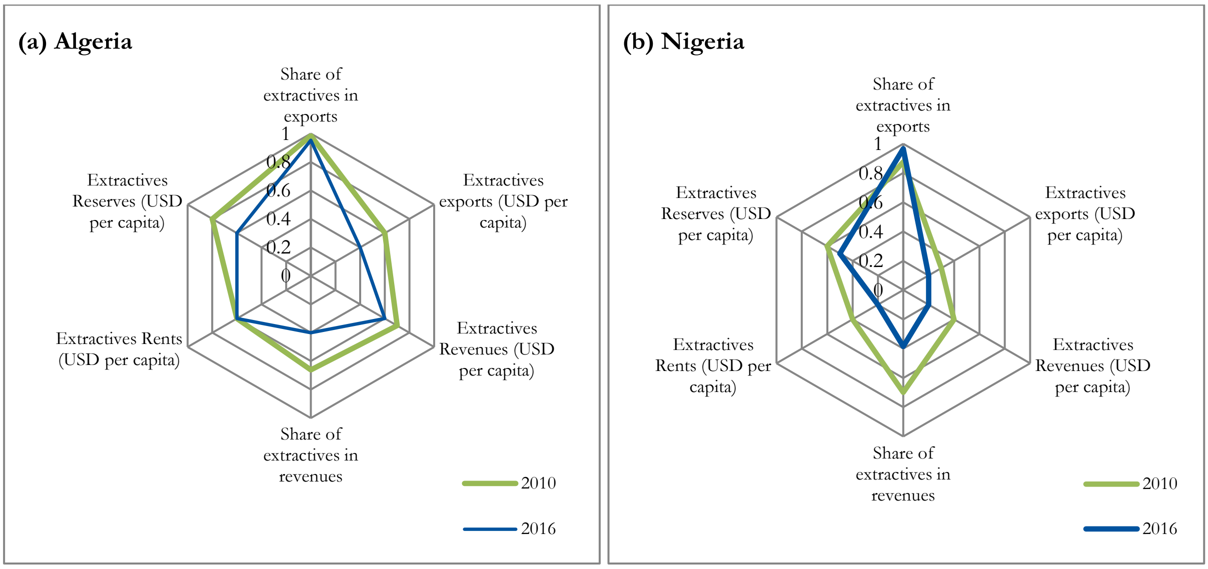
Source: author's compilation based on the MINDEX dataset.

There are further policy implications that stem from a country's MINDEX, particularly in relation to revenue mobilization and diversification strategies. In countries that fit into Case 5 (such as Chad), which are resource-dependent but resource-poor (identifiable by a vertically stretched shape of the MINDEX), the urgency to diversify *away* from extractives is very high, which stands in contrast to countries that fit into Case 1 (both resource-rich and resource-dependent), where the need for diversification is also high, but where diversification *around*—rather than *away* from—extractive activities remains a potentially attractive policy option. Indeed, the degree of urgency—and the direction—of diversification varies not only on a country's degree of resource dependence but also on its degree of resource endowment (Chang and Lebdioui 2020). The desirability of building linkages around a commodity by investing in upstream and downstream industries is subject to resource exhaustibility concerns. If countries run out of oil or copper, they might need to start to import it to keep operating related industries, which may lead to a decline in competitiveness (Chang and Lebdioui 2020).

In contrast to the two above-mentioned cases, for countries in Cases 3 or 4, the key priority is not necessarily diversification as much as it is the development and growth of the extractive sector. These cases hint at possible issues of investment attractiveness in resource activities (due to a poor business climate) or limited domestic infrastructure and capabilities to extract minerals. In those situations, because of the potential for revenue accumulation and jobs creation through extractive activities (assuming the viability of resource extraction and minimal social and environmental externalities, as further discussed in Section 3.2), it can be argued that extractives-based development should precede (or at least go alongside) diversification. Therefore, the shape of a country's MINDEX can have important diversification policy implications.

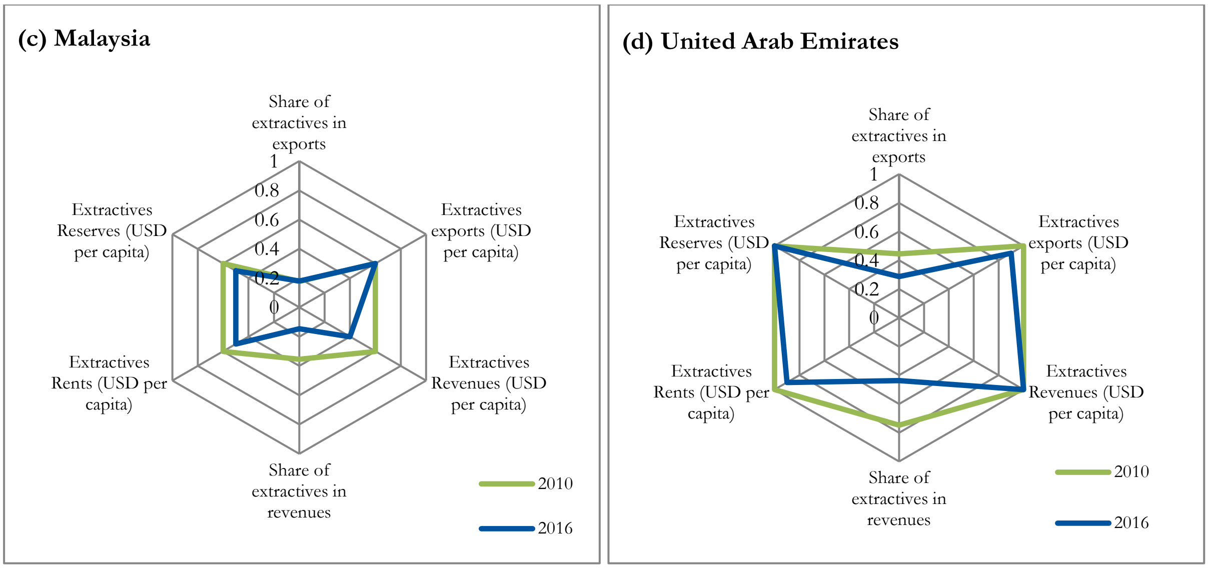
A longitudinal analysis using the MINDEX can further shed light on the degree of a country's vulnerability to commodity price fluctuations, and the extent to which it has been able to diversity its economy.[9] Figure 3 compares the shape of the MINDEX for different countries between 2010 (a year of high commodity prices) and 2016 (marked by low commodity prices). Interestingly, there is a divergence in the evolution of the 'shape of resource abundance' over time in Algeria and Nigeria on the one hand, and in Malaysia and the UAE on the other hand. In 2016, Algeria's and Nigeria's MINDEX shifted towards Case 4 (dependency), which reflects their vulnerability to commodity price fluctuations, whereas countries such as Malaysia and the UAE (as well as Norway and Chile) have relatively managed to buffer their reliance on extractives for exports and revenues when commodity prices dropped. Therefore, the MINDEX could be useful in providing a comprehensive picture of the types of structural vulnerabilities that countries may be exposed to in times of commodity price bust, and can complement existing methods that have such objective, such as breakeven prices, which face limits in terms of accurately reflecting the economic constraints facing extractive exporters (Clayton and Levi 2015).[10]

Figure 3: Evolution of the MINDEX over time in selected countries



[9] The MINDEX can also be used to evaluate the impact of policies on the level of government appropriation of mining revenues, as evidenced in the case of DRC between 2010 and 2014 (Lebdioui 2019).

[10] Breakeven prices are the minimum commodity prices that a commodity-exporting country needs for its government to meet its immediate spending needs and balance its budget.



Source: author's compilation based on the MINDEX dataset.

3.2 Integrating environmental considerations in extractives wealth measurements

Besides the multidimensionality of resource wealth, other steps forward can be identified for further improving resource wealth measurements. In the context of the climate crisis, the environmental cost of the exploitation of extractives requires particular attention. In some instances, extractive activities can harm the environment and disrupt social and economic structures within a community, instead of capturing the many benefits that can flow from the sector. There has been growing attention on how to regulate extractive activities to minimize their negative environmental impacts through environmental and social management plans, including the recent guidance note by the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development on how to improve 'legal frameworks for environmental and social impact assessment and management' (IGF 2020). This paper goes one step further by arguing that environmental considerations not only reduce the net benefits of extractive activities but also have critical implications for the valuation of the extractive resource itself.

Environmental assets can generate direct benefits to humankind in the form of new genetic material for drugs, agriculture, and increasingly ecotourism (Pearce and Pearce 2001; Swanson 1996). Their possible destruction through the extraction of resources in the ground is essentially irreversible, and valuation elements have often been left out in extraction decision-making processes.

The logic of valuation has been increasingly discussed in the literature in the context of biodiversity.[11] Nevertheless, similar discussion or valuation efforts have rarely taken place in the context of extractive industries (to the best of my knowledge). Therefore, this section discusses various avenues for improving how we value extractive wealth given their environmental externalities, such as discounting the cost of greenhouse gas (GHG) emissions and the

[11] For instance, see May et al. (2013) for a review of debates on assessing the value of the Amazon rainforest. May et al. (2013) also distinguish protection values from opportunity values and raise the issue of which parts of the Amazon forest have particularly high protection value and the extent to which some parts of the forest area should rather be used for alternative activities such as agriculture. A similar approach is taken in section 'Opportunity costs of extractive activities' (in Section 3.2) of this paper.

internalization of the broader opportunity costs of extraction. This section also extracts key lessons that can be learnt from cases across the globe.

Discounting the value of GHG emissions: strengths and limitations

Discounting the value of extractive resource extraction/production/exports for GHG emissions represents a promising area for improving natural resource measurements. It can be argued that existing extractive data resembles GDP or Human Development Index data in the sense that it may be a misleading indicator of progress and wealth in the context of the ecological crisis. The limitations of extractive wealth measurements lie in their focus on financial returns while ignoring the environmental costs of extraction. Recent work, such as the Sustainable Development Index, developed in Hickel (2020), has attempted to improve human development indices by including ecological impact indicators.[12] In order to further acknowledge the importance of ecological efficiency in delivering human development, it is timely that similar approaches are applied to the context of extractive wealth measurement.

Nevertheless, simply discounting the value of extractive wealth for GHG emissions may not be sufficient for several reasons. First, the entire lifecycle of emissions needs to be considered. Discounting an activity's carbon footprint is often limited to Scope 1 or Scope 2 emissions, while often neglecting Scope 3 emissions.[13] For instance, in the case of lithium extraction, one may be tempted to discount the value of lithium reserves based on the GHG emitted during extraction. Nevertheless, the entire lifecycle of emissions of lithium exploitation is arguably much lower if we consider that the GHG emitted during lithium extraction might be offset by the use of lithium-ion batteries for powering electric vehicles as an alternative to combustion engines usage. As a result, lithium extraction might have a positive impact on reducing GHG emissions in the long run.

Second, the possible cost of extraction of non-renewable resources reaches beyond the domain of carbon footprint. In a sense, discounting the carbon footprint from the value of extractive wealth may not give justice to the (tangible) loss of opportunity income that can arise from environmental extraction, because GHG emissions and environmental degradation might hinder the capacity to pursue other productive activities. The destruction of soils and waters might cause more economic damage to agriculture than more carbon emissions, at least in the short run. The next section reviews some of the opportunity costs that can be associated with extractive activities.

Third, quantifying the value of biodiversity is no easy task because the benefits of environmental protection are often intangible. This aspect is further discussed in the penultimate section in Section 3.2.

[12] Hickel (2020) defines ecological impact as the carbon dioxide emissions and material footprint, both calculated in per capita consumption-based terms and rendered vis-à-vis planetary boundaries.

[13] Greenhouse gas emissions are categorized into three 'scopes' by the Greenhouse Gas (GHG) Protocol. Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain (Carbontrust 2020).

Opportunity costs of extractive activities

This paper started by recalling the case of Nauru, where the exploitation of (non-renewable) extractive resources led to a considerable loss of agricultural income (which is renewable). The case of Nauru is (unfortunately) not unique since many countries today face similar dilemmas.

Bolivia's Salar de Uyuni salt flat alone holds an estimated 17 per cent of lithium globally, which makes it the largest source of lithium in the world. Nevertheless, its extraction will bring a trade off with the environment, with potentially high opportunity costs. Due to the arid nature of the climate, the Salar de Uyuni basin has a sensitive ecosystem that is heavily dependent on water resources, which is necessary to sustain the livelihoods of local populations. Aguilar-Fernandez (2009) notes that water consumption for lithium extraction and crop irrigation cannot simultaneously take place. Lithium mining and quinoa crop are therefore mutually exclusive, generating different gains to the economy of the region (see Aguilar-Fernandez 2009). Assessing these two projects, Aguilar-Fernandez (2009) found that even after subtracting the opportunity cost of not conducting the quinoa irrigation project, the net present value of the lithium extraction project remains positive.

Nevertheless, an additional point to consider is that lithium extraction threatens not only the environment but also the associated tourism revenues. With over 50,000 visitors a year (half of which are foreigners), the Salar de Uyuni is the most visited ecotourism attraction in Bolivia (Ellingson and Seidl 2007). The Salar de Uyuni is widely recognized as a site of natural beauty and is a draw for tourism, but lithium plants could consume much of the landscape (Baxter 2020). In light of the important contribution of tourism in the Bolivian economy, and to avoid a Nauru scenario, decisions to extract lithium should be informed by an adequate discounting of the value of lithium reserves in light of the opportunity income from both agriculture and tourism, besides the existential value of a unique site with exceptional beauty.

Cost of social conflict and its (monetary) impact on extractive wealth

In 2015, the Algerian president called shale gas 'a wealth that God has given us, and that we should exploit to stimulate development while respecting environment and sanitary precautions' (El Watan 2015, 2020). However, the *true wealth* constituted by Algeria's shale gas is worth investigating. Algeria's case is particularly insightful to show that the true value of extractive wealth can be much lower than the monetary wealth of extractive reverses in light of the need to discount the loss of opportunity income as well as the cost of social conflict and public resistance.

Algeria's considerable shale gas reserves are located in the water-stressed Sahara, which threatens the water supply for local populations, as well as for agriculture areas further away from shale gas sites due to the inter-connections of water basins (Aczel 2020; Belakhdar 2019; Ouki 2019). The Algerian government has attempted several times to move ahead with the extraction of shale gas, but exploratory drilling has been met with public opposition since July 2012 in Ain Salah (Aczel 2020; Malti 2016). By 2015, the government declared a temporary suspension to hydraulic fracturing, in response to the anti-shale gas protest, which notably led to the blocking of exploratory sites (Aczel 2020; Lamri 2015).[14] The importance of understanding the ramifications of the cost of social conflict is highlighted in Franks et al. (2014), which estimates the cost of conflict to companies and identifies conflict as an important means through which environmental and social risks are translated into business costs and decision making. The authors reveal that, at

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[14] Nevertheless, the government has not abandoned the intent to pursue shale and re-introduced it as part of its new energy policy (Ouki 2019).

least for the case of the extractive industries, environmental and social risks can co-constitute each other. Such findings are well reflected in the Algerian case, where the lack of 'social acceptance' translated into disruptions at exploratory drilling sites and the expensive need for security personnel to guard them from attacks (Aczel 2020; Aissaoui 2016). Against this backdrop, perhaps the real value of Algeria's shale gas is much lower than anticipated and could potentially be negative, especially considering the uncertainty of future global demand for shale gas, the risks of stranded assets, and the eventuality of carbon taxes as discussed earlier.

The value of extractive wealth is technologically dynamic

Another important point to add is that both the environmental and monetary costs of resource extraction are not static. Following up on the above-mentioned case of Algeria, it should be mentioned that the state's (rather wise) initial decision was to halt shale gas operations until technological advancements could provide alternatives to fracking for shale gas exploitations. The value of extractive wealth is indeed technologically dynamic because the opportunity, environmental, or social cost of extraction could be alleviated through the development and use of appropriate technologies, even if such technologies do not exist yet or have not reached maturity.

This notion that the discount rate is technological dynamic is also reflected in the notion of biomining, which has been particularly discussed in the context of Chile through the application of bioleaching to copper mining (Gentina and Acevedo 2013). The push for biomining in Chile since the 1990s was the result of a combination of factors, such as the rising copper prices, the depletion of higher grade ore, increased costs associated with traditional processes, and a growing concern for the environment (Domic 2007). Several innovations have been studied and attempted, such as the use of seawater to leach copper oxide ores. For instance, the Lince Project, a collaboration between the Finnish and Chilean mining companies Outokumpu and Minera Michilla, was the first operation in the world to use seawater as the sole water source in a controlled heap leach operation (Domic 2007) Notwithstanding its potential limitations, bioleaching presents several technological, environmental, and economic advantages compared with pyrometallurgy (Gentina and Acevedo 2013; Rawlings and Johnson 2007). In particular, the reduction of the carbon footprint of extractive industries through biomining has implications for the value of extractive wealth because of

- the potential to reducing costs in the eventual application of carbon taxes;
- the potential to increase the social acceptance of mining activities, thereby reducing the cost of conflict;
- the potential for higher profit margins through a premium paid for 'greener' products in the market; and
- the possibility of retaining (or gaining) market shares in response to pressures for greening entire supply chains and sustainability standards imposed by lead firms or governments.

Technological innovations also have implications for the case of lithium extraction in Bolivia, as they hold potential to increase or reduce the net value of the country's lithium in the future. If sufficient technological progress is achieved to allow the extraction of lithium without the destruction of the environment surrounding the Salar de Uyuni, the opportunity cost of lithium extraction will arguably decrease, making the commodity far more valuable. However, if lithium-less batteries become technologically mature and disrupt the lithium-ion industry, the demand for lithium will drop, making the commodity far less valuable. In such instances, decision makers should reasonably favour the agriculture and tourism industry associated with the Salar de Uyuni.

The discussion on green extraction has also been applied to the context of fossil fuels. Islam et al. (2012) investigate how the oil and gas industry can 'go green' with new processes and technologies, thus bringing the petroleum industry closer to environmental and economic sustainability. Recently, the world's first shipment of blue ammonia was exported from Saudi Arabia to Japan, where it will be used in power stations to produce electricity without carbon emissions (Ratcliffe 2020). Saudi Aramco produced this blue ammonia by converting hydrocarbons into hydrogen and then ammonia, and by capturing the carbon dioxide by-product.

Can 'blue' petroleum or 'green' mining reverse global warming? There are reasons to remain sceptical. The key message of this paper is not that technology to green extractive supply chains will resolve the climate crisis we are facing. Perhaps 'green' or 'blue' petroleum still looks too dark after all. Instead, the main message of this section is that low-carbon innovation can dramatically affect the value of extractive resources, not only in terms of the basic cost-input analysis but also in terms of how it helps reduce the loss of opportunity income and environmental damage that can increase the cost of social acceptance. Therefore, the approaches to measuring the value of extractive wealth should consider anticipated technological changes [as illustrated in Equation (1)].

The (intangible?) value of biodiversity and the pressing need for international frameworks to compensate for environmental protection

The previous sections addressed some of the direct opportunity costs of extractive activities. Nevertheless, in many contexts, the cost of extraction is intangible and goes beyond the loss of opportunity income per se. For instance, extraction can cause destruction of the means to livelihoods (water resources, as in Ain Salah), which opens discussions about access to clean water and other resources as fundamental human rights.[15] In addition, extraction may not at times pose a direct threat to human livelihood, but rather to fauna and flora, which raises the question of how we can value the existence of a plant or an animal. Extractive activities can also endanger sites that are deemed to have infinite value to some populations because of religious or spiritual value attached to it, as illustrated by the sacred aboriginal site recently blown up by the mining company Rio Tinto in Australia (Smyth and Hume 2020). In addition, the benefits of biodiversity protection are often widely shared while the opportunity cost of environmental protection is not proportionately shared. There may not be obvious practical ways to quantify the environmental value that is threatened by extractive activities, but it is nonetheless important for this discussion to take place in the context of the value of extractive wealth.

In his pioneering work on economic valuation to improve decisions on environmental protection, Pearce (1992) distinguished between direct use value, indirect use value, option value, and existence value. Direct use value is often easily measured in monetary terms and relates to goods that have a direct economic value (e.g., arable land from which agriculture income can be generated). Indirect use value is understood in terms of the 'ecological functions' (e.g., a tropical forest might help protect watersheds, or store carbon dioxide and many species which in turn may have ecological functions) (Pearce 1992). Option value relates to the amount that individuals would be willing to pay to conserve a tropical forest for future use (e.g., salt lakes in Bolivia that attract a large number of tourists every year).[16] Existence value consists of the valuation of an environmental asset

[15] As series of declarations of the United Nations and African Union emphasize the interdependence between human rights and environmental protection (e.g. the African Charter on Human and Peoples' Rights; see ACHPR 1981), as noted in Aczel (2020). There is also a growing literature adopting a human rights-based approach to understanding the impact of extractive activities (see Azubuike and Songi 2020; Finkel and Hays 2013; Short et al. 2015).

[16] Option value is thus like an insurance premium to ensure the supply of something the availability of which would otherwise be uncertain (Pearce 1992). It could also reflect on the value of environmental assets as sources of information that can feed into research, innovation, and industrial processes (see Benyus 1997; Simpson et al. 1996;

because individuals are willing to pay for its mere existence, which is especially the case when such an asset is unique (Pearce 1992). Several studies have further investigated the existential value of different environmental assets and species [see Kontoleon and Swanson (2003) for a study of the willingness to pay off OECD citizens for the conservation of the Giant Panda, for instance].

In light of Pearce's insightful framework, it is sometimes argued that even if the protection of biodiversity does not yield direct value, it can have an indirect, existential, and option value that can be useful in attracting funding from the international community (e.g., funding for reducing emissions from deforestation and forest degradation through UN REDD and REDD+).[17] Nevertheless, while preserving the world's forests is a key part of moving towards reduced atmospheric carbon, UN REDD+ does not confront the issue of subsoil rights, which means that the owners are paid for forest protection but not the extractive resources below it (Martin and Scholz 2014). The Yasuní ITT initiative in Ecuador directly confronted the issue of leaving oil in the ground, but there are considerable coordination failures that prevent such processes from taking place systematically and effectively. The example of the Yasuní ITT initiative reveals the limitations and the lack of proper incentives for biodiversity protection in the context of extractive activities. The exploitation of oil reserves was threatening biodiversity in the Yasuní National Park, one of the most biodiverse hotspots in the Amazonian region and the world. The initial proposal by the Government of Ecuador was rather innovative as it involved keeping almost a billion barrels of petroleum underground if the international community contributed with at least half of the opportunity cost of exploiting the petroleum (Larrea and Warnars 2009). This laudable initiative also proposed the creation of an internationally administered fund with United Nations participation to invest exclusively in conservation, renewable energy, and social development (Larrea and Warnars 2009). The Yasuní ITT initiative had received significant support from international institutions, European governments, and non-governmental organizations worldwide, which unfortunately did not translate into concrete action. Despite initial support from the German government, it ended up backing out of its commitment to the Yasuní ITT Trust Fund in 2010 and placed in funding in REDD+ programmes in Ecuador instead (similarly to other European donor countries), which only protect the land above the ground, thus leaving open the possibility of oil extraction (Martin and Scholz 2014).[18] The 2008/09 financial crisis had also pressure on Ecuador's international sources of financing, which led President Correa to pursue his backup plan to drill for oil if contributions were not received (Martin and Scholz 2014).

A lack of international coordination and unclear legal frameworks therefore prevented the laudable Yasuní ITT initiative from going forward, but several lessons can be learnt for the future success of similar programmes. Understanding the institutional, political, economic, and legal challenges and opportunities for the creation of global mechanisms that can allow compensation for the opportunity costs of preserving extractive wealth in the ground is an area where further research is needed. Indeed, even if the Yasuní ITT initiative failed, the implementation of appropriate international frameworks to compensate for biodiversity protection (from which everybody benefits) as well as compensation for the opportunity costs of biodiversity protection in developing countries constitutes a promising step forward towards achieving international environmental justice and a proper valuation of environmental wealth (and, by extension, extractive wealth).

Swanson 1996). Goeschl and Swanson (2002) notably highlight the differences between firm-based and social valuation of genetic resources for use in research and development activities.

[17] The UN Environment Programme, and the Food and Agriculture Organization manage funding for REDD+ through a Multi-Partner Development Fund through the UN Development Programme.

[18] UN REDD and REDD+ directly impacts on the Yasuní ITT Trust Fund and its ultimate success because they compete for funds at the global level (Martin and Scholz 2014).

Implications for policy makers: deciding to extract or not to extract?

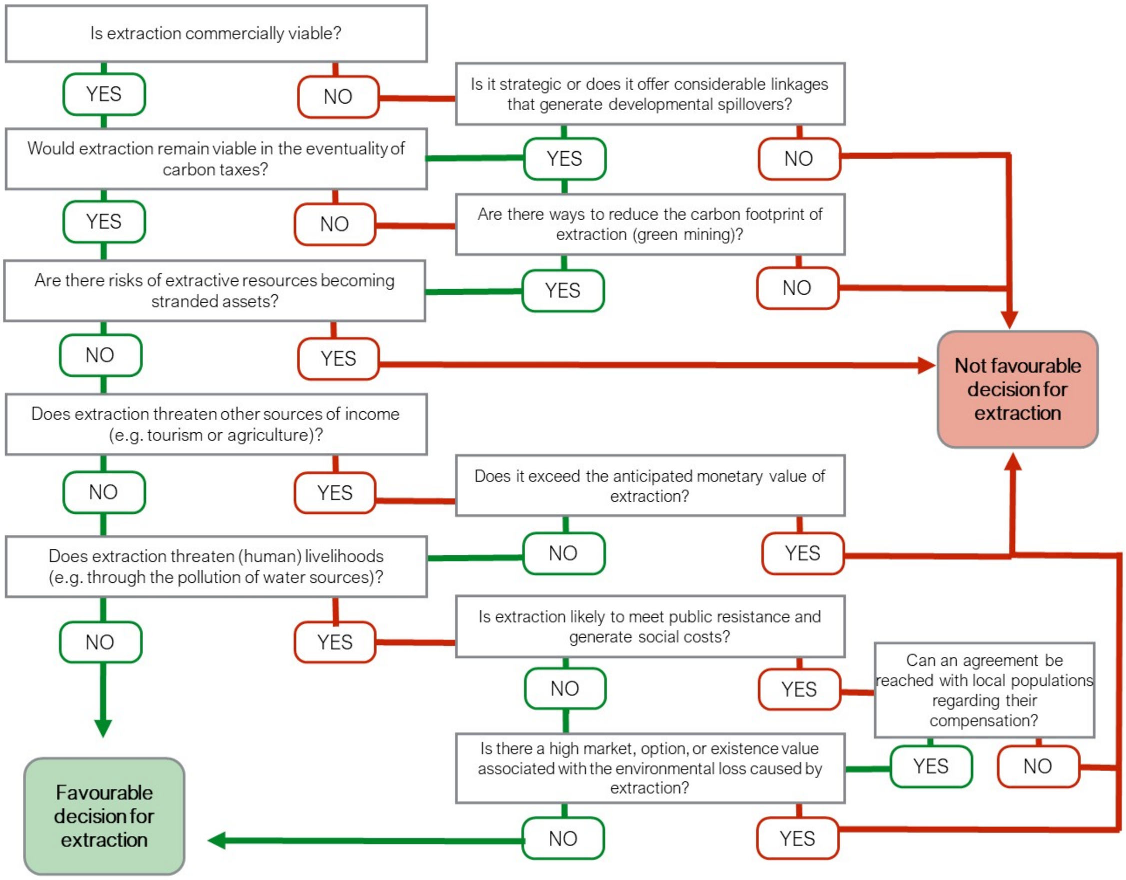
In light of the above discussion, we can argue that a better estimation of the 'true' value of resource wealth (*V*) in a particular country and for a particular commodity (*x*) would be the value of the extractive revenues (*R*)—the costs of production (*CP*) multiplied by the number of years of estimated production, minus the loss of opportunity income (multiplied by the estimated years of production of that income), the cost of social conflict, the existential value of the loss associated with environmental degradation caused by extraction (*Vexist*), and the cost of the carbon footprint of extraction, which is determined by the carbon footprint of extraction (*f*), the value of carbon taxes (*Tcar*) as well as the technological progress (*j*) that can enable to reduce the industry's carbon emissions (and environmental degradation more generally). This idea is formulated in the following equation:

$$Vx = \sum_{i=1}^{nx}(Rx - CPx) - \sum_{i=1}^{nCo} Co - Cs - \frac{f * Tcar}{j} - Vexist \quad (1)$$

where *C*=cost; *Co*=opportunity income; *Cs*=cost of social conflict; *CP*: cost of production; *fcarbon*=carbon footprint; *j*=technological progress; *R*=revenues; *Tcar*=carbon tax; *Vexist*=existential value; and *n*=years of estimated production. Such calculation requires the adoption of a long-term horizon because, as previously discussed, the commercial viability of extractive activities is influenced by long-term trends, such as climate change mitigation measures. This means that some of the opportunity costs of extractive activities may be immediate, while others may be generated in the long term. Nevertheless, policy makers, especially those who have a mandate of fewer than five years, might not have strong incentives to measure extractive wealth in the way that is suggested in this paper. It is also important to note that Equation (1) is not meant to determine an exact monetary value of extractive wealth (implying that this is even possible), but rather to bring attention on the different factors that should be considered when assessing the true value of resource wealth. From the same perspective, it is also possible to inform decisions on the value of extractive wealth through the decision tree presented in Figure 4.

After deciding whether extraction is commercially viable under existing conditions, policy makers and civil society will also need to investigate whether the extracted commodity may serve a broader developmental purpose, even if there are no commercial returns on extraction. Then, policy makers will need to assess whether the commercial viability of extraction is threatened by the eventuality of carbon taxes, and if it is the case, whether there are possible ways to reduce the extraction's carbon footprint, through the use of new technologies and the adoption of green extraction methods. The next question to raise is whether extractive resources are at risk of becoming stranded (in the context of climate change or technological innovations), and whether the opportunity cost of extraction is higher or lower than the income generated from extraction. Finally, policy makers need to assess the extent to which extraction threatens livelihoods, both human and non-human. If extraction is likely to be opposed by local (or non-local) populations, policy makers need to carefully consider whether a compensation for the loss of human livelihoods is possible, and whether its costs would exceed the commercial viability of commodity extraction.

Figure 4: The extraction decision tree



Source: author's elaboration.

4 Concluding remarks

The measurements of the value of extractive resources are central to informing decision making in terms of revenue mobilization from (and towards) extractive industries. While there is abundant literature on how to optimize the tax take from extractives, little attention has been given to how the extraction of natural resources could have a negative impact on other sources of income in the country. Therefore, we need a more holistic approach to extracting and taxing extractives. However, as this paper has shown, there is ample room for improvement in the conceptualization and measurement of natural resource wealth in general and extractives in particular.

This paper criticized the concept of extractive resource wealth (as currently understood) and proposed ways forward to improving how we value extractive wealth. First, this paper has drawn on a recently emerging body of research on the multidimensionality of resource wealth and dependence. There is no objective all-encompassing single measurement for resource abundance. The combination of several indicators of resource wealth can offer useful insights that single indicators cannot grasp on their own.[19]

[19] The two approaches that are identified in this paper are very different but are not mutually exclusive. A parameter of the 'truer' value of extractive wealth (discounting externalities and opportunity income) could also be added to the MINDEX in the future. The MINDEX methodology could also be used to generate data with further levels of

Second, this paper has raised the issue of integrating environmental externalities in resource measurements. The recognition that the environmental externalities from extractive activities can considerably reduce their net socio-economic benefits is not new. However, this paper has gone one step further by arguing that environmental considerations not only reduce the net benefits of extractive activities but also have critical implications for the valuation of the extractive resource itself. Of course, there are limitations to achieving a true valuation of extractive resource. For instance, it would be very difficult to attempt to monetize the existential value placed on some sites that are threatened by extractive activities, especially when those sites have spiritual value or sustain the livelihoods of humans but also fauna and flora that cannot be displaced. Notwithstanding some of these limitations, there is value in improving the way we conceive and measure extractive wealth, which remains an important area where further research is much needed.

The elaboration of a proper methodology to assess the true value of extractive wealth can help inform—and allow for more transparency in—extraction decisions and empower civil society to monitor and comment on policy choices. The ability of researchers and civil society to equip themselves with better tools for evaluating the true value of resource wealth is essential, given the incentives that policy makers face to adopt a shorter term approach and high discount rate when evaluating the resources in the ground (because a policy maker may be more interested in the next 10 years of oil revenues rather than the next hundreds of years of agriculture revenues or the existential value of environmental assets).

This paper suggested practical ways to adjust the net value extractives based on their opportunity costs and carbon footprint, but there are still problems in operationalizing such measurements at the national and global level. International action and coordination are needed to allow for a fairer compensation for existential value of environmental assets and the opportunity costs of keeping extractives in the ground, especially in developing countries in dire need to mobilize revenues for socio-economic development. Everyone benefits from biodiversity protection and reduced carbon dioxide emissions, but the economic loss of maintaining extractive resources in the ground disproportionately affects the local populations. International mechanisms can also pave the way for a fairer and concrete 'existential' valuation of biodiversity across the world, which would help policy makers in biodiverse regions reflect on the true value of their extractive resources and encourage them to leave them in the ground.

From that perspective, despite its eventual failure, it should be stressed that the Yasuní ITT initiative in Ecuador could inspire other developing countries with extractive reserves in biodiverse areas, and several lessons can be learnt for the future success of similar programmes. Addressing the institutional, political, and legal bottlenecks for the effectiveness of global mechanisms that can allow compensation for the opportunity costs of preserving extractive wealth in the ground is timely and urgent in the context of the post-Kyoto and Paris climate agreement. The implementation of appropriate international frameworks to compensate for biodiversity protection in developing countries constitutes a promising step forward towards achieving international environmental justice.

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disaggregation to distinguish different types of extracted commodities. The ability to isolate different types of commodities when measuring resource wealth can bear important implications for including environmental and climatic considerations. For instance, it can be useful to identify the composition of resource wealth across countries between fossil fuels (and other commodities that are at risk of become stranded assets) and 'minerals of the future' (such as copper and lithium), which may represent key ingredients of a low-carbon economy.

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