



22-1 Shift to Renewable Energy Could Be a Mixed Blessing for Mineral Exporters

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INTRODUCTION

The world's transition to sustainable energy systems has suddenly become a boon to countries rich in critical minerals used in clean energy technologies like rechargeable batteries, solar panels, wind turbines, and electric vehicles. But these countries may find their newfound wealth to be a mixed blessing.

That was the experience in the 20th and early 21st centuries for countries endowed with vast petroleum resources. Some fossil fuel-exporting countries became extravagantly wealthy. But oil exporters are in the main less democratic, less healthy, less economically stable, and more prone to civil unrest than countries without oil. Venezuela, for example—once one of Latin America's most prosperous and stable democracies—descended into authoritarianism, instability, and macroeconomic chaos as oil prices surged in the early 2000s. Nigeria's oil wealth helped foster a corrupt regulatory environment estimated to cost the country roughly \$1,200 per person—nearly a third of GDP per capita (PricewaterhouseCoopers 2014)—and fueled separatist conflicts in the Niger Delta. These ills flow from the “paradox of plenty” (Karl 1997, Ross 2012), in which wealth distorts the development of political and economic institutions, invites more meddling by major powers in resource-rich countries' domestic affairs, and emboldens more aggressive and violent foreign policies.

The hydrocarbon age is approaching twilight, as the European Union, China, and the United States begin decarbonizing their energy systems in earnest. Before 1850, oil and natural gas played no widespread role in human society. At some point in the 21st century, they will most likely return to that status. Will this change mean an end to the resource curse?

Decarbonizing global energy systems will spur demand for and a shift in geopolitical attention from hydrocarbon reserves to the critical minerals that underpin solar, wind, geothermal, and other forms of renewable energy, as well as electric vehicles: aluminum, coltan, copper, aluminum, zinc, tin, rare earths, lithium, tantalum, and cobalt, among others. Many of these minerals are valuable. Cobalt,

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for example, currently trades for almost \$55,000 per metric ton, and tantalum trades for \$160,000 per metric ton. These minerals are mined in countries such as the Democratic Republic of the Congo (cobalt) and Guinea (bauxite), which are already beset by “cursed” dynamics. Many (if not all) of these minerals are on the list of 35 “critical minerals” published by the US Department of the Interior in 2018.

Global production of some of these minerals will need to increase by a factor of 3-44 to meet the renewable energy and emissions targets established by the Paris Agreement (IEA 2021). These minerals are not just key to fueling the energy transition; as advanced militaries look for ways to reduce their own carbon footprints, these resources will become increasingly critical for the projection of military power. Both their economic and strategic significance will therefore rise.

Given that these minerals are critical to building sustainable energy systems, vital for ensuring military might, and often extremely valuable, will countries with large, exportable endowments of these minerals fall prey to the resource curse? The answer is complicated. With respect to domestic political economies, the answer is a qualified no. The size of the markets for these resources and their marginal production costs suggest that they do not have the potential to generate massive rents the way that oil and gas production has. Given that those rents are the source of many ills—authoritarianism, reduced investment in human capital, poor human rights records—this is good news. But because several of these minerals can be mined artisanally, they may lead to governance challenges related to armed conflict.

Their status as strategic resources will invite major power meddling and interventions—but only if mineral-rich economies are forced to align themselves and access to their resources with a major power, like the United States or China. So far, these countries have not been forced to do so. To ensure that they do not have to make this choice, mineral-rich countries should cultivate diverse investment and trading relationships, in order to balance major power interests in their mineral wealth and welcome both industry- and civil society-led good governance initiatives around mineral resources. Mineral-rich countries need not follow the same cursed path as their oil- and gas-rich counterparts.

DOMESTIC DIMENSIONS

In the domestic political economy, the resource curse results from two sources: (a) a surfeit of rents—or revenue greater than the cost to bring the product to market—generated by the export of lucrative natural resources and (b) the lootable nature of some types of mineral wealth.

Both oil and gas are characterized by high start-up costs but massive economies of scale, resulting in low marginal costs of production. These rents affect domestic politics and economics through a variety of channels. Because these rents are easily captured by the government—via either export taxes or direct control of the resources via national-owned or parastatal companies—they obviate the need for governments to depend on their citizens for revenue.

This outcome affects domestic politics through three main channels. First, released from the need to extensively tax their populations, governments need not defer to the policy preferences of their citizens or include them in decision-making: “No taxation without representation” becomes “no taxation, no

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representation.” They also need not invest in the bureaucratic and administrative capacity necessary to monitor the economy and collect taxes. Rent-rich countries, particularly oil- and natural gas-exporting countries, have much more authoritarian governments and lower levels of state capacity than their non-resource-rich counterparts (Andersen and Ross 2014, Hendrix 2018, Masi and Ricciuti 2019).¹

Second, rent-rich governments have fewer incentives to invest in high-quality public health and education, as high-quality human capital stocks are not the driver of economic growth. This is particularly evident in their responses to public health crises (oil- and natural gas-rich countries had systematically higher levels of HIV/AIDS infection than other countries, for example [de Soysa and Gizelis 2013]). Rent-rich governments may spend lavishly on education, particularly primary and secondary education, but this spending does not translate into better outcomes: Oil-rich countries perform more poorly on both objective and subjective indicators of quality of education (Farzanegan and Thum 2020).

Third, rent-rich governments have plenty of resources to invest in both patronage and repressive capacity. The differing responses to and outcomes of the Arab Spring uprisings of 2010–11 are instructive. Oil-rich regimes in the Middle East were much more effective at fending off these pro-democracy movements; only oil-rich Muammar al-Qaddafi’s regime in Libya fell to rebels—and they would have been crushed but for NATO intervention and support (Ross 2011). Saudi Arabia used its military might to quell the uprising in neighboring Bahrain. Kuwait responded to domestic pressures not with sticks but with carrots, with the government announcing that all citizens would receive grants of 1,000 Kuwaiti dinars (about \$4,400 in 2021 dollars) and free food staples for 13 months (Hendrix and Noland 2014). Those kinds of concessions will keep a lot of people off the streets.

If this element of the domestic resource curse ultimately boils down to the ill effects of the rents resource exports generate, the relevant question is whether the minerals that will fuel the energy transition generate—or have the potential to generate—similar rents.

The answer is no. Oil and gas are in a class by themselves in terms of both the size of the global market and the rents they can generate. Export revenues are comparatively easy for oil- and gas-rich governments to capture, via either direct state ownership or taxes and licensing fees. Total global exports of crude petroleum and liquefied natural gas were \$1.3 trillion in 2019, compared with \$60 billion for copper ore and \$5.7 billion for bauxite (OEC 2021).

Oil and gas rents can be substantial, depending on how oil and gas are extracted. The market value of a metric ton of oil in Saudi Arabia is almost \$500—about 13 times the marginal cost of production of about \$40.² The margins for most minerals are nowhere near that high. Nickel currently sells for about 50 percent more than its extraction and refinement costs. The margin

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1 Masi and Ricciuti (2019) find that oil discoveries have negative long-term consequences for democracy, though not if the country was a consolidated, highly institutionalized democracy before the discovery (e.g., Denmark and Norway, whose oil production did not begin until the early 1970s).

2 As of January 3, 2022: \$77.35 for Brent crude.

for copper is closer to 2-to-1, and margins for cobalt are about 2.5-to-1. Total export volumes and rents are thus much, much lower for transition minerals than for oil and gas.

These dynamics—smaller global markets, higher marginal production costs—suggest that the minerals that will fuel the energy transition will not have similar rent-generating potential. Table 1 compares the export values of liquefied petroleum gas (commonly known as liquefied natural gas, or LNG); oil; and various energy transition-dependent minerals. The gap between LNG and oil and the next highest value is vast—and this measure does not account for the huge differences in marginal production costs. Most critical minerals do not have the vast rent-generating potential of oil and gas. One should therefore not expect them to have similarly adverse consequences for exporting countries' domestic politics.

Table 1
Top exporters of traditional fuels and energy transition-dependent minerals, 2019

Commodity	Largest exporter	Exports per capita (US dollars)
Liquefied petroleum gas	Qatar	15,342
Crude petroleum	Saudi Arabia	4,165
Copper ore	Chile	958
Bauxite	Guinea	215
Zinc	Australia	66
Cobalt	Democratic Republic of the Congo	21
Nickel	Indonesia	4

Source: Author's calculations based on data from the Observatory of Economic Complexity (OEC 2021), as elaborated in Simoes and Hidalgo (2011); and World Bank (2021).

Domestic politics around these minerals will not be completely anodyne. Several critical minerals—especially high-value ones that can be mined artisanally, without large capital costs—have already been the source of domestic conflict. Fighting between and human rights abuses by armed groups in the Democratic Republic of the Congo over control of its tantalum, tungsten, and tin (the 3Ts) and gold deposits were the impetus for Section 1502 of the Dodd-Frank Act of 2010, which imposed stringent reporting requirements on US companies sourcing these “conflict minerals” from the region. Antimony and tin have been linked to conflict and/or human rights abuses in Afghanistan, the Central African Republic, Myanmar, Zimbabwe, and other countries (Global Witness 2021). Even more capital-intensive mining projects can result in protests, repression, and human rights abuses when mining companies fail to solicit and maintain a social license to operate in their host communities.

INTERNATIONAL DIMENSIONS

Aside from the effects of some critical minerals on political instability, there is limited reason to worry that the energy transition will lead to “oil curse”-esque dynamics in major mineral-rich and mineral-exporting countries. But domestic dynamics are just part of the story. Greater potential for “cursed” dynamics may lie in the way these resources shape exporting countries’ relations with major importers and powers.

Like oil, the minerals that will fuel the energy transition are strategic resources, necessary for building, supplying, and deploying modern militaries and securing the viability of the economies that sustain them. Maintaining access to and securing supply lines for these resources shapes the foreign policies of major economies and military powers to a significant degree, with both domestic political and second-order effects for the foreign policies of exporting countries.

Oil was the most important strategic resource in the 20th century; it will continue to be among the most significant for some time. Other than the United States and the Soviet Union/Russia, all of the mid-20th century major powers (Germany, France, the United Kingdom, Italy, Japan, and China) and current permanent members of the UN Security Council are highly dependent on oil imports and thus sensitive to the political dynamics in exporting countries.

The major powers secured access to oil through close relationships between their governments and private or state-owned/affiliated firms that operate in partnership with local governments (British Petroleum; French Petroleum Company/Total; Standard Oil’s successors [Amoco, Chevron, ExxonMobil]; and the Chinese National Petroleum Company and China National Offshore Oil Corporation [CNOOC Ltd.]). When these partnerships failed to produce benefits for host-country non-elites, they provided fuel for populist politicians—from Mohammed Mosaddegh in Iran and Abd al-Karim Qasim in Iraq in the 1950s and 1960s to Venezuela’s Hugo Chávez in the 2000s—to exploit popular rancor and promote plans to either renegotiate with foreign oil companies or nationalize their assets.

Fearing loss of access, the major powers have meddled in the domestic affairs of exporting countries. The incentives to do so were greatest during the Cold War, when both the United States and the Soviet Union developed extensive ties with governments in oil-exporting countries to secure supplies, for themselves and their allies, that would be necessary for any sustained war effort. This meddling was overwhelmingly antidemocratic: Both Mosaddegh and al-Karim Qasim were deposed in coups backed by or linked to Western intelligence agencies.³ Said meddling might better be classified as antirevisionist. Leaders who sought to challenge the status quo with respect to major power relations with exporting countries have raised the ire of major powers even when—as in the Iranian Revolution—the revolutionaries’ ambitions were anything but democratic.

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3 The role of the Central Intelligence Agency (CIA) and the United Kingdom’s MI6 in Mosaddegh’s deposal is not a subject of historical controversy. The role of the CIA in al-Karim Qasim’s ouster and execution is more disputed, although there is evidence to suggest that the United States was not directly involved only because other coup plotters simply beat them to the punch: Planning for a CIA-backed coup had begun as early as 1961 (Gibson 2015).

These dynamics were not limited to oil-exporting countries. From Salvador Allende in copper-exporting Chile to Léon M'ba in manganese- and uranium-exporting Gabon to Patrice Lumumba in copper- and uranium-rich Zaire (now the Democratic Republic of the Congo), the historical record is littered with Western involvement in or support of coups against elected leaders whose political platforms threatened Western business interests. These dynamics were alleged to have been at play in the 2019 coup against Bolivia's Evo Morales, which ensured access to Bolivia's lithium reserves.⁴

This strategic significance could also lead mineral-rich countries to be more aggressive in their foreign policies as a result of moral hazard. The strategic significance of these minerals gives major powers a huge stake in exporting countries' security. In the past, the major powers offered explicit or implicit security guarantees. President Dwight Eisenhower cited the Middle East's oil deposits in committing the United States to a policy of military aid and assistance—including troops, if necessary—to “secure and protect the territorial integrity and political independence” of Middle Eastern countries against Communist aggression. From the Carter Doctrine to the Iraq wars, US foreign policy has reflected the primacy of energy concerns.

With this implicit insurance can come an appetite for belligerence. Essentially indemnified against large battlefield and territorial losses, critical mineral exporters may be more casual about the use of force—or threats of force—in their dealings with other countries, especially countries that are not critical mineral exporters and are thus not similarly insured themselves.

As China has emerged as a peer competitor of the United States, the systemic preconditions for Cold War-esque meddling in resource-rich countries have seemingly returned, albeit with three big differences: (a) the absence of clearly defined and nearly mutually exclusive communist and market liberal trade and investment systems, (b) the nature of renewable energy versus constant consumption-based fossil fuel energy sources, and (c) the dependence of both China and the United States on mineral imports. The first two differences augur for more peaceful, less invasive major power foreign policies vis-à-vis mineral-exporting countries. The third does not.

Let's start with the good news. First, resource-rich countries have not been asked to choose a side: Many critical mineral-rich countries host mining operations owned by both Western and Chinese firms—at least so far. Mining concessions have not “changed sides” via violent overthrow of sitting governments but rather through market mechanisms. A recent *New York Times* feature on the Democratic Republic of the Congo's vast cobalt reserves and axis of US-China competition noted that “the Obama and Trump administrations... stood idly by as a company backed by the Chinese government bought two of the country's largest cobalt deposits over the past five years” but that one of the purchases—the Kisanfu concession in Lualaba Province—was actually from an

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4 Kate Aronoff, “The Socialist Win in Bolivia and the New Era of Lithium Extraction,” *The New Republic*, October 19, 2020, <https://newrepublic.com/article/159848/socialist-win-bolivia-new-era-lithium-extraction>.

American company that had held but not developed the concession for years.⁵ Before its ouster, the Morales government had signed multibillion-dollar lithium mining deals with both Chinese and German firms.⁶

Second, there is a big difference between critical minerals and oil and gas with respect to the potential for hold-up. Renewable energy sources do not consume the strategic resource on a constant basis; they are inputs to the infrastructure that will facilitate the creation and storage of wind, solar, geothermal, hydropower, and other types of renewable energy. Loss of access to critical minerals may limit opportunities to expand capacity or repair existing infrastructure, but it would not immediately translate into a full-blown crisis.

The China-Japan Senkaku boat crisis incident is instructive. Japanese coast guard officials detained the skipper of a Chinese fishing vessel after it collided with a Japanese coast guard patrol boat in disputed waters.⁷ The detention precipitated a diplomatic crisis, during which China slashed exports of rare earth minerals and informally banned their export to Japan. At the time, China accounted for 97 percent of all rare earth production, so market disruptions were significant. But the effect was relatively muted. Production of electronics slowed in Japan, but ultimately the dispute resulted in a World Trade Organization decision against China that led to it dropping its export quotas five years later. The world economy kept moving.

Any disruption to global oil and gas markets—such as an export embargo—starts a ticking clock in economies dependent on oil imports, as they begin drawing down their domestic reserves. Many wealthy countries have extensive strategic reserve systems. Japan’s strategic reserve contains 224 days of average domestic consumption (Agency for Natural Resources and Energy 2021). A 1968 directive from the European Economic Community requires that all members of today’s European Union have at least 90 days of consumption in reserve (EEC 1968). The United States and China each have reserve capacity of about 90 days as well. In contrast, many middle- and low-income countries have minimal or no reserves. Disruptions to oil supplies are thus immediately unsettling and concerning to import-dependent economies and oil global markets.

Now comes the friction point: both the United States and China are deeply dependent on imports of critical minerals, albeit in different ways. The two countries are the largest importers of mineral products, accounting for 17.8 and 8.0 percent of global imports, respectively, in 2019 (Simoes and Hidalgo 2011). China consumes 23.3 percent of global copper imports; the United States is in third place (after Germany) with 6.3 percent. But these shares for the United States vastly understate the depth of import dependence, as the United States is the largest importer of machinery, appliances, and vehicles and their parts—final goods in which critical minerals (many imported from China) are key inputs. Any

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5 Dionne Searcy, Michael Forsythe, and Eric Lipton, “A Power Struggle over Cobalt Rattles the Clean Energy Revolution,” *New York Times*, November 20, 2021, www.nytimes.com/2021/11/20/world/china-congo-cobalt.html.

6 Keith Johnson and James Palmer, “Bolivia’s Lithium Isn’t the New Oil,” *Foreign Policy*, November 13, 2019, <https://foreignpolicy.com/2019/11/13/coup-morales-bolivia-lithium-isnt-new-oil/>.

7 Mure Dickie and Kathrin Hille, “Japan’s Arrest of Captain Angers Beijing,” *Financial Times*, September 8, 2010, <https://web.archive.org/web/20101113101142/http://www.ft.com/cms/s/0/a09e651a-bb04-11df-9e1d-00144feab49a.html#axzz159jSogAt>.

significant decoupling or reshoring of manufacturing would shift US imports toward critical minerals as primary goods but would do little to address its import dependence.

As extensive as geopolitical competition over oil and gas was during the Cold War, it could have been much worse. The Soviet Union's status as a major oil producer and exporter made its relations with other oil-exporting countries relatively benign. The Soviet Union was largely supportive of moves to nationalize oil wealth in the non-Western world and happy to free ride on the price manipulations arising out of the 1970s Arab oil embargos and collusive behavior of the Organization of the Petroleum Exporting Countries (OPEC). But it did not seriously intervene in the domestic affairs of oil-exporting countries, except for its support for communist revolutions/national self-determination movements in oil-rich Angola and the Republic of Congo (Chubin 1980). The United States' relations with oil exporters were significantly more fraught, because of the import dependence of the United States and its major allies in Europe and East Asia. The counterfactual of a Cold War between the import-dependent United States and its allies and the deeply import-dependent Third Reich, Imperial Japan, or both would have been one in which competition for the world's oil reserves would have been vicious.

PATHS FORWARD

It is tempting to assume that transitions to sustainable energy systems will lead to the same kind of domestic and geopolitical dynamics that the 20th century's scramble for hydrocarbon-based energy did. But the oil curse dynamics are not likely to translate seamlessly to critical minerals. The magnitude of rents will be smaller, and the geopolitics may be less fierce.

Critical mineral-rich countries should nevertheless take proactive steps to avoid falling into the resource curse:

- *Choose an all-of-the-above strategy with investment partners.* The era of partnerships between major Western and Chinese energy and mining firms—such as the joint development of Uganda's Albertine Rift deposits by Total SA (France), Tullow PLC (United Kingdom), and CNOOC Ltd. (China)—may have passed. But critical mineral-rich countries should continue to court investment from both Western and Chinese partners. Doing so will dilute the political influence of the multinational corporation's home-country government by pitting its interests against the interests of other major powers. Picking sides can be dangerous, not just for mineral-rich countries but for the international system as a whole.
- *Take advantage of good governance initiatives.* The domestic and international resource curse dynamics associated with oil date to the Cold War and its immediate aftermath (Hendrix 2018). During the scramble to secure resources during the Cold War, the voices decrying US and UK meddling in the affairs of Iran and Zaire were few and far between. Sustainable energy transitions will occur in an environment in which corporate social responsibility and attaining a social license to operate are norms. The Extractive Industries Transparency Initiative (EITI) is a multistakeholder initiative to prevent corruption, conflict, human rights

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violations, and environmental degradation while promoting good governance around extractive industries and helping resource-rich countries avoid the resource curse (Hendrix and Noland 2014). Since 2021, the EITI standard has been amended to include mandatory public disclosures of new or amended contracts and project site (i.e., mine-level) reporting of government revenues (EITI 2019). In the event EITI is not enough to promote good governance and mineral-fueled shared prosperity, civil society watchdogs like Global Witness and the Enough Project stand ready to bark.

The looming sustainable energy transition will have vast implications for both importers and exporters of legacy energy, as well as countries rich in the minerals that will fuel the transition. The 20th century's scramble to secure oil resources led to cursed dynamics in oil-rich societies, but historical precedent is not destiny. Mineral-rich countries may avoid the resource curse, especially if they develop diverse investment and trading relationships to balance major power interests in their mineral wealth and embrace industry- and civil society-led good governance initiatives around mineral resources.

REFERENCES

- Agency for Natural Resources and Energy. 2021. Current State of Oil Stockpiling. Available at www.enecho.meti.go.jp/statistics/petroleum_and_lpgas/pl001/results.html#headline2 (accessed December 9, 2021).
- Andersen, Jørgen J., and Michael L. Ross. 2014. The Big Oil Change: A Closer Look at the Haber-Menaldo Analysis. *Comparative Political Studies* 47, no. 7: 993-1021.
- Chubin, Shahram. 1980. *Soviet Policy towards Iran and the Gulf*. London: International Institute for Strategic Studies.
- De Soysa, Indra, and Theodora-Ismene Gizelis. 2013. The Natural Resource Curse and the Spread Of HIV/AIDS, 1990-2008. *Social Science & Medicine* 77: 90-96.
- EEC (European Economic Community). 1968. Council Directive 68/414/EEC of 20 December 1968 Imposing an Obligation on Member States of the EEC to Maintain Minimum Stocks of Crude Oil and/or Petroleum Products. Available at <https://op.europa.eu/en/publication-detail/-/publication/2cb8ce18-ff8c-4cf2-8708-9a43206a10f9/language-en> (accessed January 10, 2022).
- EITI (Extractive Industries Transparency Initiative). 2019. *EITI Standard: Overview of Key Changes*. Oslo.
- Farzanegan, Mohammad Reza, and Marcel Thum. 2020. Does Oil Rents Dependency Reduce the Quality of Education? *Empirical Economics* 58, no. 4: 1863-1911.
- Gibson, Bryan R. 2015. *Sold Out? US Foreign Policy, Iraq, the Kurds, and the Cold War*. London: Palgrave Macmillan.
- Global Witness. 2021. *Responsible Minerals*. Available at www.globalwitness.org/en/campaigns/conflict-minerals/ (accessed December 2, 2021).
- Hendrix, Cullen S. 2018. Cold War Geopolitics and the Making of the Oil Curse. *Journal of Global Security Studies* 3, no. 1: 2-22.
- Hendrix, Cullen S., and Marcus Noland. 2014. *Confronting the Curse: The Economics and Geopolitics of Natural Resource Governance*. Washington: Peterson Institute for International Economics.
- IEA (International Energy Agency). 2021. *The Role of Critical Minerals in Clean Energy Transitions*. Paris.

- Karl, Terry Lyne. 1997. *The Paradox of Plenty: Oil Booms and Petro-States*. Berkeley: University of California Press.
- Masi, Tania, and Roberto Ricciuti. 2019. The Heterogeneous Effect of Oil Discoveries on Democracy. *Economics & Politics* 31, no. 3: 374–402.
- OEC (Observatory of Economic Complexity). 2021. The Observatory of Economic Complexity, 5.0. Available at <https://oec.world/en/> (accessed December 5, 2021).
- PricewaterhouseCoopers. 2014. *Impact of Corruption on Nigeria's Economy*. London.
- Ross, Michael L. 2011. Will Oil Drown the Arab Spring? Democracy and the Resource Curse. *Foreign Affairs*, August: 2–7.
- Ross, Michael L. 2012. *The Oil Curse: How Petroleum Wealth Shapes the Development of Nations*. Princeton, NJ: Princeton University Press.
- Simoes, Alexander James Gaspar, and César A. Hidalgo. 2011. The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. *Workshop at the 25th Association for the Advancement of Artificial Intelligence Conference on Artificial Intelligence*, August 7–11.
- World Bank. 2021. *World Development Indicators*. Washington.



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