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live wire

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Africa's Resource Export Opportunities and the Global Energy Transition

THE BOTTOM LINE

Sub-Saharan Africa has vast non-fuel mineral resources that in some countries constitute major shares of their gross domestic product. The region also contains large oil and natural gas resources, which have been reliable sources of revenue for decades. The region as a whole may be able to prosper from the global shift from oil and gas to renewable energy, but individual countries will feel the impact of the shift in different ways. To predict how these impacts may be felt—and what can be done to strengthen opportunities for export—estimates of trade elasticities of hydrocarbons and nonhydrocarbon metals and minerals provide a guide.

How might clean energy technologies change Africa's resource export markets?

The natural resources needed for renewable energy technologies may replace hydrocarbons … eventually

Sustainable Development Goal 7 aims for universal access to affordable, reliable, clean, and modern energy. Achieving the goal requires urgent action on climate change that could radically transform the global energy system. This transformation is expected to increase the demand for certain materials required in clean energy technologies and may have a dramatic effect on mineral-exporting countries. Meanwhile, likely reductions in the use of coal, oil, and natural gas would affect countries with large hydrocarbon reserves. This Live Wire examines the potential impacts of the energy transition on mineral- and hydrocarbon-rich economies in Sub-Saharan Africa (SSA) over the coming decade.

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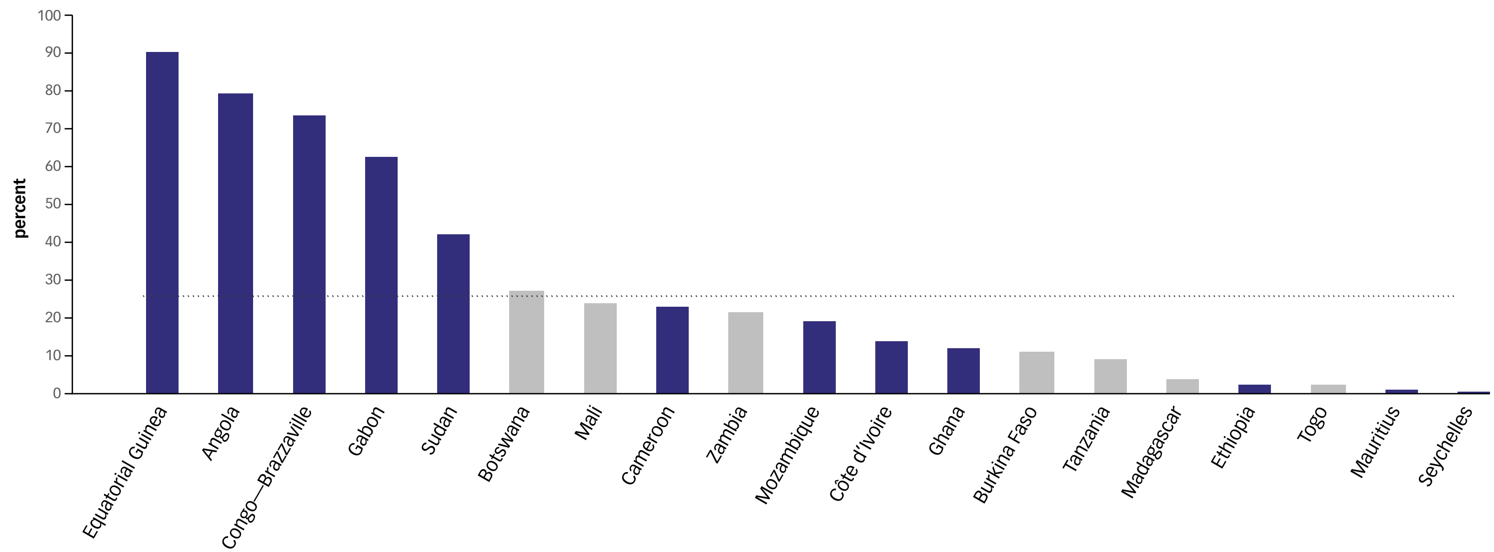
We focus here on so-called "mineral energy materials" (MEMs) such as cobalt, nickel, and copper that are expected to play an important role in the energy transition. MEMs and associated products (23 percent), together with hydrocarbons (48.5 percent), made up more than 70 percent of the value of SSA's exports to the rest of the world between 1995 and 2018. Exports of crude oil, natural gas, and metals accounted, on average, for 25 percent of government revenues in the region in 2014 (figure 1). Major oil producers include Angola, Cameroon, and Nigeria; significant potential future producers of natural gas include Mauritania, Mozambique, Senegal, and Tanzania. The *main importers* of the region's energy resources (both MEMs and hydrocarbons) include China, the European Economic Area, Japan, India, and the United States.

The export structure of MEMs and hydrocarbons has changed markedly over the past two decades, both in absolute terms and across trading partners. While hydrocarbon products remain the largest source of SSA's exports to other regions, their value has fallen sharply in recent years (figure 2, left panel). By contrast, the value of MEM exports (figure 2, right panel) has risen steadily, growing seven-fold since 1995. The export destinations have also changed over time. While the European Economic Area is a consistently large importer, since 2009 China has come to play a large and growing role in MEM imports.

Factors other than trade links are shaping the trade patterns of resource-rich SSA countries. These include difficult access to ports

While hydrocarbon products remain the largest source of SSA's exports to other regions, their value has fallen sharply in recent years, while the value of non-fuel mineral exports has risen steadily.

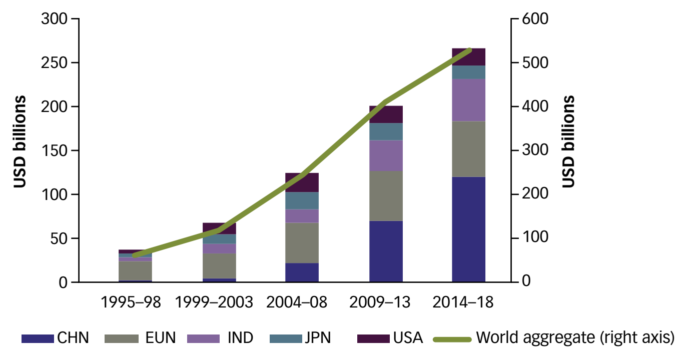
Figure 1. Natural resource exports as a percentage of government revenue for selected SSA countries, 2014
Countries whose hydrocarbon earnings exceed those from MEMs are highlighted in blue



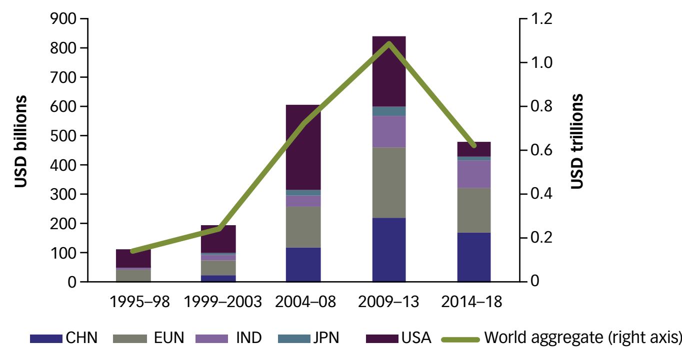
Source: Natural Resource Revenue Dataset (February 2020 version) of the Natural Resource Governance Institute (NRGI), contributed by the International Monetary Fund, the International Centre for Tax and Development (ICTD), and the Extractive Industries Transparency Initiative (EITI). NRGI defines "natural resources," as oil, natural gas, and products of mining activities. To reduce measurement error, we averaged the available estimates of all revenue contributors in each country for 2014.

Figure 2. Export structure of SSA hydrocarbons and mineral energy materials, 1995–2018, by main importers (left axis applies to bars; right axis, solid line)

Selected nonhydrocarbon mineral energy materials, their refined metals, and chemicals



Oil and gas



Source: UN Comtrade Harmonized System Code using classification version from 1992 (HS 92); cleaned for errors; reported free-on-board by the Centre for Prospective Studies and International Information; and published in the CEPII international trade database at the product level (2020).

Note: The HS chapters used for these figures are detailed in the methodological note at the end of this Live Wire. All values are in 2018 U.S. dollars.

A low *price elasticity of import demand* for a given commodity implies that prices have a small impact on export demand from a given country. A *high price elasticity of export supply* indicates that a country can boost commodity exports when prices increase.

for landlocked countries, internal social issues, underdeveloped financial sectors, and volatility of prices for both MEMs and hydrocarbons (van der Ploeg and Poelhekke 2009; Renner and Wellmer 2019).

The COVID-19 pandemic, too, is having a substantial effect on prices and exports. Following the outbreak, average yearly forecasts of Brent oil prices were revised downward from $62.7 to $39.0 a barrel in April 2020, and nickel prices were revised downward from $6.2 to $5.7 a pound that same month (S&P Global Market Intelligence). However, not all MEM prices have fallen sharply.

Mining company operations have been interrupted by viral outbreaks and government-mandated shutdowns in key exporting countries (Deloitte 2020). South Africa's lockdown, for example, temporarily disrupted 75 percent of the global output of platinum, a key material in many clean energy technologies and emissions control devices. The country later allowed mines to operate, but due to social distancing, some ran at 50 percent capacity (IEA 2020).

The Democratic Republic of Congo has experienced an even greater shock from the shutdown of the Mutanda cobalt mine owing to an unreliable supply of sulfuric acid, a key input for cobalt extraction (Reuters 2019), accompanied by reduced demand for its exports owing to COVID-19. Mining companies in Zambia, Africa's second-largest copper producer, suffered a 30 percent revenue drop during the first three months of the COVID-19 pandemic. The Zambia Chamber of Mines expects the fallout could last for at least 12 months (Reuters 2020).

Why is it important to understand trade elasticities of prices and demand?

Trade elasticities provide insights into the relative responsiveness of demand and supply

Elasticity is an important concept in economics. It measures the percentage change of one economic variable in response to a change in another. In this study, we analyze how the quantity of traded natural resources responds to changes in their prices.

The relationship between price and import demand is negative by definition. That is why, when the price elasticity of import demand is close to zero (or has a low absolute value) a country's exports will be little changed if the price of those exports rises. By contrast, the relationship between price and supply is positive. A high price elasticity of export supply (that is, one farther from zero) indicates that a country can boost commodity exports when prices increase. Therefore, from the exporter's perspective, the best combination is a low import demand price elasticity and a high export supply price elasticity relative to other exporting countries.

To analyze SSA's export attractiveness for its main importers, we assessed price elasticities for SSA's export supply and import demand over 1995–2018 for the main importers identified above.

Figure 3 plots the differences of the export supply and import demand price elasticities for the region relative to the rest of the world. The elasticities are calculated in terms of differences between elasticities for all countries in the world except for SSA, and all countries in the world including SSA. For the rationale behind this approach and details of the calculations, see the methodological note at the end of this brief.

The size of the bubbles allows us, in addition, to gauge the importance of SSA exports to the main importers. (MEMs are shown in red, hydrocarbons in purple.) The price elasticity of export supply is positive by definition. A negative value on the y-axis indicates that adding SSA to the sample increases the elasticity of supply, an advantage for SSA exporters. Recall that the price elasticity of import demand is negative by definition. A negative value on the x-axis suggests that adding SSA to the sample brings the elasticity of demand closer to zero (and a lower absolute value), which is also an advantage for SSA exporters. On the opposite side, positive values on both axes of figure 3 suggest that SSA has relatively lower export supply and relatively higher import demand price elasticities than the rest of the world, a disadvantage for SSA exporters.

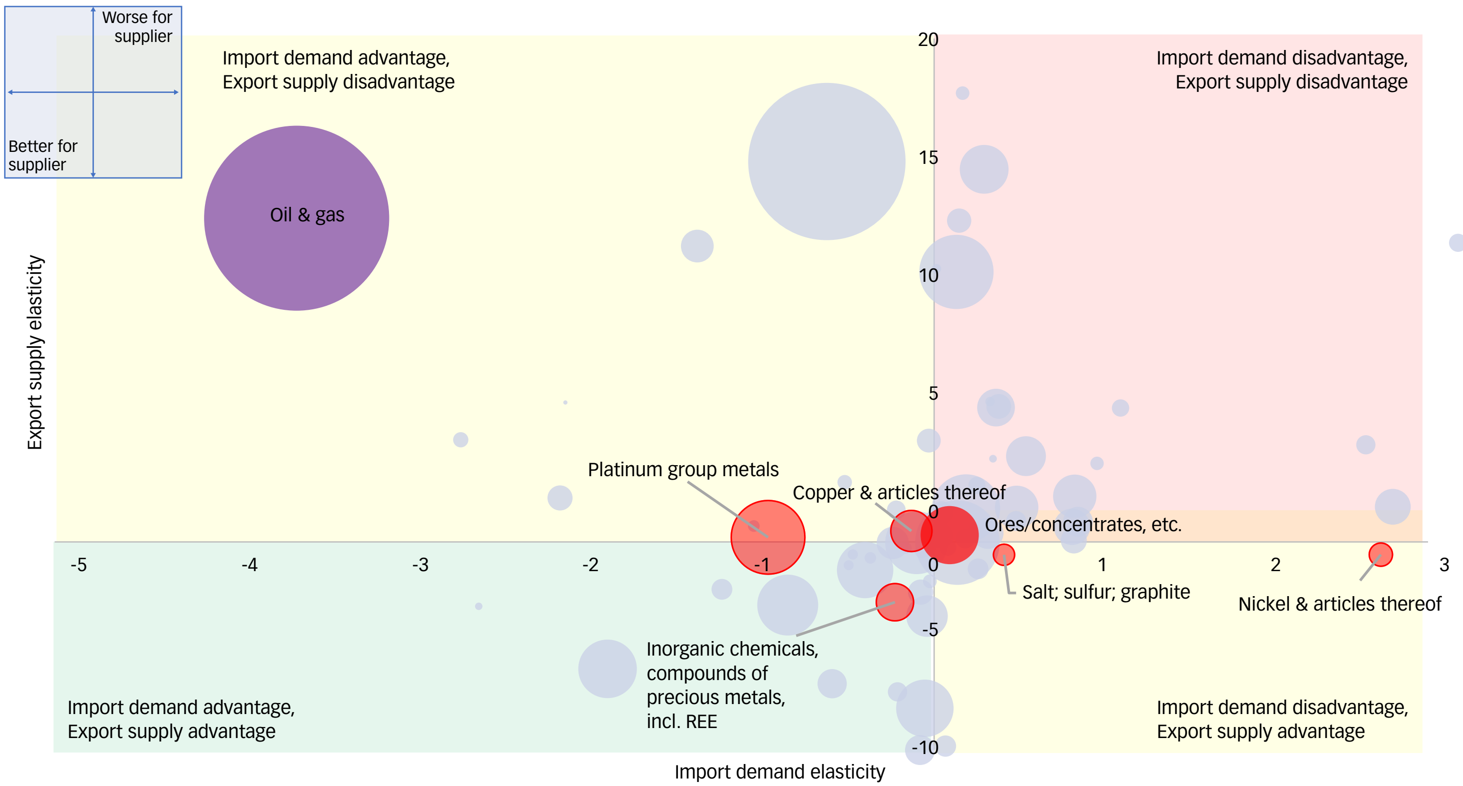
The results suggest that, among MEMs:

- Nickel, salt, sulfur, and graphite exports from the region have a relative advantage in terms of elasticity of export supply and a relative disadvantage in terms of elasticity of import demand, compared with exports from elsewhere in the world. This means exports can respond relatively more on the supply side, while importer demand is relatively more responsive to a given change in prices.

- Platinum group metals and copper exports from SSA have a relative advantage in terms of elasticity of import demand and a relative disadvantage in terms of elasticity of export supply compared with the exports from elsewhere in the world.
- Inorganic chemicals, including rare-earth metals, have a relative advantage in terms of both import demand and export supply elasticities.
- Ores and concentrates exports from the region have a relative disadvantage in terms of both import demand and export supply elasticities.
- As for hydrocarbon exports, compared with exports from the rest of the world, SSA has a relative *advantage in terms of elasticity of import demand* and a relative *disadvantage in terms of elasticity of export supply*.

Over recent decades the share of primary exports from SSA to the leading MEM importer, China, has soared for all major primary commodity categories, except for ores and metals.

Figure 3. Export supply and import demand elasticities of SSA exporters to main importers, relative to rest of world, by chapter of the Harmonized System



Source: UN Comtrade Harmonized System Code using classification version from 1992 (HS 92); cleaned for errors; reported free-on-board by the Centre for Prospective Studies and International Information; and published in the CEPII international trade database at the product level (2020). Elasticity calculations based on authors' modification of Broda and Weinstein (2006) and Soderbery (2015).

Note: For details pertaining to the Harmonized System (HS), see the methodological note at the end of this brief.

What can trade elasticities tell us about export prospects for the region's resources?

Elasticity estimates indicate that for some MEM's (such as rare-earth metals and inorganic chemicals), SSA is relatively well positioned, compared with the rest of the world, to meet the growing demand

They also suggest that the region's exports of hydrocarbons, such as crude oil and natural gas, along with platinum group metals and copper, are relatively less responsive than other MEMs to import price fluctuations. On the one hand, the estimates mean that falling hydrocarbon prices may affect SSA export revenues to a lesser extent than the rest of the world. On the other, the SSA's exports of metal ores are less able to take advantage of improving market conditions compared with those of other exporters in terms of trade elasticities.

To analyze how the global energy transition might affect the export value of major SSA resources, we estimated trade elasticities for several commodities at a more disaggregated level, and applied the calculated elasticities to existing price forecasts. The analysis was done for oil, cobalt, nickel, and copper (figures 4–7). The selection of commodities was based on availability of price forecasts and the importance of trade for SSA. For instance, figure 7 focuses on copper cathodes (HS 7405) both because these are important for SSA and because there are sufficient data to estimate elasticities for them.

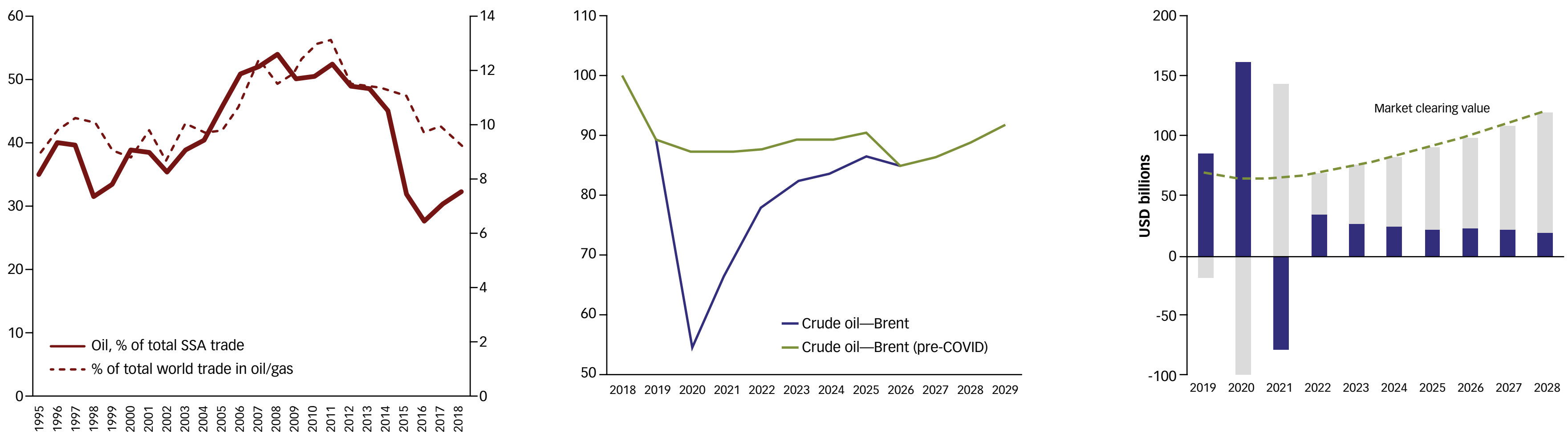
> The COVID-19 pandemic has drastically altered the demand for and price of crude oil, the main export commodity of the region. Prices are not expected to regain pre-COVID-19 levels until 2026.

Figure 4. Forecast factors of hydrocarbon exports

Oil, % of total SSA trade (solid line; left axis), % of total world trade in oil (dashed line; right axis)

Oil (Brent), price forecast, 2018=100

Crude oil, estimated SSA export value in current USD, price elasticity of demand effect (blue) and other factors (gray)



Source: UN Comtrade Harmonized System Code using classification version from 1992 (HS 92); cleaned for errors; reported free-on-board by the Centre for Prospective Studies and International Information; and published in the CEPII international trade database at the product level (2020). Price forecasts are from S&P Global Market Intelligence. Elasticity calculations are based on authors' modification of Broda and Weinstein (2006) and Soderbery (2015).

Note: We were not able to calculate elasticities for all major importers. India and the United States are missing from this data.

Each figure has three columns presenting the following data:

- The importance of SSA in world trade for that product, and the importance of the product in total SSA trade
- The price forecast for the commodity, according to S&P Global Market Intelligence
- The export value forecast for the product, accounting separately for the price effect (based on the estimated import demand elasticities and the price forecasts), and the effect of other factors, such as income and technological change.

The COVID-19 pandemic has drastically altered the demand for and price of crude oil, the main export commodity of the region (which constituted about 30 percent of its total trade value in 2018). As of the date of this analysis, prices were not expected to regain pre-COVID-19 levels until 2026, while ranging from 54 to 91.5 index points over the period 2019–28. The positive effect of effect of lower prices on demand in 2020 exceeds negative price effects on supply and other factors, and the market clears at about $75 billion. But the future growth of oil export revenues in Africa is expected to be modestly positive in the coming decade.

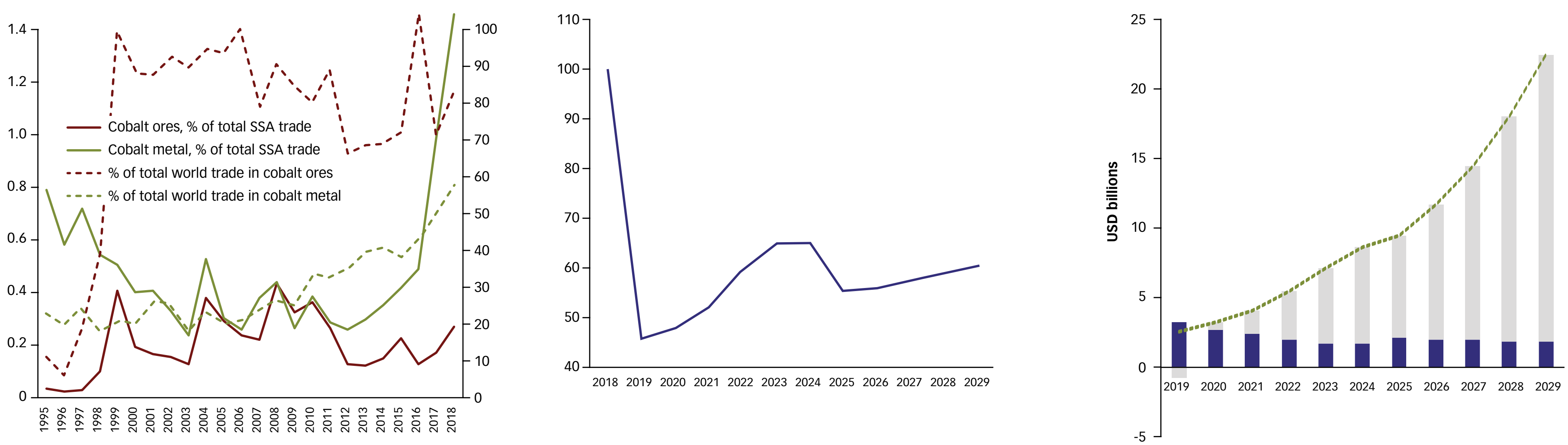
Cobalt prices are expected to make a modest recovery after the 2019 collapse (figure 5). The positive effect of elasticity of import demand owing to the price shock of 2019–20 is notable in the near term but is expected to diminish when compared with other factors, such as increasingly greater demand for energy storage in transport, power, and consumer electronics. This creates an opportunity for future export revenue growth for the region's cobalt exporters, particularly the Democratic Republic of Congo.

Figure 5. Forecast factors of cobalt exports

Cobalt ores (red) and metal (green), % of total SSA trade (solid line; left axis), % of total world trade in cobalt (dashed line; right axis)

Cobalt, price forecast, 2018=100

Cobalt ores, estimated SSA export value in current USD, price elasticity of demand effect (blue) and other factors (gray)

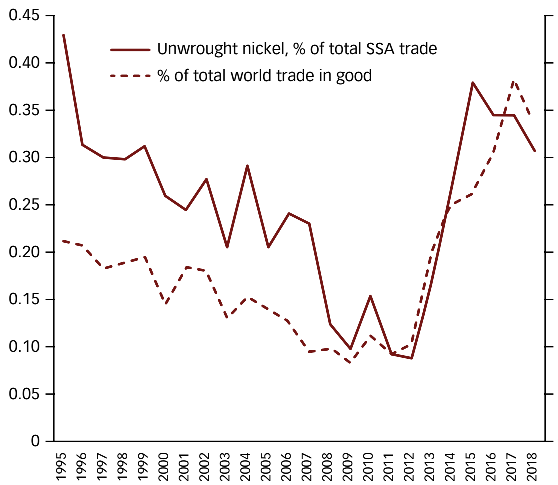


Source: UN Comtrade Harmonized System Code using classification version from 1992 (HS 92); cleaned for errors; reported free-on-board by the Centre for Prospective Studies and International Information; and published in the CEPII international trade database at the product level (2020). Price forecasts are from S&P Global Market Intelligence. Elasticity calculations are based on authors' modification of Broda and Weinstein (2006) and Soderbery (2015).

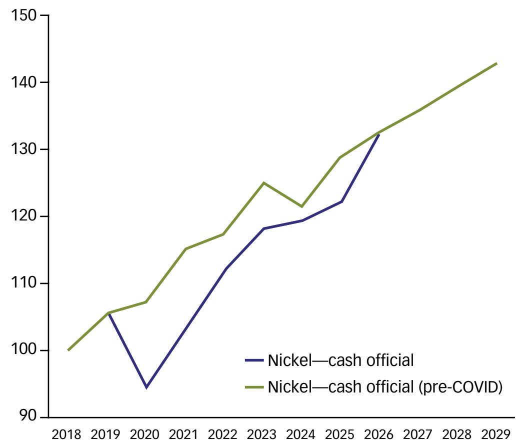
As with other MEMs, nickel price forecasts (figure 6) have been revised downward through about 2026 owing to the COVID-19 pandemic. The effect of the pandemic on price forecasts is, however, less severe in comparison with oil. Between 2019 and 2029, prices are expected to rise by 94 to 139 index points for nickel. The corresponding figures for copper are 91 to 130.5 index points (figure 7). The positive effect of import price elasticity of demand in the near term contributes a larger portion of the market-clearing value for copper than for nickel, suggesting that other factors may affect the growth of the SSA nickel market. This should benefit major SSA exporters, such as Zimbabwe and Côte d'Ivoire, since the export supply elasticity is relatively high for these commodities in Africa. It also means that African producers have shown their ability to expand export supply in response to global macroeconomic factors.

Figure 6. Forecast factors of nickel exports

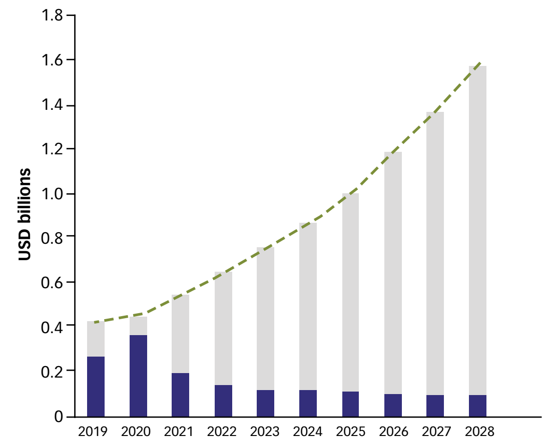
Unwrought nickel, % of total SSA trade (solid line, left axis), % of total world trade in good (dashed line, right axis)



Nickel, price forecast, 2018=100



Nickel, unwrought/not alloyed, estimated SSA export value in current USD, price elasticity of demand effect (blue) and other factors (gray)



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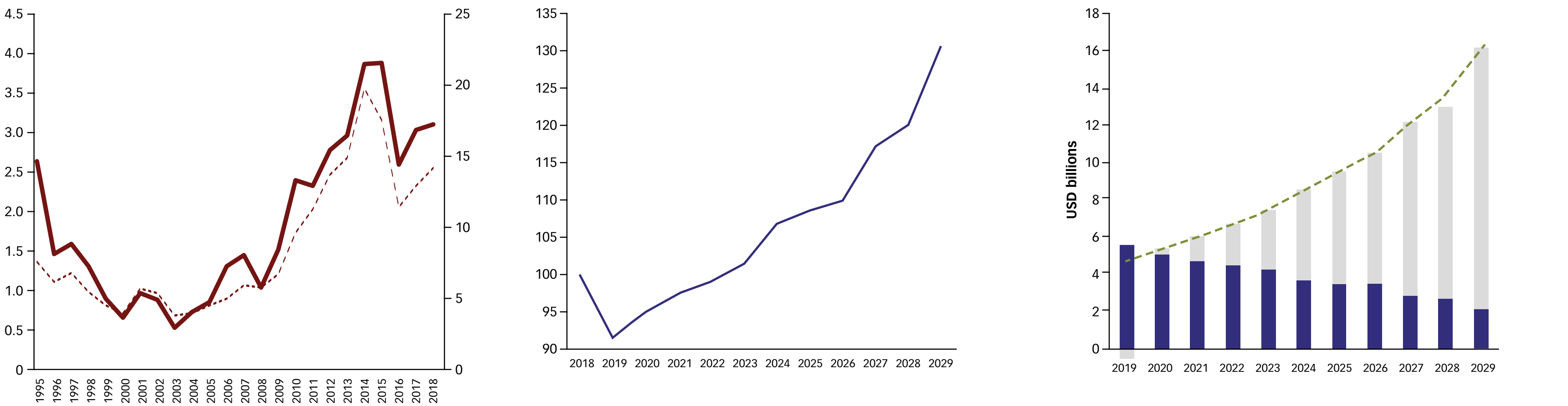
Note: We were not able to calculate elasticities for all major importers. China and the European Economic Area are missing from this data.

Figure 7. Forecast factors of copper exports

Copper cathodes, % of total SSA trade (solid line, left axis), % of total world trade of good (dashed line, right axis)

Copper, price forecast, 2018=100

Copper cathodes, estimated SSA export value in current USD, price elasticity of demand effect (blue), and other factors (gray)



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What is the outlook?

Countries with significant MEM reserves have an opportunity to expand their exports and capture the potential of the global energy transition and the recovery from COVID-19

Our trade elasticity analysis suggests that the region's MEM exporters will have to become more export responsive in order to take advantage of anticipated rising demand from the global energy transition.

The elasticity results also suggest that SSA hydrocarbon producers face relatively low demand import elasticity compared with the rest of the world. This implies that there remains a potential for hydrocarbons to remain a significant source of export revenues over the short to medium term. As global oil and gas demand may begin to decline permanently as the global energy transition progresses, SSA hydrocarbon producing countries will need to adapt to these new market conditions. For the moment, however, they still have some time to manage an orderly transition away from fossil fuels.

As global oil and gas demand begins to decline permanently with the global energy transition, SSA hydrocarbon producing countries will need to adapt. For the moment, however, they still have some time to manage an orderly transition away from fossil fuels.

Methological note: Calculation of trade elasticities

Feenstra (1994) and Broda and Weinstein (2006) showed us how to compute demand and supply (import and export) trade elasticities. They used customs data to track changes in the relative share of goods over time and varieties (an exporter–good pair for each importer country).

We use the Stata codes provided by Soderbery (2015) for the calculation. The input to the STATA do-file consists of UN Comtrade data cleaned by CEPII and updated yearly. More details are available from CEPII. The model requires five input variables from customs data: trade year, product traded, exporter, quantity, and value. Each input file, and set of results, is for a given importer.

Taking the narrowest possible interpretation of results, we introduced the five input variables for a certain country's imports from across the globe. This yields a measure of how China, for example, shifts its demand for a certain good from one exporter to another in response to price changes. On the supply side, the model yields a measure of how exporters allocate their production to China among themselves when a good's price changes. Therefore, the output is technically the constant elasticity of substitution (CES), though Krugman (1980) shows that it becomes the *trade demand elasticity* when the number of varieties is large. In this case, we are using all possible varieties available in real-world data.

The data in figures 2 and those highlighted in figure 3 are from the following chapters of the UN Comtrade Harmonized System Code using the 1992 classification (HS 92): chapters 25-28, 71, 74-75, and 81. Specifically, HS chapter 25 contains salt; sulfur; earths and stone; plastering materials, lime, and cement. Chapter 26 contains ores, slag and ash, and Chapter 27 contains hydrocarbons (oil, gas), mineral oils and products of their distillation; bituminous substances; mineral waxes. Chapter 28 contains inorganic chemicals and organic or inorganic compounds of precious metals, rare-earth metals, radioactive elements, or isotopes. Chapter 71 includes natural or cultured pearls, precious or semiprecious stones, precious metals (including platinum group metals), and metals clad with precious metal. Chapters 74 and 75 contain copper and nickel, and their articles thereof, respectively. Finally, Chapter 81 contains base metals not otherwise specified in other HS chapters and their articles.

The results in figure 3 are from estimating the model for each major importer separately, and then weighing the results by each importer's share of trade in the group. This yields an overall trade elasticity for all major importers, by chapter of the Comtrade Harmonized System. When it comes to extracting usable estimates for a region as a whole, it is not possible to limit the input data to that region because, in a narrow sense, this would simply show how an importer shifts its demand for a certain good from one exporter to another when prices change. In our example, we would obtain a measure of how China distributes its import demand among the SSA countries when prices change. We prefer to avoid the broad interpretation used above because the quantity of varieties is more restricted in a regional sample.

To obtain the desired interpretation of how the region's exports stand in comparison with the world's exports, we compare the model estimates of two samples. The first is for the world excluding SSA; the second, for the entire world. The direction of the change between these two samples reveals whether the SSA countries have made importers more or less responsive.

The estimation output consists of 11 variables, which include product, reference country, σ, and ω. We report the negative of σ (CES import demand elasticity) and the inverse of ω (the CES export supply elasticity). As an added note for those well versed in the literature, we make sure the outputs are comparable by choosing the same reference country in both samples.

In figures 4–7, we disaggregate estimates further by product, converting the CES trade elasticity for all main importers to the trade demand elasticities for the SSA products based on Ramskov and Munksgaard (2001).

MEMs chosen for analysis, with UN Comtrade Harmonized System codes

	Commodity	Expected change, 2050 (percent)	SSA share of world production (2017)	Comtrade chapter (HS2)	Comtrade good, (HS4 or HS6)
1	Cobalt	+585	66.5	26, 28, 81	2605, 2822, 8105
2	Vanadium	+173	15.7	26	261590
3	Graphite	+383	2	25	2504
5	Lithium	+965	1.6	28	282520, 283691
6	Manganese	+2	49.44	26, 28	2602, 2820
7	Chromium	—	51.12	26	2610, 2819, 8112 (various)
8	Nickel	+108	6.16	75	75, various
9	Copper	7	10.21	74	74, various
10	Rhodium	-46	86.31	71	711031, 711039
11	Platinum	—	79.9	71	711011, 711019
12	Palladium	—	44.3	71	711021, 711029
13	Crude oil	—	5.2	27	2709
14	Natural gas	—	1.8	27	2711

Source: La Porta and others (2017); UN Comtrade. Data on expected change for rhodium are from Bloomberg New Energy Finance (2019). Data on SSA percentage of world production are from Federal Ministry of Agriculture, Regions, and Tourism (2020).

Note: — = data not provided in La Porta and others (2017)

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References

Bos, Kyra, Joyeeta Gupta. 2019. "Stranded assets and stranded resources: Implications for climate change mitigation and global sustainable development." *Energy Research and Social Science* 56 (Oct.): 101–215.

Broda, Christian, and David E. Weinstein. 2006. "Globalization and the gains from variety." *Quarterly Journal of Economics* 121(2): 541–85.

Deloitte. 2020. "Understanding COVID-19's impact on the mining and metals sector. Guidance for mining and metals executives." https://www2.deloitte.com/global/en/pages/about-deloitte/articles/covid-19/understanding-covid-19-s-impact-on-the-mining---metals-sector---.html

Federal Ministry of Agriculture, Regions, and Tourism. 2020. World Mining Data 2020. Vienna. https://www.world-mining-data.info/wmd/downloads/PDF/WMD2020.pdf.

Feenstra, Robert. 1994. "New product varieties and the measurement of international prices." *American Economic Review* 84(1): 157–77.

Hund, Kirsten, Daniele La Porta, Thao P. Fabregas, Tim Laing, and John R. Drexhage. 2020. "Minerals for climate action: The mineral intensity of the clean energy transition." Climate-Smart Mining Facility. World Bank, Washington, DC.

IEA (International Energy Agency). 2020. "Clean energy progress after the Covid-19 crisis will need reliable supplies of critical minerals." Paris. https://www.iea.org/articles/clean-energy-progress-after-the-covid-19-crisis-will-need-reliable-supplies-of-critical-minerals

La Porta, Daniele, Kirsten L. Hund, Michael S. McCormick, Jagabanta Ningthoujam, and John R. Drexhage. 2017. "The growing role of minerals and metals for a low-carbon future." World Bank, Washington, DC. http://hdl.handle.net/10986/28312

Mayer, Jörg, and Pilar Fajarnes. 2008. "Tripling Africa's primary exports: What, how, where?" *Journal of Development Studies* 44(1): 80–102.

Ramskov and Munksgaard. 2001. "Elasticities: A Theoretical Introduction." https://www.researchgate.net/publication/255575591_Elasticities_-_a_Theoretical_Introduction

Renner, Sven, and Friedrich W. Wellmer. 2019. "Volatility drivers on the metal market and exposure of producing countries." *Mineral Economics*. https://doi.org/10.1007/s13563-019-00200-8.

Reuters. 2019. "Glencore's Mutanda mine in Congo shuts a month early." *Consumer Goods and Retail*, November 26.

Reuters. 2020. "Zambia mining revenues drop 30% due to COVID-19, Chamber of Mines says." *Business News*, June 18.

Soderbery, Anson. 2015. "Estimating import supply and demand elasticities: Analysis and implications." *Journal of International Economics* 96(1): 1–17.

Sovacool, Benjamin K., Saleem H. Ali, Morgan Bazilian, Ben Radley, Benoit Nemery, Julia Okatz, and Dustin Mulvaney. 2020. "Sustainable minerals and metals for a low-carbon future." *Science* 367(6473): 30–33.

Van der Ploeg, Frederick, and Steven Poelhekke. 2009. "Volatility and the natural resource curse." *Oxford Economic Papers* 61(4): 727–60.

Wellmer, Friedrich W., Peter Buchholz, Jens Gutzmer, Christian Hagelüken, Peter Herzig, Ralf Littke, and Rudolf K. Thauer. 2018. *Raw Materials for Future Energy Supply.* Springer.

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