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The Multidimensional Indicator of Extractives-based Development (MINDEX): A new approach to measuring resource wealth and dependence

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ABSTRACT

Despite the vast amount of academic work estimating the impact of natural resources on development, very little attention has been devoted to the implications of using one type of natural resource measurement over another. This study fills this important gap in two ways. Firstly, it puts forward the biases and statistical misconceptions associated with different measurements of resource wealth, which have often led to the wrong classification of resource-poor countries as resource-rich and vice versa. As a result of the limitations of existing measurements, the discourse around extractives-based development has tended to lump various countries together, considering them all to be 'resource-rich', which is misleading. Instead, this paper shows that resource wealth and dependence are multifaceted.

Secondly, in contrast to the conventional measurements that have relied on different indicators of resource wealth in isolation from one another, this study sheds light on the need for a multidimensional approach to measuring resource endowment. I propose a new indicator, the MINDEX, which weights six different variables of both resource abundance and dependence across several dimensions (extractives reserves, production, exports, and government revenues) that relate to the different steps of resource exploitation chain to harness natural resources for development.

Because of its methodology, the MINDEX can also serve as a diagnostic tool that contributes to identifying some of the extractives-related policy challenges that a given country may face at a given time (such as illegal commodity smuggling, poor appropriation/taxation of commodity revenues, limited production capacity of existing deposits, vulnerability to commodity price fluctuations, and acute commodity dependence). It therefore also responds to the need for a new measure of extractives-based development to indicate whether a country is moving in the right or wrong direction over time and has clear relevance for informing resource mobilization dynamics and development strategies.

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

1. Introduction

Natural resources have – and continue to – play an important role in the development (or lack thereof) in many countries. Over two-thirds of developing countries (and almost 90% of Least Developed Countries) are still dependent on natural resources (and most often extractives resources, such as minerals or fossil fuels) (UNCTAD, 2019).[1] In addition, 63 out of the 72 most extractive-dependent countries have increased their dependence on extractives in the past 15 years (Roe and Dodd, 2018). Natural resources therefore continue to play an important role in the dynamics of revenue mobilization in developing countries. As a result, improving how we conceptualize, and measure, resource wealth and dependence is a particularly timely agenda and is of central importance to informing broader development conversations.

The scholarly interest in the impact of natural resources on economic and human development can be traced back to at least the 14th century with Ibn Khaldun's work (1967 [1377]). Such interest has been renewed over the past three decades with a plethora of

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[1] UNCTAD considers a country to be commodity-dependent when commodities represent more than 60% of its total merchandise exports in value terms.

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econometric and statistical studies attempting to find a correlation between natural resource wealth and economic development. Some have found a positive correlation (e.g. Bravo-Ortega & de Gregorio, 2007; Brunnschweiler, 2008; Davis, 1995; Findlay & Lundahl, 1999; Pineda & Rodríguez, 2010); some have found a negative one (e.g. Gylfason, Herbertsson, & Zoega, 1999; Neumayer, 2004; Mehlum, Moene, & Torvik, 2006; Sachs, 1995; Sachs & Warner, 1997), while others did not find any clear-cut statistical correlation (e.g. Bond & Fajgenbaum, 2014; James, 2015). The heterogeneity of results in the literature is partly due to the variety of methods that have been used to measure natural resource wealth (and dependence). Nevertheless, despite the vast amount of academic work that aims to estimate the impact of natural resources on development, very little attention has been devoted to the implications of using one type of natural resource measurement over another.

This study fills an important gap in the literature in the quest for more adequate measurements of natural resource wealth and notably responds to the growing concern regarding the critical need to better distinguish resource abundance from resource dependence (Adebayo, Lashitew, & Werker, 2021; Gylfason, 2011; Lashitew, Ross, & Werker, 2020). Firstly, it puts forward the biases and statistical misconceptions associated with different measurements of resource wealth. Such biases have important implications and raise serious questions on the validity of existing studies that aim to estimate the impact of natural resource wealth on development. For instance, the widespread conflation between resource abundance and resource dependence has led to the wrong classification of resource-poor countries as resource-rich countries and vice versa, which raises concerns regarding the true meaning of the evidence in support of the resource curse theory.

Secondly, most of the literature has relied on different indicators of resource wealth in isolation from one another. Because harnessing natural resources for development is a multi-level process, this article also outlines the need for a multidimensional approach to measuring resource endowment. It is only recently that scholarly work has emphasized that extractive dependence is multidimensional (Hailu & Kipgen, 2017; ICMM, 2020). To take a further step in highlighting the multidimensionality of both resource dependence and abundance and its implications for development strategies, I propose a new measurement: the Multidimensional Indicator of Extractives-based Development (MINDEX), which weights different indicators of both resource abundance and dependence, across several dimensions (such as extractive reserves, production, exports, and revenues). The MINDEX represents an effort to go beyond common conceptual flaws when measuring resource wealth and also responds to the call by several scholars for a new measure of extractive dependence and economic diversification over time to indicate whether a country is moving in the wrong direction (see Lahn & Stevens, 2018; Mitchell & Stevens, 2008; Stevens, Lahn, & Kooroshy, 2015).

Thirdly, this study shows that the discourse around extractives-based development has tended to group various countries, considering them all to be resource-rich, which can be misleading because of the very different ways in which these countries exploit and depend on extractive resources. By applying the MINDEX, this article evidences important distinctions amongst economies that hold/produce/export natural resources and allows to differentiate at least seven case scenarios that entail considerably different policy challenges for harnessing extractive resources as a lever to promote development. The distinctions in the "shape" of resource wealth have great implications for the suitability of different economic development strategies.

The next section of this paper examines definitions of resource wealth before reviewing existing methods to measure resource wealth and their limitations. Section 3 introduces the MINDEX, its methodology, as well as the results of its application to several countries (including through both cross-country and longitudinal analyses). Section 5 lays out the concluding remarks of this study and identifies further steps for improving natural resource measurements.

2. Defining and measuring resource abundance

2.1. Classifying natural resources

The first important issue to clarify is what is meant by 'natural resources' in this study. The measurement of what constitutes resources has evolved with time in the development literature (Lashitew et al., 2020). The earlier studies on the staples theory (Innis, 1930; Mackintosh, 1923), as well as the early resource curse literature (Sachs & Warner, 1995, 1997) treated all primary products (such as fossil fuels, metals and agricultural commodities) as resources. However, in subsequent research, extracted resources have often been distinguished from other types of natural resources because of the particular political and economic circumstances associated with them.

A distinction has been made between "point source" and "diffused" resources (Isham, Woolcock, Pritchett, & Busby, 2005). It is considered that mineral resources tend to generate 'point' rents, which exhibit concentrated and capturable revenues (and therefore easier to control), rather than 'diffuse' rents such as agriculture (Boschini, Pettersson, & Roine, 2007). Point rents also tend to be capital intensive and associated with enclave industries since they generate fewer production and consumption linkages in poor economies than more 'diffuse' resources (Auty & Gelb, 2000:141; Hirschman, 1981). Hard and energy commodities such as oil and gas are typical examples of natural resources that are considered to generate 'point' rents. Point and diffuse resources can be distinguished by the mode of exploitation but also by their spatial concentration (Le Billon, 2001). The former is concentrated in an area and mostly includes resources exploited by extractive industries while the latter is more widely spread and mostly includes resources exploited by productive industries over large areas (i.e. agriculture, forestry, and fisheries) (ibid.).

However, there are exceptions, and the above-mentioned characterizations appear to be based on generalizations (or observations) rather than systematic and clear-cut differences. For instance, artisanal and small-scale mining tend to generate diffuse resources, while agricultural resources can be concentrated through state marketing boards, cooperatives, large buyer-companies. In addition, while it is generally true that hard and energy minerals tend to have a much higher value in international commodity markets than most soft commodities, there are some exceptions, such as low-value minerals (e.g. industrial minerals such as limestone and silica sand) or saffron (which has a higher commercial value to weight than gold). While it is often perceived that commodity price volatility tends to be more accentuated for mineral commodities than agricultural commodities, it can be also argued that soft commodity price volatility is further affected by climatic uncertainties, pathogens, and other risks associated with farming, which do not necessarily affect hard and energy minerals. In reality, both agricultural and mineral exhibit outbreaks of volatility (OECD, 2012).

There are, however, other reasons for singling out hard and energy commodities. The most important one lies in the fact that such commodities are non-renewable while soft commodities are renewable. This difference leads to different dynamics and challenges in terms of managing those industries in the long run (especially once those resources are depleted) as well as their political and developmental effects. For instance, several studies mostly grounded in the political ecology approach (e.g. Homer-Dixon, 1999; Ide, 2015; Collier & Hoeffler, 2004) have sustained that conflicts are caused by resource scarcity when it comes to renewable resources but by resource abundance when it comes to non-renewable resources.[2]

The second most important difference lies in the fact that soft commodities (agriculture, fisheries, etc) can be human-induced. In contrast, mineral commodities are always "indigenous" to the area in which they are found. This is why measuring natural resource abundance (by including agricultural commodities) in Chile or Malaysia for instance would neglect the fact that the palm oil, rubber, salmon, and forestry sectors have been the result of government-induced diversification. The focus on mineral resource abundance in the rest of this study is thus justified for these two reasons.[3]

2.2. Different existing ways to measure resource abundance and dependence (and the overlooked distinction between the two)

This section reviews how resource abundance and dependence have been measured in the literature to date.[4] After showing the limitations of various existing measurements, I argue that no objective all-encompassing single measurement for resource abundance, which is why looking at several indicators through a multidimensional approach is necessary.

An important issue when dealing with natural resource measurements consists in finding accurate ways of measuring resource richness and distinguishing resource abundance from resource dependence. Distinguishing between resource dependence and abundance is critical and bears considerable implications for development outcomes, as noted by recent work (Adebayo et al., 2021; Lashitew et al., 2020; Lebdioui, 2019a). Gelb (2010) shows that studies that focus on resource abundance tend to find positive relationship with economic growth, and those focusing on resource dependence tend to find a negative relationship. Lashitew et al. (2020) further found that more resource-dependent countries appear to perform worse on measures of human capital and intellectual capital, whereas resource-abundant countries perform better on public capital and human capital accumulation as well as broader competitive capabilities.[5] A proper elaboration of the implications of the distinction between resource abundance and dependence, which are subjective and complex concepts, remains a key gap in the literature on the impact of natural resources on development.

Some of the most influential studies on the resource curse have been characterized by statistical misconceptions. For instance, the negative correlation between economic growth and natural resource wealth found in Sachs and Warner (1997) relies on measurements of the share of resources output/exports out of total output/exports. This measurement is misleading because it reflects resource dependence rather than resource abundance.[6] Several studies (see Brunnschweiler & Bulte, 2006; Di John, 2011; Gelb, 2010) have indeed pointed out the endogeneity between resource dependence and growth (the two variables used in Sachs & Warner, 1997), which suggests that the poor economic performance in many LDCs is more likely to be due to resource dependence than abundance. In particular, this methodological choice has two important implications: First, it misclassifies (as resource-rich) countries that are resource-poor but export little else than the few commodities they have (because they have little other products to export to foreign markets, which is a characteristic of an underdeveloped economy). For instance, some countries, such as Chad and Mali, may have few mineral resources but depend on those few for the bulk of their export earnings (Gylfason, 2011:10). Second, the statistical confusion between resource dependence and abundance leads to a selection bias that ignores successful resource-based development experiences. In historical terms, several now-industrialized resource-rich countries, such as the United States, Canada, Australia, Sweden, 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 by definition qualify as resource-dependent anymore.

In a similar perspective, Ross (2001) investigates whether oil wealth has an impact on democracy but uses indicators of oil reliance rather than oil abundance. The implications of this methodological distinction are considerable and are reflected in Fig. 1. In the index of oil reliance in Ross (2001), which is based on data for the year 1995, Nigeria ranks 4th and precedes Yemen (ranked 7th) and Norway (ranked 16th). 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 USD) rather than oil reliance. 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. Such divergence opens important questions on how the impact of natural resources on various indicators of development has been estimated in the scientific literature to date.

Several scholars have discussed and defined the difference between resource abundance and resource dependence. Gylfason (2011:10) provides an interesting way of distinguishing resource abundance from resource dependence, whereby abundance relates to the amount of natural capital that a country has at its disposal (i.e. mineral deposits, oil fields, forests, or farmland), while dependence relates to the extent to which the nation in question depends on these natural resources for its livelihood. Similarly, Hailu and Kipgen (2017) argue that *resource abundance* refers to resource endowments or stocks, which to a large extent are endogenously determined, while *resource dependence* refers to the importance of the resource sector to an economy in generating tax revenues, foreign exchange, growth, and employment. Thus, resource dependence becomes applicable once extraction takes place while being resource-abundant does not necessarily imply extraction of those resources (ibid.). Nevertheless, it could be argued that the distinction between abundance and dependence goes beyond the difference between resource availability and resource exploitation because a country could exploit its natural capital without necessarily depending on it as it may also have alternative ways of sustaining its livelihoods.

There are further concerns that arise when defining and measuring resource dependence. A country is commonly considered resource-dependent when natural resources constitute the bulk of this country's export basket or government revenues. However, should we distinguish mono-resource exporters from multi-resource exporters (countries that depend on several types of natural resources)? In other words, should we consider multi-resource exporting countries (such as Chile, the Democratic Republic of the Congo, or South Africa) to be as resource-dependent as mono-resource exporters (Algeria, Angola, or Venezuela) that feature

[2] Such argument has been criticized in Le Billon (2001) and Cramer (2002).

[3] In this paper, I will use the terms commodities, extractives, and resources interchangeably.

[4] See Hailu and Kipgen (2017) for a similar review of common measures of resource dependence.

[5] For instance, Lashitew et al. (2020) explain that the differences between Canada and the Republic of Congo can be explained by differences in resources dependence rather than resource wealth. The two countries have the same levels of natural resource endowment (in terms of resource rents per capita) but Canada's GDP is nearly eight times higher than that of the Republic of Congo because it has managed to diversify away from natural resources and develop a highly productive non-resource sector while the Republic of Congo has failed to do so (ibid.).

[6] Other studies have used similar measures of resource wealth that rely on the share of primary exports in GDP/GNP/Exports (e.g. Boschini et al., 2007; Mehlum et al., 2006; Havranek, Horvath, & Zeynalov, 2016).

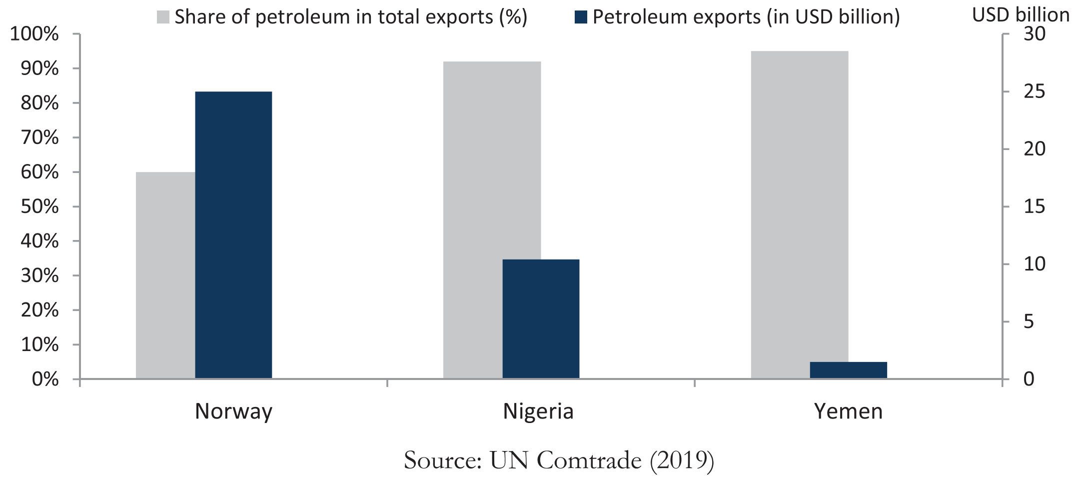


Fig. 1. Divergent trends in terms of oil reliance and abundance in selected countries in 1995. Source: UN Comtrade (2019).

similar shares of natural resource in their revenues/export basket? In such a scenario, it can be argued that 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 to understand the impact of natural resources on development? Resource exports by country is also an imperfect indicator of resource wealth for at least three reasons:

Firstly, such 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, the Chatham House Resource Trade Database (CHRTD) enables to rank countries according to the level of resource exports in any given year. Unsurprisingly, resource-poor countries such as Germany, Switzerland, Hong Kong, or Singapore often rank amongst the top resource exporters in the world.

Secondly, resource exports do not equate to 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 cost for producing an oil barrel in recent years has been about USD9 for Iran and Saudi Arabia, in comparison to USD44 in the United Kingdom, USD29 in Nigeria, and USD28 for 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 consideration also means that if commodity prices go below the value of the commodity production costs in a given country, it can be considered that this country's resource wealth has 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, how we value a country's resource wealth over time should reflect such considerations.

Thirdly, 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 & Stevens, 2018). It can be argued that it would not be accurate 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 190million people in Nigeria and only five 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!

In 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 Sachs (1995) study. This measurement appears to be a much better reflection of resource abundance then than the share of natural resources in GDP/exports. Nevertheless, it remains imperfect for the first two reasons discussed above.

It is also possible to look at indicators other than exports. For instance, resource abundance could also be measured in terms of the value of production (see Leamer, 1984; Moroney, 1975); the size of resource revenues (see IMF, 2012b; Matsen & Torvik, 2005); or resource rents (see Cammett, Diwan, Richards, & Waterbury, 2015; Chang & Lebdioui, 2020; Collier & Hoeffler, 2009; Chauvet & Collier, 2008; International Monetary Fund, 2012b). Resource rents per capita are perhaps one of the most accurate indicators 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.[7] Indeed, in light of the some of above-mentioned methodological limitations, recent studies have started to use indicators of resource abundance by calculating resource revenues or rents per capita (e.g., Alexeev & Conrad, 2009; Ross, 2017; Chang & Lebdioui, 2020). However, measurements that focus on resource rents or revenues may misclassify countries with large mining sectors such as Madagascar (ilmenite) as resource-poor because of a very low resource rent of the commodity (the market price of ilmenite is only marginally above its cost of extraction in Madagascar) (Bond & Fajgenbaum, 2014:126). In those cases, focusing on resource rents may misrepresent the importance of extractive sectors for the domestic economy.

Other studies have measured resource abundance by using indicators of physical resource endowment, by comparing resource reserves or deposits per square kilometer across regions (See

[7] Gelb, Kaiser and Vinuela (2012) raise the interesting question of how much does it cost 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 imputes the cost of exploration.

Collier, 2011; Arezki, Van der Ploeg, & Toscani, 2016). 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 reserve data faces important limitations. Firstly, the data available on extractives reserves by country is related to a country's technological level. As a result, relying on this indicator alone could misrepresent the true resource wealth of nations but also give uneven weighting to the resource wealth of more advanced economies where a higher number of geological explorations may have been conducted. For instance, 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. Secondly, 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 think of 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 on extractability grounds: Reserves are quantities that are relatively more certain geologically and more likely to be economic to extract, while resources are less geologically certain and may never be economically extracted.[8]

While many indicators have been used to measure resource abundance, both absolute terms and relative terms (as a 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 3 countries (Brunei, Kuwait, and Saudi Arabia) feature in the rankings for each of the six indicators (and only one other country, the UAE, features in the top 12 for at least four indicators out of six). This shows that using different indicators may have a great influence on study results.

2.3. Multidimensional approaches to measure resource wealth and dependence

As shown in the previous section, existing measurements have mostly relied on resource measurements in isolation from one another. There is no objective all-encompassing single measurement for resource abundance, which is why it is important to look at several indicators. A country can be dependent on extractive resources as a source of gross national income, exports, employment, and inputs for other industries. Each of these types of dependence has different implications. Resource dependence and exposure are difficult to measure when analyzing individual aspects of dependence in isolation (Le Billon & Good, 2016). Hailu and Kipgen (2017) further argue that understanding the type of dependence on non-renewable resources helps craft the right policies for diversification.[9]

The combination of several indicators of resource wealth (such as resource production, exports, rents, and government revenues) can consequently offer useful insights that single indicators cannot grasp on their own. The recognition that extractive dependence is multidimensional was recently emphasized by scholarly work on the Extractives Dependence Index (Hailu & Kipgen, 2017) and the Mining Contribution Index (ICMM, 2020). The Extractives Dependence Index (EDI) is a measure to monitor a country's dependence on the extraction of oil, gas, and mineral resources. It measures the share of export earnings from extractives; their share of revenue in total revenue; and their value-added in GDP. The resulting composite index is used to rank countries through values ranging from 0 to 100, with 100 being the highest dependence score. They find that Iraq, Libya, Equatorial Guinea have the highest EDI values, while the Philippines, Sao Tome and Principe, and the UK had the lowest extractive dependency scores.

Very recently, another indicator, the Mining Contribution Index (MCI), developed by the International Council on Mining and Metals (ICMM, 2020), synthesized into a single number three variables, namely the share of the mining sector's contribution to exports; to GDP; and the increase/decrease in mineral export contribution over 2005–2010. The three variables are weighted equally at 1/3, summed up, and multiplied by 100.

The two methods reviewed above represent laudable efforts to capture the several dimensions of resource dependence but may not suffice to capture the multidimensionality of both resource wealth and dependence simultaneously. Building on these valuable works, I propose a new index, the Multidimensional Indicator for Extractives-based (MINDEX), which takes one step further by: (i) including variables of resource abundance in both relative and absolute terms (rather than in relative terms alone); (ii) visualizing the data into radar charts to avoid the synthesis into single numbers, which may shadow important variation in the distribution of value across different variables; (iii) including all types of extractive resources (rather than mining alone, although the type of commodity can be further isolated). As a result, the MINDEX may be the most comprehensive effort so far to capture the multidimensionality of resource abundance and dependence.

3. Resource abundance comes in several shapes: the MINDEX

3.1. Overview and objectives

Harnessing natural resources for development is a multi-level process and the types of variables that we choose to measure resource abundance reflect different aspects of the natural resource management chain. As a result, in this section, I show how relying on several indicators simultaneously may be a useful way to identify specific developmental challenges a resource-rich country faces. The Multidimensional Indicator for Extractives-based (MINDEX) builds on recent work on multidimensional indices to provide a better picture of the multidimensionality of resource wealth and dependence. It weights six different indicators on a scale of 0 to 1. Those six indicators are:

- The share of extractives in total exports (%)
- Extractives exports (in USD per capita)
- Extractives rents (in USD per capita)
- Government revenues from extractives (USD per capita)
- The share of extractives in total government revenues (%)
- Extractives reserves (USD per capita)

Four of these indicators are measures of "resource abundance" (extractives exports, rents, reserves, and government revenues) while the remaining two are measures of resource dependence

[8] However, there is no standardization of these categorizations, with several nations deriving their own definitions (e.g. JORC in Australia, CIMVal in Canada, SAMVal in South Africa) (Davis, 2010).

[9] They show that the shares of export earnings from the extractive sectors in Zambia and Norway are similar (76 percent and 74 percent respectively), but the two countries have vastly different levels of resource dependence based on economic development, technological capabilities, and revenue diversification. The two countries consequently have different levels of exposure to commodity busts, which suggests that the share of extractives in total exports is not, in and of itself, sufficient to judge the degree of extractive dependency of an economy (ibid.)

Table 1
Countries ranked across various indicators of extractive abundance and dependence.

Ranking/Units	Extractive exports *USD per capita*	Extractive exports *%*	Extractive reserves *USD per capita*	Extractive rents *USD per capita*	Extractive revenues *USD per capita*	Extractive revenues *%*
1	Qatar	Angola	Venezuela	Qatar	Kuwait*	Iraq
2	Kuwait*	Venezuela	Kuwait*	Kuwait*	Brunei*	Brunei*
3	Brunei*	Algeria	Botswana	UAE	Qatar	Eq. 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	Eq. Guinea	Oman	Congo, Rep.
9	Australia	Nigeria	Iran	Australia	Bahrain	Azerbaijan
10	Canada	Kazakhstan	UAE	Iraq	Eq. Guinea	UAE
11	Kazakhstan	Saudi Arabia*	Guyana	Trinidad and Tobago	Trinidad and Tobago	Nigeria
12	Botswana	Zambia	Norway	Libya	Iraq	Yemen

Source: MINDEX database.

(share of extractives in total exports, and in total government revenues).

These indicators were also selected because they all represent different dimensions of extractive activities. Government revenues from extractives relate to the fiscal linkages arising out of extractives, which provides information on the State's ability to mobilise revenues in the broader development context. Relatedly, the share of extractives in government revenues reflects the extent to which governments depend on extractive activities for their fiscal revenues, which matters because a country's vulnerability to commodity price volatility is directly related to its fiscal dependence on commodities (Hailu & Kipgen, 2017). A large body of literature has addressed the development implications of fiscal dependence on extractives (e.g. Lane & Tornell, 1996; Mehlum et al., 2006; Sala-i-Martin & Subramanian, 2013).

The indicator of resource rents also reflects the revenue dimension while accounting for the costs of production (as explained in footnote 10). Measures of resource exports can indicate how much foreign exchange revenues a country generates from the resource sector, and the degree of country's dependence on the extractive sector to generate foreign exchange revenues, which is important because economic diversification requires the creation of additional sources of foreign exchange (outside the extractive sector). There is a large body of literature on the developmental impact of extractive dependence and the role of export diversification as an engine of structural change and economic development (e.g. Agosin, 2009; Cadot, Carrère, & Strauss-Kahn, 2011; Cherif, Hasanov, & Wang, 2018; Hausmann, Hwang, & Rodrik, 2007; Lebdioui, 2019a, 2019b).

The last indicator, namely extractives reserves, reflects the quantity and value of resources are available to extract, as well as exhaustibility concerns. Such considerations matter in the context of development and diversification strategies because the desirability of building production linkages around a commodity depends on the exhaustibility of its reserves (Lebdioui, 2019a). If countries run out of oil or copper, they might need to import it to keep operating related industries (ibid.). The size of extractive reserves, therefore, has an important influence in terms of the impact of forward linkages on extractive dependence because it influences the ability of domestic downstream industries to reach economies of scale, which is important for their long-term competitiveness and their impact on economic diversification (Lebdioui & Bilek, 2021).

Those six indicators also 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 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 their investment for developmental purposes (see Table 2).

As such, 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 to proven reserves, poor appropriation of revenues, or an insufficiently diversified economy reflecting the poor investments of resource revenues for structural transformation).[10] The possibility of identifying policy challenges through the MINDEX is reflected by the seven case scenarios identified in Table 3.

3.2. Methodology

The development and application of the MINDEX have faced several methodological challenges such as issues of data availability and comparability. Such issues have been addressed through the establishment of a scoring system and appropriate benchmarks for each indicator (see Table 4). The value of extractives exports, rents, reserves, and revenues are expressed in USD (constant) and in per capita terms. Per capita measurements are a better reflection of resource abundance than national measurements, as discussed earlier in Section 2.[11]

The methodological choices and data sources underlying this scoring system are further explained in the following subsections for each of the indicators. Despite its imperfections, such methodology represents the best effort to date to capture the multidimensionality of resource abundance.

3.2.1. Resource exports

Data on resource exports was collected from UN Comtrade and WTO databases. Table 5 indicates the commodity codes that have been used to isolate extractive resources using the Standard International Trade Classification (SITC), in line with the definition and classification of extractive resources that are provided in Section 1.2.1.

The use of measurements of real GDP (in constant 2010 USD) is preferred over nominal GDP (in current USD) to remove the effects of inflation over time and more accurately reflect changes in production volume and commodity prices. Nevertheless, export data from UN Comtrade and WTO databases is expressed in nominal

[10] An indicator of developmental outcomes (such as the HDI) could be added in future updates of the MINDEX to consider the last step of the resource revenue management chain, which is investing for human development.

[11] The wealth of countries that are holding/producing/exporting the same volume of extractives depends on how many people will share the benefits of such wealth.

Table 2
Different steps of the resource revenue management policy chain.

		Chang (2007)	*Collier & Laroche (2015)*	*EITI*	*Henstridge & Roe (2018)*	*NRGI (2014)*	**RELATED INDICATORS**
STEPS OF THE RESOURCE REVENUE MANAGEMENT POLICY CHAIN	**Discovery**		*Discovering*		*Discovery (Exploration)*	*Discovery*	**Size of resource reserves**
	Exploitation & production		*Exploiting*	*Awards of contracts & licences; Regulation & monitoring of operations*	*Development (Investment & construction), Production (Monetization)*	*. . .and deciding to extract*	**Resource rents and exports**
	Resource rents appropriation	*Appropriating the rents*	*Taxing*	*Collection of taxes and royalties*	*Revenue (Transfer rent)*	*Getting a good deal*	**Resource revenues**
	Management of resource revenues & avoiding resource dependence	*Investing the rents across financial assets, capacity building, and for diversification.*	*Investing in investing*	*Resource revenue management & allocation*	*Public Investment*	*Managing revenues*	**Degree of resource dependence** *(share of resources in exports/ revenues)*
			Investing	*Social & economic spending*	*Human Development*	*Investing for sustainable development*	

prices rather than real prices. I have therefore used the values of each years' consumer price index (accessible in the World Development Indicators database) to deflate the export data values. The use of real prices rather than nominal prices also enables better comparability over time.

The scoring criteria for resource exports is based on a continuous variable using an exponential function for resource exports per capita values. This function corresponds with the distribution of average resource exports per capita values by country. The corresponding exponential equation is $f(x) = 35.121e^{0.594x}$.

3.2.2. Resource rents

The value of extractive rents was calculated by using data from the World Development Indicators, which feature the share of various types of natural resource rents as a share of GDP. To obtain absolute values in per capita terms for each year, the sum of the share of extractives rents (namely oil, mineral, and coal rents, using the WDI terminology) as a share of GDP was multiplied by the value of GDP (in constant 2010 USD), and divided by the population size recorded for that year.

The scoring benchmarks differ between resource rents and resource exports because the value of resource rents does not include the cost of resource production, unlike resource export values (World Bank, 2019). Based on my calculations, resource exports are on average twice (2.01) as high as resource rents over the period 1997–2010. The scoring criteria (see Table 4) for resource rents and exports take this ratio into account.

3.2.3. Government revenues

Data availability has always been an issue when measuring government resource revenues (Prichard, Salardi, & Segal, 2018). Fortunately, the most recent update of the International Centre for Tax and Development (ICTD) database has included isolated data on resource revenues, which represents both taxes from resource revenues and non-tax resource revenues (such as royalties, dividends, etc). Nevertheless, the data is still missing for several countries and time periods. In order to complete this database, I have used data from the resource revenue dataset published by the Natural Resource Governance Institute (NRGI) and from direct governmental sources (such as government statistics offices and central banks).

In the ICTD database, tax revenues are expressed as a percentage of GDP. To obtain absolute values per capita, I have converted such values by multiplying them by the corresponding GDP per capita (in constant 2010 USD) for each country.

Besides data availability concerns, another issue is to define what counts as government revenues. Should profits that are retained by SOEs (such as national oil companies) be taken into account? For instance, many SOEs have more than purely commercial missions but also spend their revenues for social purposes (such as spending on fuel subsidies by Petronas, etc).[12] Because of the lack of data on SOEs' profits and spending patterns, it would be too difficult to include profit retains by SOEs in the analysis, which consequently only focuses on resource revenues paid to the central government.

Another key concern is to distinguish federal revenues from subnational revenues. In some countries (such as the USA or Malaysia) resource revenues do not only accrue to the central government but also provincial governments. As a result, US government resource revenues may appear as low, when in fact most resource revenues accrue to state governments. The ICTD database only includes revenues to the central government. Future updates of the MINDEX will attempt to include revenues at the subnational level.

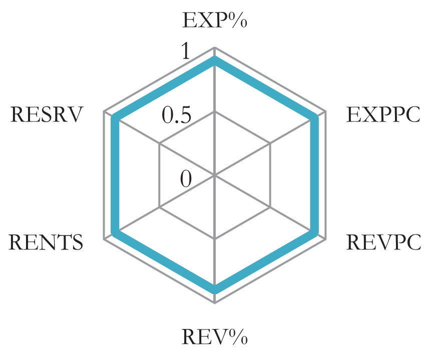
Lastly, the remaining concern has been the establishment of an appropriate benchmark for scoring resource revenues. The lack of data on government fiscal revenues for many countries renders international comparisons a difficult task. As a result, how can we judge whether a government's resource revenues are truly high or low? The solution found has consisted of using resource rents values as a baseline. Evidence suggests that on average, governments should capture about two-thirds of resource rents. While fiscal regimes for extractive industries vary greatly, the IMF (2012a) finds that governments should retain around 40–60% of rents in the mining sector and around 65–85% of rents in the hydrocarbons sector. Fiscal regimes that raise less than these benchmark averages may be cause for concern or regret (ibid.). It is consequently reasonable to assume that across extractive activities, the government should receive about 60% of the value of resource rents, which is why I have imposed threshold values based on a government resource revenues/ resource rents ratio of 0.6 in the scoring criteria (see Table 4). While this method suffers from limitations due to the variety of fiscal regimes across different

[12] Interestingly, countries where private firms dominate oil production appear among the world's top tax collectors, while similarly resource-rich countries that rely on national petroleum companies appear among the worst tax collectors (Pritchard et al., 2018).

Table 3
Seven case scenarios and 'shapes' of resource endowment.

<table>
<tr><th>Case Scenario</th><th>Description and interpretations</th></tr>
<tr><td>

Case 1



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'Resource-rich and dependent':
All six indicators are high
The country is both resource-abundant and resource-dependent.

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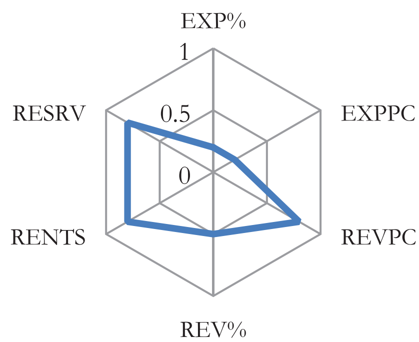
Case 2



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'Internal resource wealth':
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.

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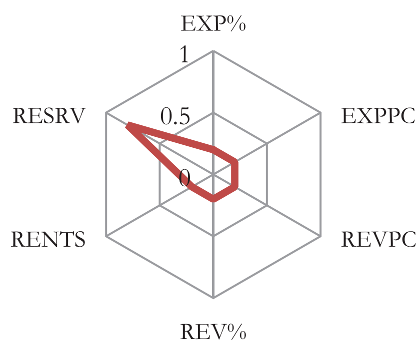
Case 3



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'Below-ground resource wealth':
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); local conflict (e.g. Libya) restraining resource production and exports; or decisions to leave extractives in the ground for environmental reasons.

</td></tr>
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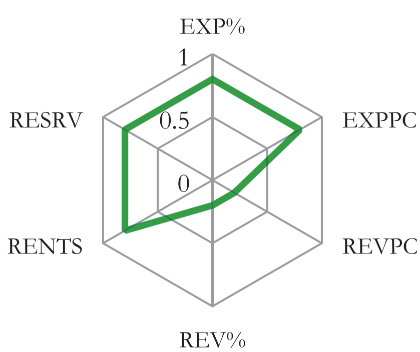
Case 4



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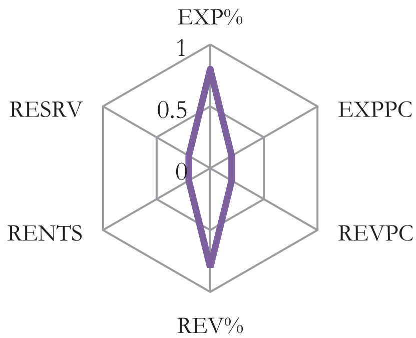
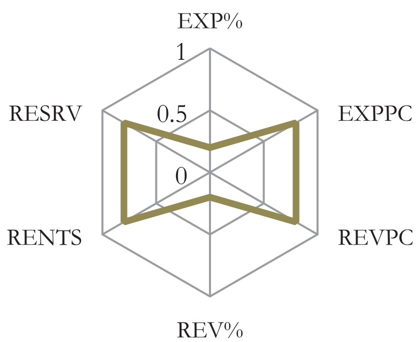
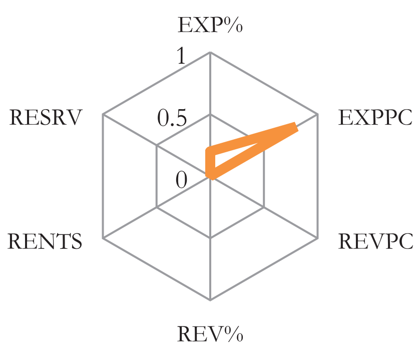
'Unappropriated resource wealth':
High levels of resource production (or resource rents) but low government revenues from resource exploitation.
The country faces issues of appropriation of resource revenues and possible insufficient taxation on mineral production/exports.

</td></tr>
</table>

Table 3 (*continued*)

Case Scenario	Description and interpretations
Case 5 	*Resource-poor but resource-dependent:* *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 	*'Resource-abundance without dependence':* *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 imported commodities in crude form or after some processing (India and Israel with diamonds; Switzerland and UAE with gold; Singapore with unrefined petroleum and fuel); or after the illegal smuggling of commodities into the country (e.g. Congo or Liberia with diamonds respectively smuggled from DRC and Sierra Leone).

EXP%: Share of extractives in total exports.
EXPPC Extractives exports (in USD per capita).
REVPC: Government revenues from extractives (in USD, per capita).
REV%: The share of extractives in government revenues.
RENTS: Extractives rents (in USD per capita).
RESRV: Extractives reserves (in USD per capita).

types of extractive sectors, it is useful as it enables to directly compare government resource revenues with resource rents for the same year.

3.2.4. Share of extractives in total exports and total revenues

Scoring the share of extractive resources in total exports and total fiscal revenues has been relatively straightforward given that the value of these two indicators (both expressed in percentages) was linearly converted into the scores (which range from 0 to 1). Both indicators were calculated using the same sources and methodology as described in Sections 3.2.1 and 3.2.3.

3.2.5. Resource reserves

Measuring and comparing extractives reserves is a daunting task because of the uneven availability of data across countries and types of commodities. Beyond data availability, another important consideration is data comparability. Firstly, it is difficult to distinguish extractive reserves/deposits from extractive resources that are more difficult to extract. Secondly, commodity reserve data, when accessible, tends to be measured in weight (metric ton, ounce, barrels, or else) rather than value, which renders difficult the task of comparing countries that sit on different types of extractives resources. To enable comparability across commodities (because an ounce of gold does not have the same value as an ounce of limestone) and across the various indicators of the

Table 4
Underlying scoring criteria of the MINDEX.

Score	Share of extractives in exports (%)	Share of extractives in government revenues (%)	Extractives exports *(USD per capita)*	Extractives rents *(USD per capita)*	Extractives reserves *(USD per capita)*	Government extractives revenues *(USD per capita)*
1	100%	100%	>13,000	>6,500	>170,000	>3900
0.9	90%	90%	Between 7,500 and 13,000	Between 3750 and 6,500	Between 170,000 and 90,000	Between 3900 and 2250
0.8	80%	80%	Between 4,000 and 7500	Between 2000 and 3750	Between 90,000 and 50,000	Between 2250 and 1200
0.7	70%	70%	Between 2,500 and 4000	Between 1250 and 2000	Between 50,000 and 25,000	Between 1200 and 750
0.6	60%	60%	Between 1000 and 2500	Between 500 and 1250	Between 25,000 and 18,000	Between 750 and 300
0.5	50%	50%	Between 750 and 1000	Between 375 and 500	Between 18,000 and 10,000	Between 300 and 225
0.4	40%	40%	Between 500 and 750	Between 250 and 375	Between 10,000 and 5000	Between 225 and 150
0.3	30%	30%	Between 250 and 500	Between 125 and 250	Between 5000 and 2000	Between 150 and 75
0.2	20%	20%	Between 100 and 250	Between 50 and 125	Between 2000 and 1000	Between 75 and 30
0.1	10%	10%	Between 50 and 100	Between 25 and 50	Between 1000 and 500	Between 30 and 15
0.0	0%	0%	<50	< 25	Below 500	< 15

Table 5
Commodity codes related to mineral resources using SITC3.[19]

Commodity code	Description
28	Metalliferous ores and metal scrap
3	Mineral fuels, lubricants and related materials
68	Non-ferrous metals
667.2	Diamonds (other than sorted industrial diamonds), whether or not worked, but not mounted or set
667.3	Precious stones (other than diamonds) and semiprecious stones, whether or not worked or graded but not strung, mounted or set; ungraded precious stones (other than diamonds) and semiprecious stones, temporarily strung for convenience of transport
97	Gold (non-monetary)

[19] Trade data using the Harmonised System (HS) of commodity classification has been used to gather data on countries for which SITC data is not available.

MINDEX (such as resource exports, rents, revenues, which are all measured by value), commodity reserves data has been converted into USD per capita. This conversion has been conducted by using averaged commodity prices (for a given commodity) on a yearly basis. This method was chosen after considering several alternatives, including using averaged commodity prices for a longer period or using the share of global commodity reserves that a country holds as scoring criteria. However, both alternative measurements have limitations. For instance, using average prices for a longer-term period would not reflect immediate changes (or the direction of changes) in terms of the commodity prices/value of commodity reserves. Using the share of global reserves would also not allow comparability across different types of commodities.

Data on yearly prices by commodity was extracted from IMF, UNCTAD, IndexMundi, and the Federal Reserve of St Louis datasets. Data on commodity reserves was collected from US geological surveys, the CIA factbook, EITI reports, and governmental sources.[13]

As a result of this methodology, variations in the score of extractives reserves across years can be interpreted in two ways: Changes can either reflect fluctuations in commodity prices, or changes in the volume of commodity deposits (either through their exhaustion or discovery). The strength of this method (compared to averaging commodity prices over a longer time period or using a reference year in terms of commodity prices) is that that it would more accurately reflect the evolution of the value of given commodities. This methodology also reflects more accurately the risk of stranded assets for commodities whose values depreciate over time.

The scoring criteria for resource reserves is based on a continuous variable using an exponential function. The exponential equation is: $f(x) = 352.73e^{0.62x}$.

3.3. Application and results[14]

3.3.1. Cross-country analysis

Several key observations can be drawn from the cross-country analysis in Fig. 2. First of all, it is possible to match each country with at least one of the seven case scenarios identified in Table 3, 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.

Secondly, it is 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. Nigeria). 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 analyses. In the context of Burkina Faso, EITI (2016) revealed that only 37 of the certified 63 trading houses declared their revenues to the Office of Mines and Geology. EITI (2016:1) also reported that: "the declared production from artisanal mining was 0.5 tons in 2013, but undeclared production was estimated as at least 8.8 tons [...] and slips through the country's borders undetected. In 2013, the NGO [the Berne Declaration] reported that approximately seven tons of gold left the country undeclared and was exported to Switzerland via Togo."

The DRC's MINDEX, revealing possible issues of appropriation of resource revenues and insufficient taxation on mineral production/exports, is also consistent with existing accounts of its mining sector: "In the DRC, the picture in mining taxation is more difficult to quantify since a large part of the mining is undertaken by nearly two-million informal workers, and because most of the mining

[13] The commodities that have been included in this first round of data collection on extractive reserves by country include: crude oil, copper, diamonds, gold, iron ore, natural gas, lithium, bauxite, phosphate, cobalt, uranium, and zinc.

[14] See Appendix A for details on each country data and measurements.

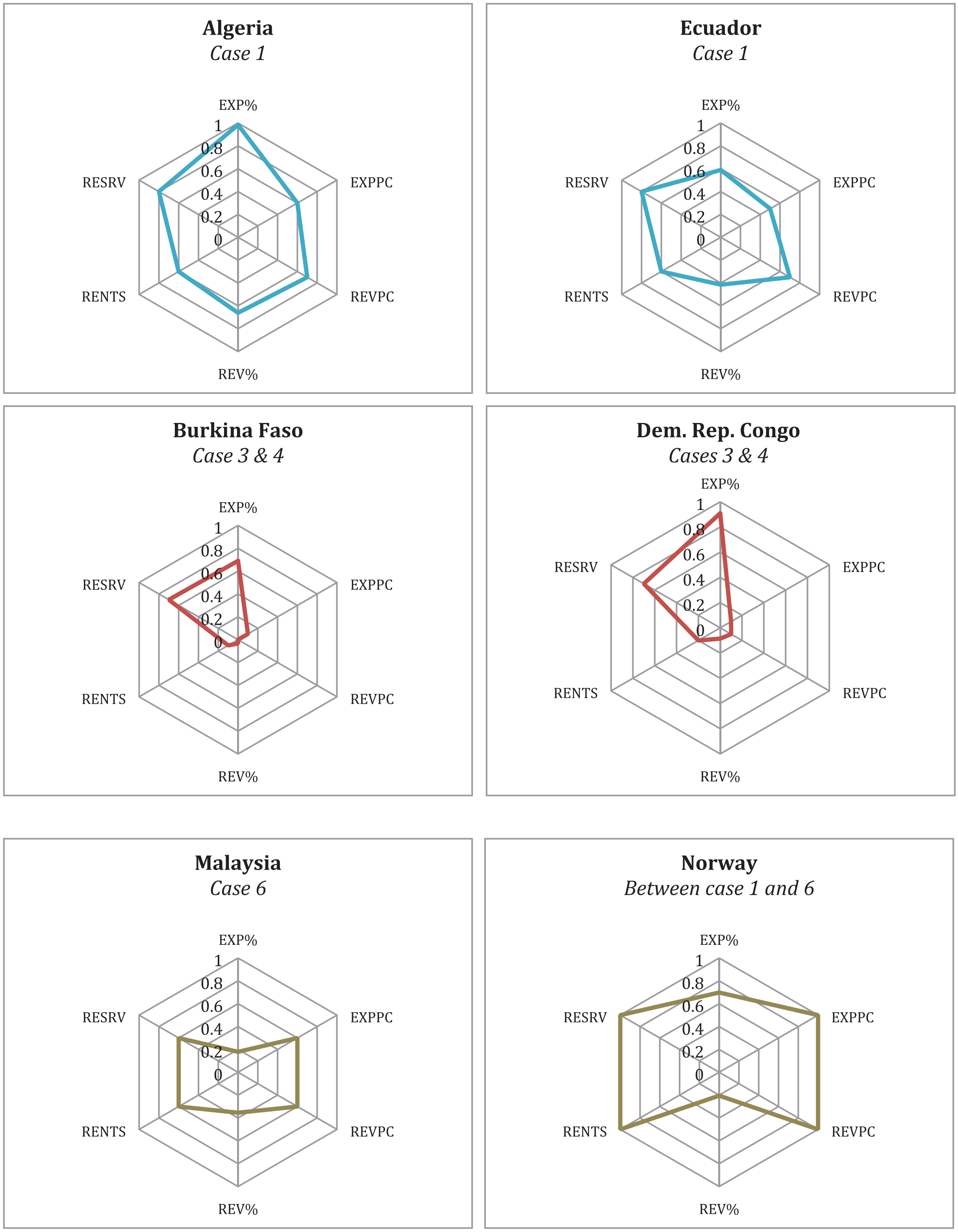
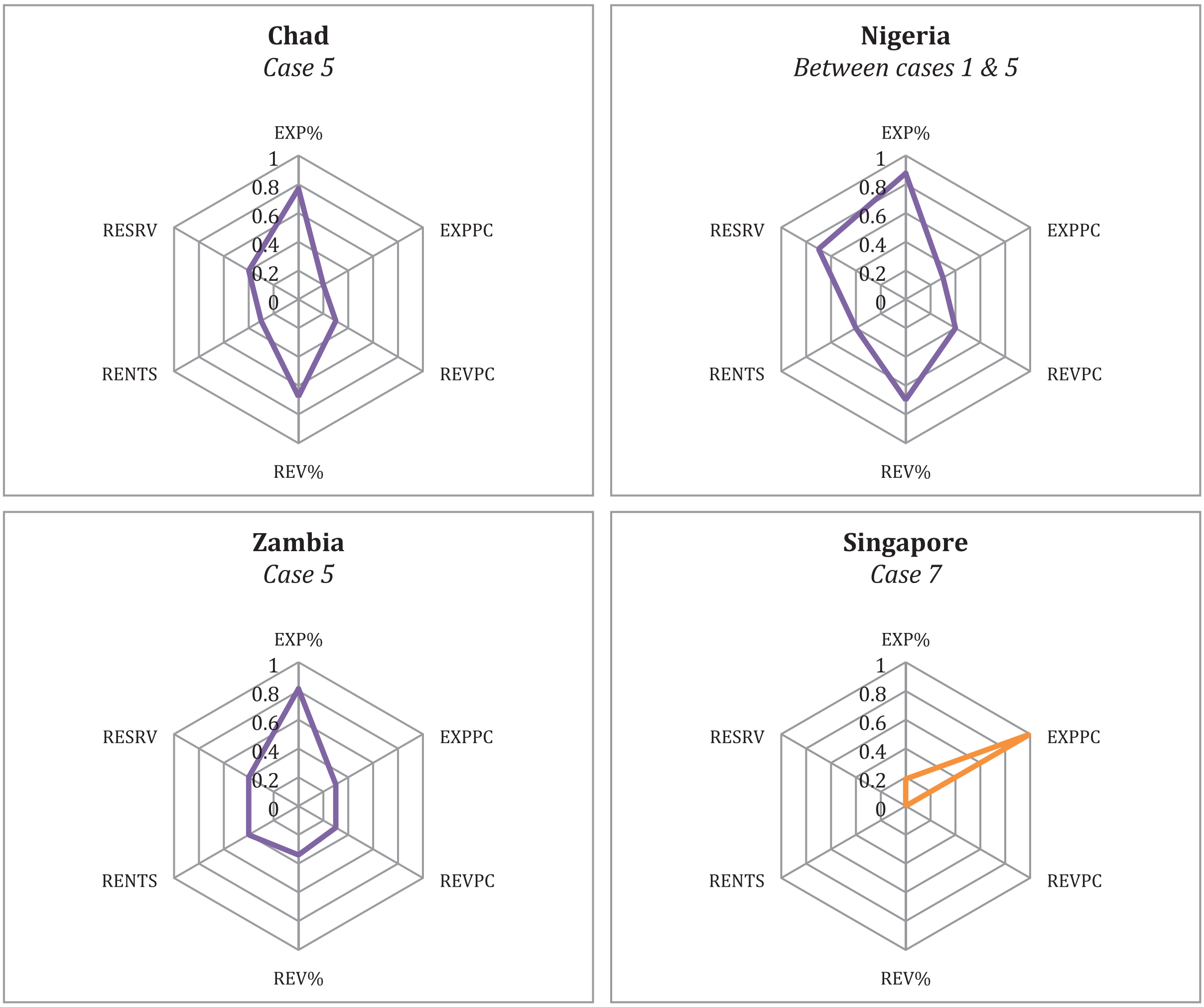


Fig. 2. Application of the MINDEX to selected countries (year 2010). EXP%: Share of extractives in total exports; EXPPC Extractives exports (in USD per capita); REVPC: Government revenues from extractives (in USD, per capita); REV%: The share of extractives in government revenues; RENTS: Extractives rents (in USD per capita); RESRV: Extractives reserves (in USD per capita). The year 2010 was chosen over more recent years to present accentuated shapes (before the commodity price drop in 2014). A comparison between 2010 and more recent years is found in Fig. 4.



EXP%: Share of extractives in total exports;
EXPPC Extractives exports (in USD per capita);
REVPC: Government revenues from extractives (in USD, per capita);
REV%: The share of extractives in government revenues;
RENTS: Extractives rents (in USD per capita);
RESRV: Extractives reserves (in USD per capita).
The year 2010 was chosen over more recent years to present accentuated shapes (before the commodity price drop in 2014). A comparison between 2010 and more recent years is found in figure 5.

Fig. 2 (*continued*)

contracts of even the large companies are secret." (Di John, 2010:19).

Other analyses also evidence the smuggling of commodities from DRC to its neighbouring countries. Smillie (2007:115) shows that in the late 1990s and 2000s, when the DRC was undergoing conflict, Belgium imported several hundred USD million worths of diamonds from Congo-Brazzaville. However, in 1999, when the political situation was more stable in the DRC, Belgium imported only USD14.4 million worth of diamonds from Brazzaville, and there was growth in imports from the DRC. [15]

Nevertheless, comparing fluctuations in commodity exports does not suffice to detect commodity smuggling (since such fluctuations can be explained by several factors, including production increases, the discovery of deposits, and so on). Instead, such irregularities can be detected more effectively and systematically by comparing changes in commodity exports with changes in other variables, as enabled through the MINDEX. Fig. 3 and Table 6 show that the jump in diamond exports in Congo (Brazzaville) between 1976 and 1980 (from USD1.2 million to almost USD40 million) has not been accompanied by an increase in diamond rents (extractive rents had even declined in that period). As a result of its multidimensional and holistic approach to resource measurement, the MINDEX can therefore be used as a diagnostic tool to detect (or at least suspect) illegal commodity smuggling by identifying abnormal spikes/drops in commodity exports in relation to commodity rents.

[15] Another example is provided by the case of Sierra Leone, where there were no government-supervised diamond exports from the 1970s to 1999, while across the border in Liberia, a country with a very low diamond production of its own, diamond exports were thriving (Smillie, 2007). Diamonds were being simply smuggled across the river to Brazzaville (ibid.).

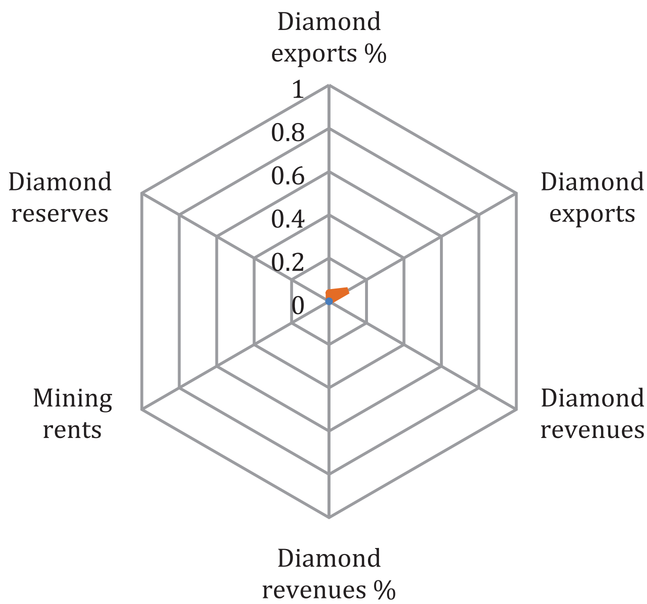


Fig. 3. Rep. of Congo *(1980). Case 7.*

Table 6
Key statistics on diamond exploitation in Rep. of Congo (Brazzaville).

Key Variables	1976	1980
Diamond exports (%)	0%	4%
Diamond exports *(USD per capita)*	3.08	56.24
Diamond revenues *(USD per capita)*	n/a	n/a
Diamond revenues (%)	n/a	n/a
Mining rents *(USD per capita)*	0.64	0.44
Diamond reserves *(USD per capita)*	n/a	n/a

Source: Author's elaboration based on the MINDEX database.

There are further policy implications that stem from a country's MINDEX, particularly concerning diversification strategies. In case 5 countries such as Chad, which is resource-dependent but resource-poor (identifiable by a vertically stretched shape of the MINDEX), the urgency to diversify *away* from extractives is very high. This 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 remain 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 & 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 import it to keep operating related industries, which may lead to a decline in competitiveness (Lebdioui, 2019a, 2019b).

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 job creation through extractive activities (assuming the viability of resource extraction and minimal social and environmental externalities), it can be argued that extractives-based development should precede (or at least go alongside) diversification.

The shape of a country's MINDEX can therefore have important diversification policy implications.

3.3.2. Evolution over time: Longitudinal analysis

A longitudinal analysis using the MINDEX can shed light on several phenomena, such as the degree of a country's vulnerability to commodity price fluctuations, the degree of its resource dependence even as commodity revenues drop, the possibility of illegal resource smuggling, or the outcomes of government efforts towards appropriating resource revenues.

3.3.2.1. Vulnerability to commodity price fluctuations and changes in terms of economic concentration. Commodity prices have a considerable impact on commodity-exporting countries. Three dates were therefore selected to analyse the changes in various countries' MINDEX following two shifts in commodity prices: 1997 and 2016 were marked by low commodity prices while 2010 was a year of commodity boom. Interestingly, for most countries, the 2016 'shape' seems to return to its 1997 'shape'. Most importantly, 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, Chile, Norway, and the UAE on the other hand. In times of low commodity prices, the striking difference between these countries is accentuated. In 1997 and 2016, while Malaysia, Chile, and Norway's MINDEX shift towards case 6 (resource-rich but diversified), Algeria's and Nigeria's MINDEX shift towards case 4 (extreme dependency), which reflects their vulnerability to commodity price fluctuations. Norway, Malaysia, and Chile have relatively managed to buffer their reliance on extractives for exports and revenues when commodity prices drop.

The case of the UAE is worth singling out. In contrast to the above-mentioned cases, the UAE has experienced a gradual and steady diversification over the past 20 years, as shown by lower degrees of reliance on extractives as a source of government revenues and exports, thereby reducing its vulnerability to commodity price fluctuations (see Fig. 4). The UAE's MINDEX has consequently gradually shifted from a case 1 in 2000 to a case 6 by 2016.

The MINDEX could therefore be useful to illustrate a country's vulnerability to commodity price fluctuations and can complement existing methods that have such an objective. For instance, breakeven prices – that is the minimum commodity price that a commodity-exporting country needs for its government to meet its immediate spending needs and balance its budget – have become popular among analysts as indicators of the economic and political stability of commodity-exporting countries. There are nevertheless important limits to the insights that breakeven prices provide and relying on them narrowly may not accurately reflect the economic constraints facing oil exporters (Clayton & Levi, 2015).[16] In contrast, the MINDEX can contribute to providing a more comprehensive picture of the types of structural vulnerabilities that given countries may be exposed to in times of commodity price bust.

[16] For instance, governments may be able to adjust their spending, borrow against future revenues, draw down existing financial reserves or allow their currency to depreciate (Clayton & Levi, 2015).

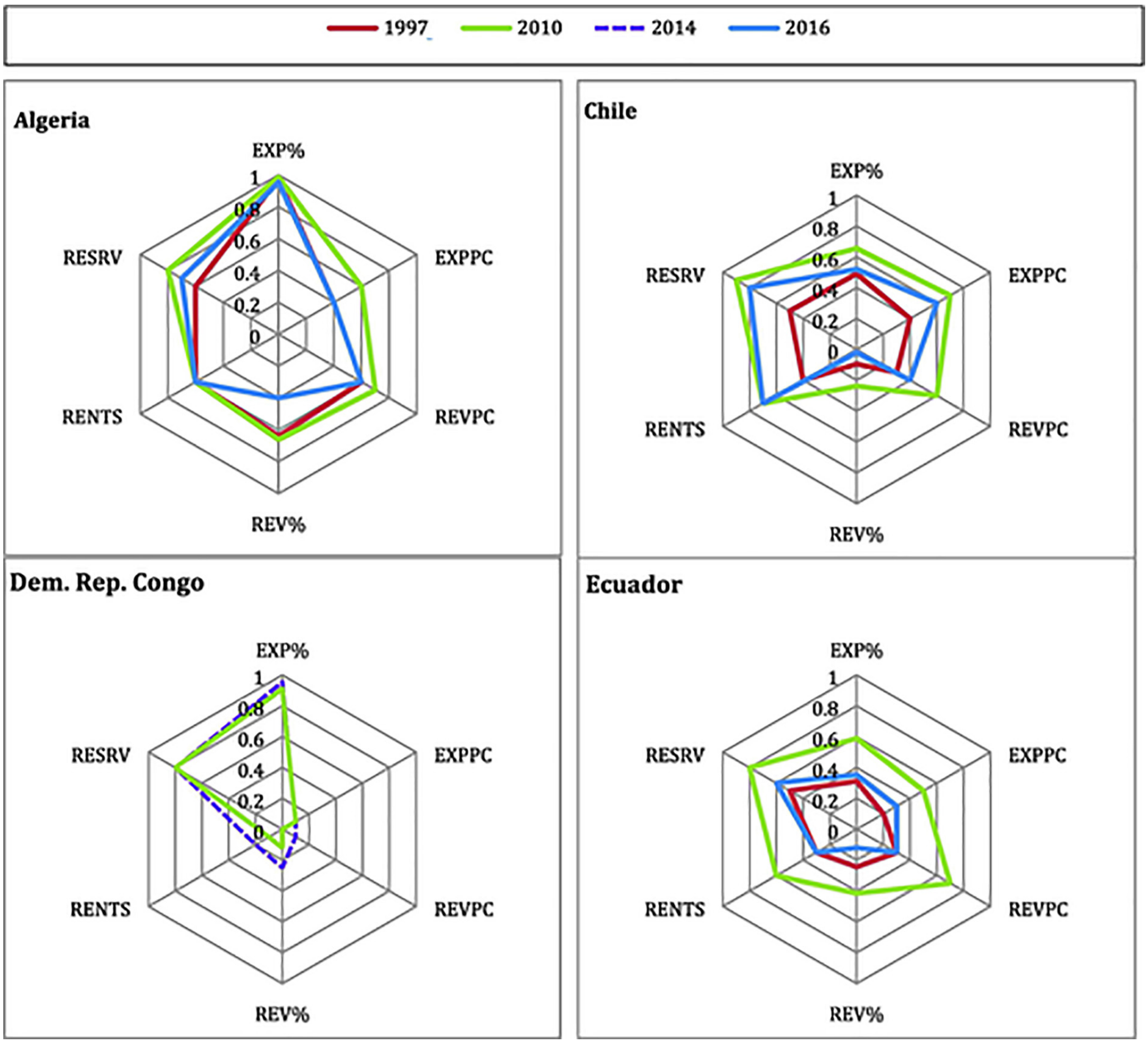


Fig. 4. Longitudinal analysis through the MINDEX for selected countries.[18] [18]Data for the year 2000 was used instead of the year 1997 for the case of the UAE due to data availability issues. EXP%: Share of extractives in total exports; EXPPC Extractives exports (in USD per capita); REVPC: Government revenues from extractives (in USD, per capita); REV%: The share of extractives in government revenues; RENTS: Extractives rents (in USD per capita); RESRV: Extractives reserves (in USD per capita).

3.3.2.2. Government appropriation of mining revenues. The diagnostic tool also suggests that more resource revenues have accrued to the government of DRC in 2014 than in 2010. This can be explained by the recent efforts from the DRC government towards appropriating more resource revenues, notably through a mining code revision process since 2012. This tool can thus serve to evaluate (and/or illustrate) the impact of policies on extractives-based development and dependence over time.

4. Limitations

This section reflects on some of the limitations of the MINDEX and how they could be address in future work. Firstly, the accuracy and reliability of the country data have been -and will most likely remain- important concerns. In few instances, there were discrepancies across different data sources (especially regarding government revenues and extractives reserves). Those challenges were addressed by choosing the most plausible values based on secondary information and analyses. In addition, given the existence of possible data discrepancies, the MINDEX's multidimensional method remains less prone to biases than unidimensional measurements of resource wealth.

Secondly, as previously mentioned, what counts as government revenues can be measured differently across countries. In some countries, profits from extractive activities are retained by SOEs. The methodological decision to leave out SOE revenues and focus on resource revenues paid to the central government can therefore significantly bias the government revenues measure in some countries where SOEs retain a large share of resource rents (e.g. Malaysia). Future updates of the MINDEX could address this issue by collecting data on profits retained by SOEs as more information becomes available. Similarly, another key concern is to distinguish federal revenues from subnational revenues. In some countries (such as the USA, the UAE, or Malaysia) resource revenues do not only accrue to the federal government but also provincial governments. The ICTD database only includes revenues captured by the central government. Future updates of the MINDEX could attempt to include revenues at the subnational level too in order to provide a more comprehensive picture of resource mobilisation dynamics.

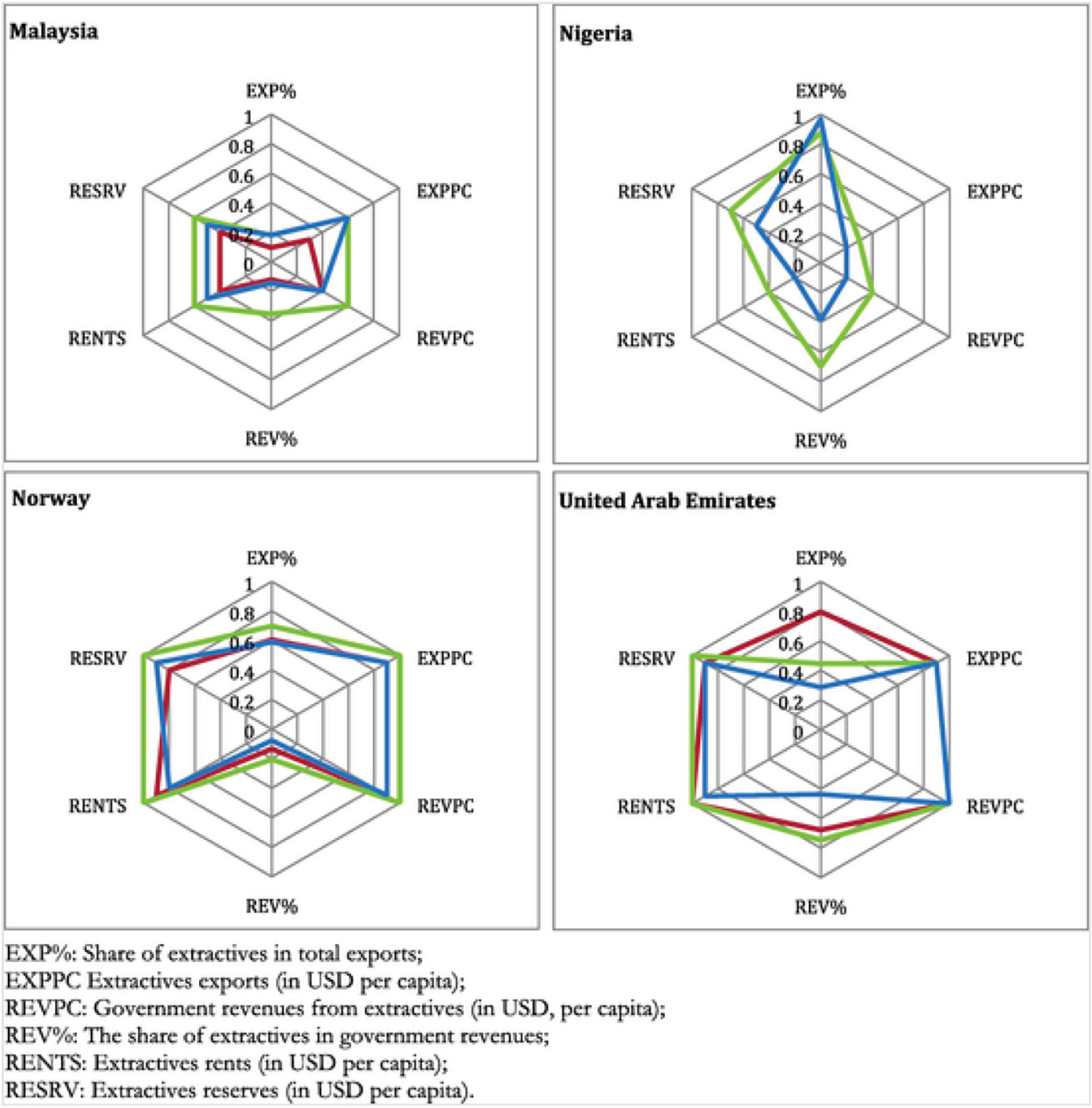


Fig. 4 (*continued*)

Thirdly, it can be questioned whether I have chosen a truly 'timeless' measure of the different variables of the MINDEX by choosing USD per capita index scores by focusing on the distribution of countries in the present time. In the long run, the role of (some) commodities could shrink (e.g. petroleum); but at the same time, some of them may rise in value as commodities get scarcer and demand increases (e.g. cobalt or lithium). The way that MINDEX is currently set up may therefore require a "smell test" every decade or so to make sure that the values are still reasonable.

Fourthly, it is important not to oversell the ability of the MINDEX's radar graphs to track on its own the impact of what are complex development problems that require further qualitative analysis. The primary intention of the MINDEX is to help detect and raise attention to potential issues in terms of how a country has been managing its extractives wealth, but such issues would need to be further examined and analysed on a case-by-case basis. As a result, rather than providing final answers, the MINDEX can help researchers and policymakers identify areas where closer attention is required.

5. Conclusion and next steps

This study has filled an important gap in the literature in the quest for more adequate measurements of natural resource wealth and dependence, which is key to informing the long-standing academic interest in analyzing the impact of natural resources on development. The research contribution of this article has been twofold:

First, it has reviewed the limitations and implications of existing methods for measuring resource abundance and dependence. Understanding the implications of choosing one type of natural resource measurement over another greatly contributes to explaining the heterogeneity of results in the literature estimating the impact of natural resources on economic growth, democracy, inequality, and development more broadly. By responding to the growing concern in the literature regarding the need to better distinguish resource abundance from resource dependence, this study also lays the ground for future research to investigate with more precision how different facets of resource wealth and dependence influence development outcomes.

Second, it has provided an alternative to existing measurements by developing a novel multidimensional indicator of resource-based development. By building on the growing recognition of the multidimensionality of resource wealth (Hailu & Kipgen, 2017; Le Billon & Good, 2016), the MINDEX represents a major rethinking of natural resource measurements and constitutes the most comprehensive database and method to evaluating resource wealth and dependence to date. Because the six variables that it integrates relate to the different steps of the resource revenue management policy chain, the method used in the MINDEX holds the potential to be used as the basis of a preliminary "diagnostic" tool that helps identify the specific challenges of extractives-based development faced by given countries at a given time. The MINDEX can indeed contribute to identifying issues related to resource exploitation, taxation, and dependence, thereby generating insights that can contribute to informing broader revenue mobilisation dynamics, which are central to development processes.

The scoring system of the MINDEX also enables to benchmark countries against the performance of other countries, which can be useful in helping to manage expectations from extractive resource endowment and discoveries as well as adapt resource mobilization and broader development strategies accordingly.[17] For instance, recent oil discoveries have urged several African countries to design and implement local content policies and led to high popular expectations for the future impact of petroleum on the domestic economy (Ovadia, 2016). However, euphoria may not be helpful, and strategies should be guided by realism (Addison & Roe, 2018). In that context, this tool enables to carefully examine the degree of resource abundance by country and helps to show that extractive resource exporters such as Chad or Mali may in fact be closer to the conditions of resource-poor East Asian countries than resource-rich countries such as Australia, Norway or Qatar. Emulating the resource-based development model of the latter countries may thus be misleading and out of reach. The need and type of resource-based development and diversification strategies also depends on a country's 'shape' of resource-richness. In such a perspective, it is hoped that future research on the MINDEX will enable the analysis of patterns over time and across countries to examine the impact of different developmental models across the different case scenarios outlined.

I am not suggesting that this alternative method is beyond criticism. The accuracy and reliability of the country data have been (and will remain) important concerns as discussed in section 4. Nevertheless, this method is less prone to biases than unidimensional measurements of resource wealth and offers a good step forward towards improving resource measurements.

Other steps forward can be identified for further improving resource wealth measurements. The MINDEX can include the generation of data with further levels of 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 becoming stranded assets) and so-called 'minerals of the future' (such as copper and lithium), which may represent key ingredients of a low carbon economy. To further acknowledge the urgency of climate change, identifying ways to discount the value of resource extraction/production/export for carbon emissions also represents an interesting area for further research that could help improve natural resource measurements.

Lastly, the MINDEX, its full dataset, and its future updates will be made available online. Democratizing access to this methodology and database (which has required over 1500 h to collect and compile) can provide researchers across academia, civil society, and government institutions with useful information to continue monitoring the developmental impact of extractive resources across countries.

[17] As phrased by Addison and Roe (2018:10): "The soaring architecture of the Gulf states, built on oil wealth, captivates the modern imagination. The scale of the potential rewards inspires explorers, miners, and investors, while politicians dream of fast-tracks to national prosperity."

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2021.105633 and will soon be made available on mindexdata.org.

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