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EXECUTIVE BOARD MEETING

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September 6, 2023

To: Members of the Executive Board

From: The Secretary

Subject: **October 2023 World Economic Outlook—Analytical Chapter 3 and Online Annex**

Board Action:	Executive Directors' **consideration** (Formal)
Tentative Board Date:	**Tuesday, September 26, 2023**
Publication:	Yes, it is intended that the full set of the World Economic Outlook documents will be released to the public at the time of World Economic Outlook press conference, tentatively scheduled for **Tuesday, October 10, 2023.** The analytical chapters will be made available to the public on the IMF website in advance of the publication of the full document.
Questions:	Mr. Stuermer, RES (mstuermer@imf.org) Ms. Topalova, RES (ext. 39557)
Additional Information:	The paper will be revised for publication in light of the Executive Board discussion. If Executive Directors have additional comments, they should notify Mr. Stuermer and Ms. Topalova by **5:30 p.m. on Friday, September 22, 2023**.

CHAPTER 3

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CHAPTER 3

FRAGMENTATION AND COMMODITY MARKETS: VULNERABILITIES AND RISKS

Russia's invasion of Ukraine in 2022 caused major commodity markets to fragment, and continued geopolitical tensions could make matters worse. This chapter examines the key channels through which further disruptions in commodity trade could impact prices, economic activity, and the clean energy transition. It finds that commodities are particularly vulnerable to fragmentation. Their production is highly concentrated because of natural endowments, and many are difficult to substitute in the short term. Further fragmentation of commodity markets—which had been on the rise even before the war in Ukraine—could cause large price changes and more price volatility. Model simulations suggest that trade disruptions could result in substantial economic impacts in commodity-dependent economies. However, due to offsetting effects across producing and consuming countries, global economic costs appear modest. Crucially, low-income countries with a high reliance on agricultural imports would be disproportionally affected, raising food security concerns. The fragmentation of mineral markets could also make the clean energy transition more costly and lead to lower-than-needed investment in renewable energy and electric vehicles. Taken together, the findings present yet another argument for multilateral cooperation on trade policies. At the very least, agreements on a "green corridor" for critical minerals and a "food corridor" would safeguard the global goals of averting climate change and food insecurity.

Introduction

Since the end of the Cold War, primary commodity markets have become more integrated as a result of trade liberalization, technological innovation, and declines in transportation costs. Integrated commodity markets have provided cheap inputs that supported global growth and so helped raise living standards, especially in emerging markets.[1]

However, the war in Ukraine put this process in reverse. For the first time since the 1970s, commodities such as crude oil, natural gas, and wheat were broadly used to exert pressure in a major conflict. Exports were restricted and counter-sanctions imposed. These disruptions in commodity trade contributed to surging inflation in 2022 in many parts of the world, food insecurity in low-income countries, and slower global growth (IMF 2023).

While most commodity prices have normalized, geopolitical tensions signal that more severe fragmentation of commodity trade is a major risk.[2] Many countries are trying to reshore commodity supply chains as a national security measure or for geopolitical reasons. This includes critical minerals for clean energy technologies, semiconductors, and defense (examples of actions are the US Inflation Reduction Act, the EU Chips Act, and China's export restrictions on gallium and germanium).

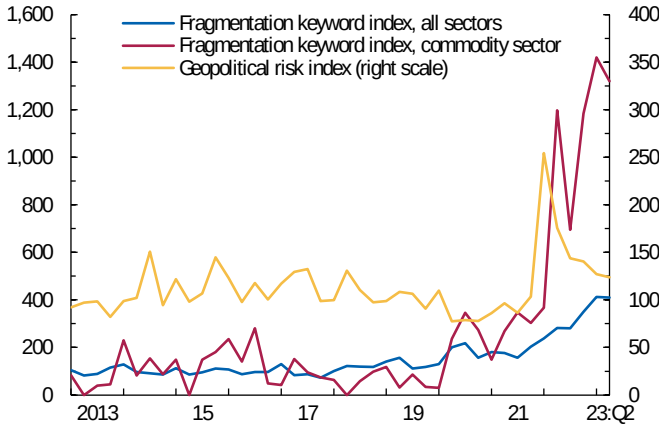
The authors of this chapter are Jorge Alvarez (co-team lead), Mehdi Benatiya Andaloussi, Christopher Evans, Chiara Maggi, Marika Santoro, Alexandre Sollaci and Martin Stuermer (co-team lead), with contributions by Marijn Bolhuis, Jiaqian Chen, Benjamin Kett, Seung Mo Choi, Peter Nagle and Alessandra Sozzi, and under the guidance of Petia Topalova. Yarou Xu, Carlos Morales, and Canran Zheng provided outstanding research assistance. Andrei Levchenko was the external consultant.

[1] Economic theory suggests that the consumption gains and the more efficient use of resources generated by trade should boost GDP. See Feyrer (2019, 2021) for recent analysis and Irwin (2019) for a review of the literature on trade and growth.

[2] Building on Aiyar and others (2023), the chapter defines geoeconomic fragmentation (referred to as "fragmentation" for brevity in the rest of the chapter) as any policy-driven reversal of integration, including reversals guided by strategic considerations such as national security. It encompasses trade, fiscal and financial measures such as tariffs, export restrictions, subsidies, and restrictions on payments. The trade literature of the early 2000s used fragmentation to describe the geographic dispersion of production processes in globally integrated supply chains (Arndt and Kierzkowski 2000; Deardorff 2001).

As a result, concerns about fragmentation, deglobalization, and nearshoring have risen sharply, especially in the commodity sector (Figure 3.1.). Text mining analysis of earnings calls reveals that prior to the COVID-19 pandemic firms barely mentioned keywords related to fragmentation, but usage surged after Russia's invasion of Ukraine.

Figure 3.1. Fragmentation Keywords in Earnings Calls
(Indices, 2013–15 = 100)



Sources: Caldara and Iacoviello (2022); Hassan and others (2019); NL Analytics, Inc.; and IMF staff calculations.
Note: Fragmentation indices measure the average number of sentences, per thousand earnings calls, that mention at least one of the following keywords: *deglobalization, reshoring, onshoring, nearshoring, friend-shoring, localization, regionalization.*

There is little consensus on the economic costs of fragmentation in the fast-growing literature. Estimates of long-term output losses from restricting the international flow of goods and services, finance, and technology range from 0.2 percent to 12 percent of global GDP, depending on the scenario and assumptions.[3] Commodity markets could be another important channel through which further disruptions in trade affect activity. Commodity production is hard to relocate as it is linked to natural endowments such as geological deposits or soil quality. Their consumption is often difficult to substitute in the short term. Moreover, many commodities are crucial inputs for manufacturing and technologies, including those related to the clean energy transition.

Against this backdrop, the chapter studies the main channels through which further fragmentation of markets for energy, agricultural, and mineral commodities could affect economies and global public goods—namely, the energy transition. It focuses on the following questions:

- What makes commodity markets vulnerable to fragmentation?
- Is there fragmentation in commodity markets, and what form does it take?
- Which commodities are most vulnerable to disruptions in international trade?
- What would be the economic impact of commodity market fragmentation across blocs and countries, as well as on the global economy?
- What might be the implications of such fragmentation for the clean energy transition?

[3] See Aiyar and others (2023) for an overview of potential channels of impact. Recent studies that quantify aggregate losses from restricting trade include Albrizio and others 2023; Attinasi, Boeckelmann, and Meunier 2023; Bolhuis, Chen, and Kett 2023; Fally and Sayre 2018; Felbermayr, Mahlkow, and Sandkamp 2022; Hakobyan, Meleshchuk, and Zymek, forthcoming; and Javorcik and others 2022. Chapter 4 of the April 2023 *World Economic Outlook* (WEO) examines the consequences of restrictions on investment, and Chapter 3 of the April 2023 *Global Financial Stability Report* (GFSR) does the same for portfolio flows, whereas Cerdeiro and others (2021) and Goes and Bekkers (2022) quantify the losses once technological decoupling is also considered.

The chapter covers nearly all countries and focuses on more than 40 commodities, including agricultural goods, energy commodities—namely, coal, crude oil and natural gas, and other mineral commodities. It builds a unique database of commodity output, use, and bilateral trade. It uses a combination of descriptive statistics, empirical analysis, and model simulations.

The chapter simulates a highly stylized risk scenario in which commodity trade between two geopolitical blocs is persistently disrupted, to illustrate the channels through which commodity market fragmentation could affect prices and output. The baseline scenario defines the two theoretical blocs by using the 2022 United Nations (UN) vote on the war in Ukraine as a transparent starting point. However, the chapter examines alternative scenarios, including the role of neutral countries and the impact of countries' switching blocs, given the sensitivity of the analysis to bloc configurations and the difficulty of assessing bloc configurations' plausibility.[4,5]

The main findings are as follows:

- *Commodities are vulnerable to fragmentation.* The importance of natural endowments for production can lead to high geographic concentration of output. For example, the three biggest suppliers of minerals account for 75 percent of global production on average. Coupled with low demand elasticities and their upstream use in many manufacturing processes and key technologies, commodities are highly traded. However, many importers rely on just a few suppliers. These features raise the cost of trade disruptions.
- *There is rising fragmentation in commodity markets.* Measures restricting commodity trade surged in 2022, much more than for other traded goods. For selected commodities, price differentials across geographic markets have emerged. And commodity sector foreign direct investment (FDI) and cross-border mergers and acquisitions (M&As) were on the decline even prior to the war in Ukraine.
- *Fragmentation could cause large price changes.* The scale of the price effects depends on the supply and demand imbalances caused by fragmentation and the price elasticities of supply and demand. Partial equilibrium model simulations suggest that price effects could be particularly strong for some minerals critical for the green transition and some highly traded agricultural goods. Spikes in agricultural commodity prices could be concerning for many low-income countries reliant on imports to feed their population.
- *Fragmented commodity markets would also lead to higher price volatility.* Smaller markets in a fragmented world would provide fewer buffers against commodity supply and demand shocks, leading to larger price responses than under free trade. Moreover, commodity producers would have powerful incentives to switch allegiances given potentially significant differences in commodity prices between blocs. This would induce more supply shocks,

[4] Countries' geopolitical alignment could be partly driven by trade linkages and risk management strategies to reduce the fallout from spikes in geopolitical tensions. However, the endogenous formation of blocs remains beyond the scope of the chapter. The two-bloc scenario presented here is meant to provide a clearly defined baseline and to make the exercise comparable to the recent literature. Introducing neutral countries reduces fragmentation's impact, as discussed below.

[5] Online Annex 3.1 provides details on the commodities, countries and their allocation across blocs as well as data sources.. Online Annex 3.6 discusses the robustness of some of the key findings to different bloc configurations. All online annexes are available at www.imf .org/en/Publications/WEO.

volatility, and uncertainty in commodity markets, challenging fiscal, monetary, and financial stability.

- *For many commodity-dependent economies, fragmentation would lead to sizable macroeconomic impacts.* For some low-income countries and emerging market economies, trade model simulations point to long-term output losses exceeding 2 percent. Due to vastly different and often offsetting impacts across net commodity-producing and net commodity-consuming countries, however, economic losses appear relatively modest at the global level. This should not lead to complacency: the chapter quantifies only the restriction of commodity trade between blocs. Should the world fragment into isolated blocs, the flow of other goods and services, finance, technology, and know-how would most likely also be disrupted, amplifying global economic costs (Aiyar and others 2023). The higher volatility and uncertainty brought on by commodity market fragmentation would complicate policy making and add to the costs, a channel which is also not captured. Moreover, within countries, offsetting effects on commodity consumers and producers imply strong distributional impacts even absent large aggregate output effects. Fragmentation in agricultural commodity markets could raise food insecurity in low-income countries, with high social and humanitarian costs not included in the chapter's model simulations. In sum, commodity market fragmentation could throw a sizable economic blow in an already challenging environment of slow global growth, tight financial conditions, and high debt in many vulnerable countries.
- *Fragmentation in mineral markets could make the clean energy transition more costly*. Demand for critical minerals is projected to rise severalfold in a net-zero-carbon-emissions scenario. These minerals are highly concentrated geographically, and their elasticity of demand and supply is low, so trade disruptions could add to upward pressure on mineral prices in the bloc where demand exceeds supply after fragmentation. But the mineral-rich bloc cannot reap the benefits from oversupply, as refining capacity cannot be scaled up quickly. In the illustrative simulation, fragmentation results in up to 30 percent lower-than-needed investment in renewables and electric vehicles (EVs) at the global level by 2030.

What Makes Commodities Vulnerable to Fragmentation?

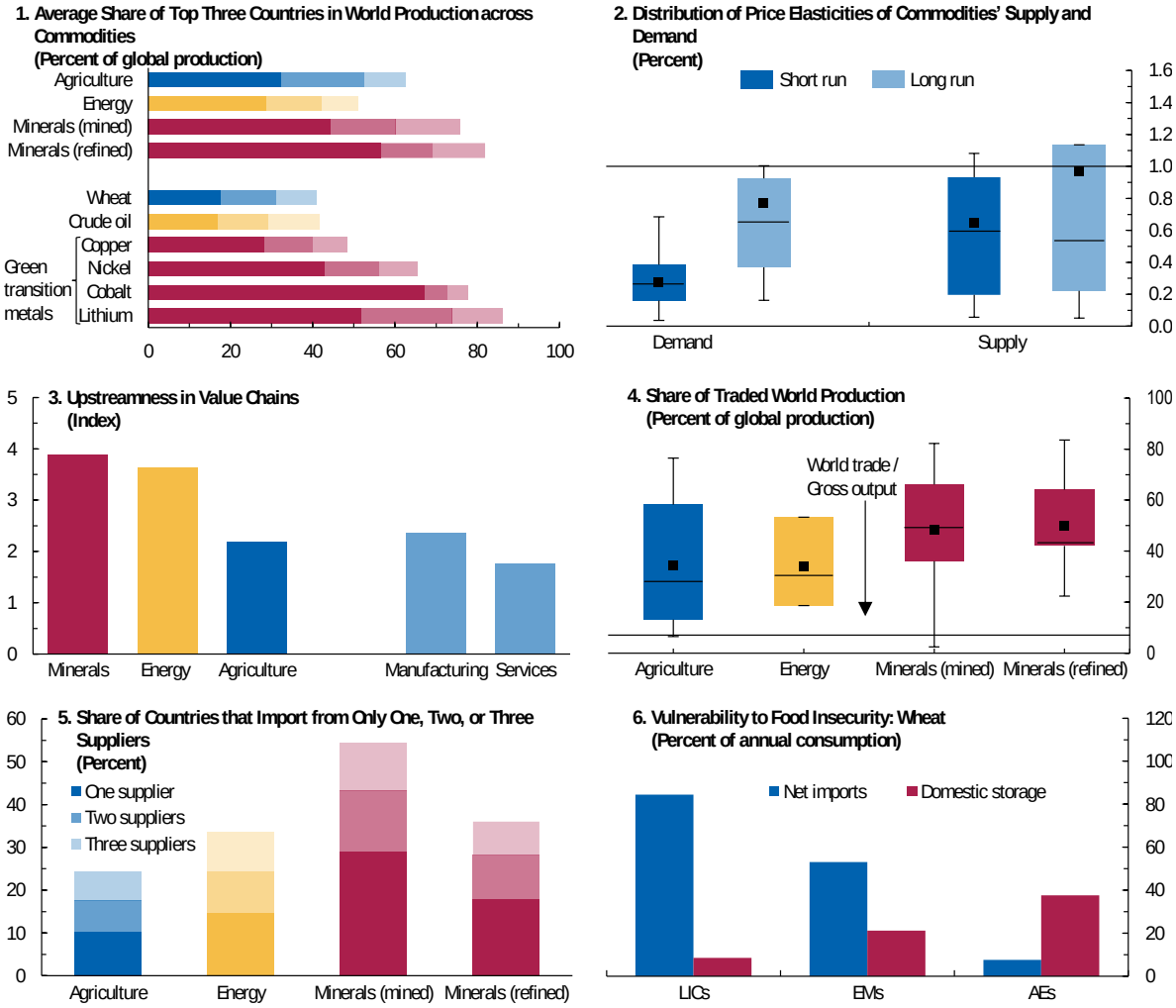
This section documents several features of commodity markets that would raise the economic costs of disrupting their trade, despite commodities' homogeneity and fungibility.

Production Concentration

The first production stage of commodities depends on natural endowments that can be heavily concentrated geographically. For instance, the extraction of minerals and energy commodities requires cost-effective geological deposits. Availability of fertile soil, water, and an adequate climate can constrain agricultural production and yields. As a result, the three largest-

producing countries account for about 65 percent of the global output of agriculture, about 50 percent of energy, and 75 percent of mineral commodities.[6,7]

Figure 3.2. Commodities: Key Characteristics



Sources: Antràs and others (2012); British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); International Energy Agency; US Department of Agriculture; US Geological Survey; and IMF staff calculations.
Note: "Energy" refers to coal, natural gas, and crude oil. This figure uses 2019 data due to data availability and to avoid biases caused by the pandemic. Panel 1 provides the share of global production that the top three producing countries account for (see Online Annex Figure 3.2.2) and gives averages across commodity types. In panels 2 and 4, the horizontal lines in the bars represent the median, the squares the average, the bars the interquartile range, and the whiskers the minimum and maximum values across commodities in the group. In panel 3, sectoral upstreamness is based on Antràs and others (2012) and is computed as the weighted average position of an industry's output in the value chain. The upstreamness index captures how far a specific sector is from the final end usage, with a lower index value (minimum value of 1) implying that the sector is closer to final demand. Panel 5 depicts the simple average across commodities of each group. Panel 6 depicts the simple average across countries within each income group, for 2019. AEs = advanced economies; EMs = emerging markets; LICs = low-income countries.

[6] The chapter focuses on countries and not firms. Commodity extraction is often done by multinationals or firms owned by foreign investors (Leruth and others 2022). Firm-level concentration could be different from country-level concentration. However, governments are typically the ultimate owners of land or reserves and lease them to firms for a limited time. Renegotiations of lease terms, as well as expropriations, are common (Jaakkola, Spiro, and Benthem 2019). The chapter also focuses on production rather than reserves due to data availability. Reserves and production are highly correlated (USGS 2023).

[7] Online Annex 3.2 provides the production and import concentration and the share of trade in output for the commodities. Concentration of production is also apparent at the firm level, with a few countries taking stakes in key firms (Leruth and others 2022).

Minerals represent a special case: production is concentrated both at the first stage (mining) because of the geographic concentration of deposits and also at the second (processing) stage (Figure 3.2., panel 1). Relocating production at the mining stage may be impossible over the short and medium term, given the importance of natural endowments.

Elasticities of Supply and Demand

The price elasticity of supply, which measures how output responds to price changes, is relatively low for commodities in the short term (Figure 3.2., panel 2). Scaling up production requires large investments, environmental permitting, and community consultations that can delay a supply response to price changes. For example, it takes on average 16 years from exploration to the opening of copper mines (IEA 2021). Discovering new deposits is also costly and takes time.[8] Setting up processing capacity comes with its own challenges, such as regulations, access to know-how, technology, and skilled labor; infrastructure requirements; and labor costs (IEA 2023). These help explain the geographic concentration at the refining and processing stages.

On the demand side, many commodities are inputs for key technologies and products or are essential to household consumption (food, heating, cooking, and transportation are examples). Disruptions to their supply can cause ripple effects across sectors and value chains. As upstream inputs for the production of a vast array of goods and services (Figure 3.2., panel 3), they are often hard to substitute, and demand responds little to swings in prices. This is reflected in their low price elasticity of demand, particularly in the short term.

Importance of Trade

With production highly concentrated and demand often broadly spread across countries, commodities are heavily traded. Their homogeneity and fungibility—despite low demand and supply elasticities, commodities have high elasticity of substitution across suppliers—also contribute to market integration. The share of production traded internationally across commodity classes is consistently higher than the ratio of world trade to gross output (Figure 3.2., panel 4). On average across agricultural commodities, 40 percent of output is dedicated to trade (30 percent for energy and almost 50 percent for minerals at the mining stage), with the shares substantially higher for many commodities.[9]

As a result, imports satisfy a large part of the demand for commodities. However, many countries depend on only a handful of suppliers (Figure 3.2., panel 5). For example, roughly half

[8] Elasticities below one are generally considered low. See Fally and Sayre (2018) and Dahl (2020) for a literature review on supply and demand elasticities across commodities. Arezki, van der Ploeg, and Toscani (2019) analyze the responsiveness of resource discoveries to market incentives. It is worth noting that the sizable investments needed to expand the supply of commodities may be hindered by the disruptions in external capital flows and higher uncertainty that geoeconomic fragmentation might trigger, as discussed in the April 2023 WEO and April 2023 GFSR.

[9] Even though commodities are heavily traded, their share in global trade has declined as trade liberalization, lower transportation costs, and cross-border production chains have supported the rapid rise in intermediate goods trade. The share of primary goods in total goods trade has declined from roughly 45 percent in the first half of the 20th century to about 13 percent in 2019–21 (Online Annex Figure 3.2.4.).

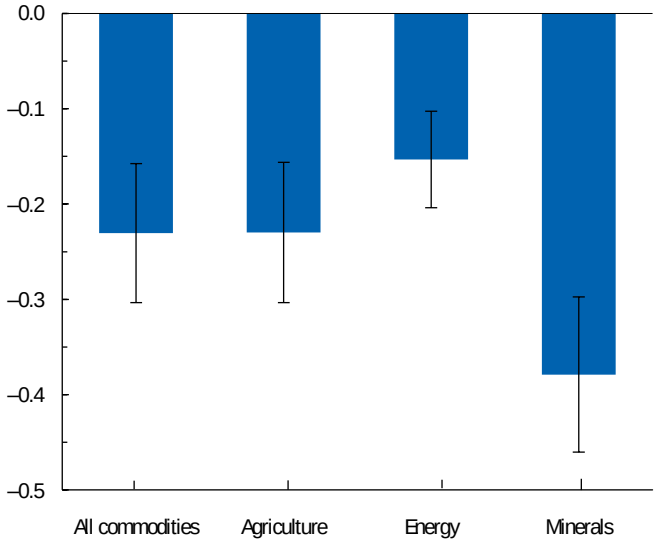
the countries rely on three or fewer exporting countries for their imports of minerals, and a quarter on only one. This leaves them vulnerable to supply disruptions in the near term.[10]

Import dependence in agricultural commodities can lead to food insecurity, particularly in low-income countries. For instance, the average low-income country imports over 80 percent of the wheat it consumes. Given low storage capacity, consumption smoothing can be difficult in these countries, exposing populations to large swings in prices or food shortages (Figure 3.2., panel 6). The ramifications of food commodity shocks, which have been linked to social unrest, conflict, and migration (Kelley and others 2017; Missirian and Schlenker 2017; Burke and McGuirk 2020), go beyond the economic analysis that follows.

Sensitivity to Geopolitics

Analysis of trade patterns suggests that commodity trade is historically associated with countries' geopolitical alignment. Gravity equations, estimated for the commodities in the sample and augmented to include the similarity between countries' portfolios of military alliances, show that bilateral commodity trade flows are negatively associated with military distance (Figure 3.3.).[11] However, notable differences are apparent in the strength of the relationship across types of commodities: a one-standard-deviation increase in the distance of military alliances (approximately the distance between India and Morocco in 2018) would decrease trade in energy commodities by about 15 percent, but decrease trade in minerals by more than 35 percent. The exercise suggests that changes in military alliances because of rising geopolitical tensions could go hand in hand with disruptions of trade flows and fuel fragmentation of commodity trade.

Figure 3.3. Commodity Trade and Distance of Military Alliances
(Coefficients)



Sources: Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); Leeds and others (2002); Signorino and Ritter (1999); and IMF staff calculations.
Note: "Energy" refers to coal, natural gas, and crude oil. The bars in the figure denote the point estimates, and the vertical lines represent 95 percent confidence intervals. Standard errors are clustered at the importer country level. Estimates are based on an inverse hyperbolic sine specification to account for zeros. Distance of military alliances is measured using the similarity between countries' portfolios of military alliances and standardized so its standard deviation is 1 in each year. A standardized military distance of 1 is approximately the distance between India and Morocco in 2018.

[10] Historically, countries were often able to adapt to trade disruptions over the medium to long term by finding alternative suppliers due to commodities' homogeneity or by developing substitutes (see Box 3.2.).

[11] The gravity model is widely used to explain bilateral trade flows based on country and country pair characteristics that capture trading costs, such as geographic distance or a common border, language, or currency. Online Annex 3.3 provides details and robustness checks. Distance in military alliances is associated with lower trade in minerals across specifications. The results are more sensitive for other measures of geopolitical alignments, namely the ideal point distance based on UN votes, used in Chapter 4 of the April 2023 WEO in a similar analysis for FDI flows (see also Jakubik and Ruta 2023). Hakobyan, Meleshchuk, and Zymek (forthcoming) examine distance in military alliances and sectoral trade flows.

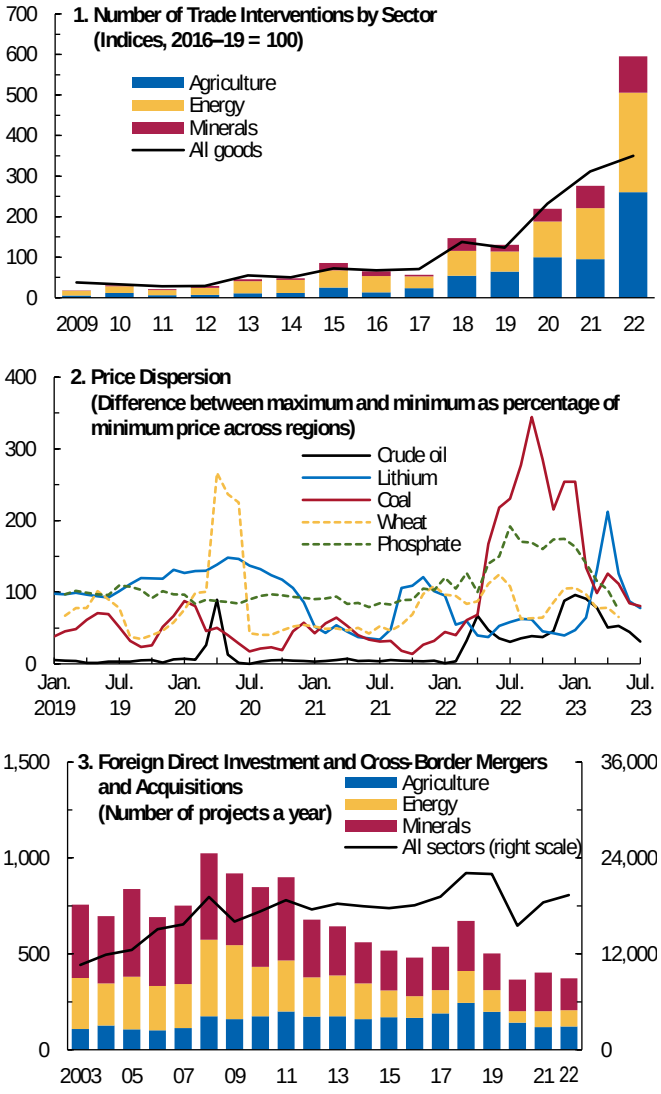
Fragmentation in Commodity Markets

This section takes stock of various measures of fragmentation. The number of new interventions in commodity trade has risen every year since 2018, initially fueled by tensions between the US and China and the COVID-19 pandemic. In 2022, Russia's war in Ukraine caused a major spike in new trade restrictions, especially for commodities: there were more than six times more new restrictions affecting trade in commodities in 2022 than the 2016–19 average. In contrast, trade-restricting measures on overall trade increased 3.5 times (Figure 3.4, panel 1).[12]

Price dispersion across locations can also be a symptom of fragmentation: since commodities are homogeneous goods, they should trade under one price after accounting for transportation costs. There is, however, significant and rising dispersion in some commodity prices, especially in some metals, such as lithium, and energy commodities (Figure 3.4, panel 2). For example, Russian coal traded at a price almost three times lower than Australian coal in September 2022. Price dispersion for crude oil and natural gas also rose as the war in Ukraine and associated sanctions disrupted trade. Box 3.1 documents these shifts using real-time vessel-tracking data.

Other proxies for fragmentation are changes in the number of FDI projects and cross-border M&As, which are also an indicator of future trade. They were declining in the energy and mineral sectors even before the war in Ukraine, which could presage a slowdown in commodity trade

Figure 3.4. Signs of Fragmentation



Sources: Argus Media, Inc.; Bloomberg Finance L.P.; FDI Markets; Global Trade Alert database; Refinitiv Eikon; UN Comtrade; and IMF staff calculations.
Note: Trade-liberalizing interventions are excluded from calculations and adjusted for reporting lag. Prices for crude oil, coal, and lithium are market prices in different regional markets as retrieved from Bloomberg Finance L.P. Wheat and phosphate price dispersion is estimated based on export prices for countries that account for more than 5 percent of global exports, based on export data from UN Comtrade. Panel 3 presents the total number of foreign direct investment and cross-border mergers and acquisitions projects at the global level. The bars provide a breakdown by commodity group.

[12] Trade interventions in the Global Trade Alert include both measures that increase fragmentation, such as import tariffs and export restrictions, and measures that aim to limit the economic fallout from fragmentation by encouraging diversification, such as subsidies for local producers, local content requirements, and the like—though a strict distinction between the two is difficult.

(Figure 3.4., panel 3).[13] Shifts have also occurred in the origin and destination of commodity FDI and cross-border M&As. US and EU investors are increasingly targeting projects in advanced economies, whereas China and Russia have increased their investments in Africa (see Online Annex Figure 3.2.5.).[14]

No measure of fragmentation is perfect. It is still too early to assess how long-lasting price dispersion will be; the decline in FDI could reflect moderation in commodity prices since 2015, following the decade-long commodity boom, and it is not clear due to lagging data to what extent trade-restricting measures have affected trade flows (Goldberg and Reed 2023). However, taken together, these measures suggest rising commodity market fragmentation.

Which Commodities Are Most Vulnerable?

To assess individual commodities' vulnerability to fragmentation, this section presents a single-commodity, multi-country partial equilibrium model based on Alvarez and others (2023) (see also Online Annex 3.4 for details). It computes price changes that would occur if trade for each of the 40+ commodities were banned across two blocs.

For illustrative purposes, the baseline scenario assumes that the two theoretical blocs are constructed based on the 2022 UN vote on Russia's war in Ukraine. The bloc containing countries that voted for Russia to withdraw from Ukraine is labeled the "US-Europe+ bloc"; the remaining countries are in the "China-Russia+ bloc".[15] The exercise assumes in a highly stylized and extreme way that there is no trade in commodities between blocs and that intra-bloc trade is not subject to trade costs. Box 3.2 discusses more fluid experiences of fragmentation. Investigating the impacts of those intermediate scenarios is beyond the scope of the chapter. Rather, its goal is to identify the relative vulnerabilities across commodity markets and to illustrate transmission channels, recognizing that partial interaction between blocs and arbitrage opportunities could mute the economic effects implied by the model simulations.

For each commodity, the model's initial calibration is based on observed 2019 trade flows. They are assumed to reflect an integrated world, where goods are traded at one global price.[16] The trade ban across blocs yields bloc-specific prices that clear bloc-level supply and demand.

Fragmentation induces opposite price effects across blocs. The price falls in the bloc that used to be a net exporter of the commodity and increases in the net importing bloc. The size of price changes depends on (1) bloc-level supply and demand imbalances prior to fragmentation—that is, the extent to which a bloc relies on imports to satisfy its demand at the integrated world price, and (2) the capacity of demand and supply to respond to changing prices (the price elasticities of demand and supply). Commodities with inelastic demand and supply and with high imbalances across blocs are more vulnerable to price changes.[17]

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[13] Following Chapter 4 of the April 2023 WEO, the focus is on the number rather than the value for FDI and cross-border M&As. Data on values are limited and often estimated. However, FDI values suggest a similar decline in the commodity sector.

[14] Chapter 4 of the April 2023 WEO documents FDI flows that are increasingly concentrated among geopolitically aligned countries, particularly in strategic sectors.

[15] See also Chapter 3 of the 2022 October *Regional Economic Outlook: Asia and Pacific*.

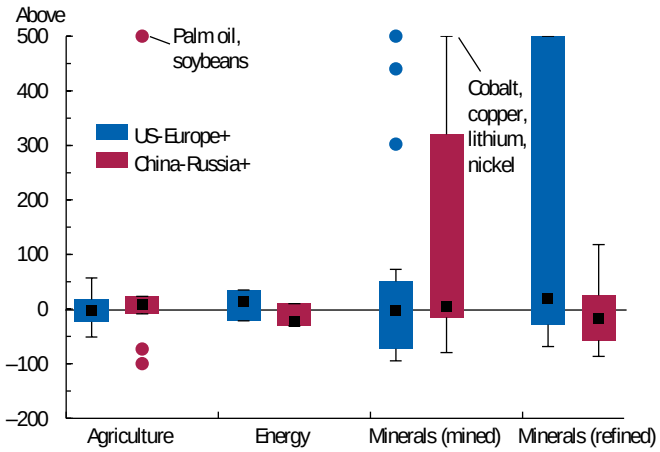
[16] The assumption of perfect trade integration in the baseline oversimplifies reality, as markets for some commodities were not perfectly integrated globally even before the war in Ukraine.

[17] The exercise does not explicitly model storage, which is an important feature of volatility smoothing.

Model simulations suggest that the potential price impact of fragmentation varies significantly across commodities, with some potentially experiencing very large price increases (Figure 3.5.; see Online Annex Figure 3.6.1. for the underlying commodity-specific results). In the China-Russia+ bloc, the price of mined minerals, including cobalt, lithium, copper, and nickel, which are critical for the green transition, would rise substantially. Production of these minerals is concentrated in a handful of countries in the US-Europe+ bloc but are largely used as inputs in the China-Russia+ bloc (see Online Annex Figure 3.2.6.). At the same time, the US-Europe+ bloc could experience similar increases in the prices of refined minerals, which are processed mostly in China, South Africa, and Russia.

Figure 3.5. Price Changes Due to Fragmentation in Individual Commodity Markets

(Percent)



Sources: British Geological Survey; Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Price effects are capped at 500 percent for readability. "Energy" refers to coal, natural gas, and crude oil. The black squares in the bars represent the median, the bars the interquartile range, and the whiskers the data points within 1.5 times the interquartile range from the 25th or 75th percentile across commodities in the group. The dots indicate outliers. Selected commodities which experience price increases higher than 500 percent are labeled. For the underlying complete information on commodity-specific price changes, see Online Annex Figure 3.6.1. The bloc including the countries that voted for Russia's withdrawal from Ukraine in the 2022 UN vote is labeled the "US-Europe+ bloc," and the remaining countries are included in the "China-Russia+ bloc."

In contrast, the potential price changes of energy and most agricultural commodities are more subdued in the baseline simulation. Since their production is less geographically concentrated, supply and demand are more balanced across the two blocs. However, palm oil and soybeans represent two important outliers: more than 80 percent of production occurs in the US-Europe+ bloc, whereas most of the consumption takes place in the China-Russia+ bloc.

Because of high geographic concentration, the vulnerability of commodities depends on the distribution of key exporters (and importers) across blocs. Simulations based on different country compositions of the two blocs, described in Online Annex 3.6.3., suggest that, similarly to the baseline, fragmentation would lead to significant price increases for minerals at the mining stage and for key agricultural staples (such as soybeans) in the China-Russia+ bloc. In an alternative bloc scenario, where all emerging market and developing economies, excluding India, Indonesia, and Latin American countries, are assigned to the China-Russia+ bloc, the US-Europe+ bloc could experience large price increases for some mined minerals as key swing producers are allocated to the other bloc, and it could become more vulnerable to trade restrictions on some agricultural commodities (such as cocoa) and crude oil.

Higher Commodity Price Volatility

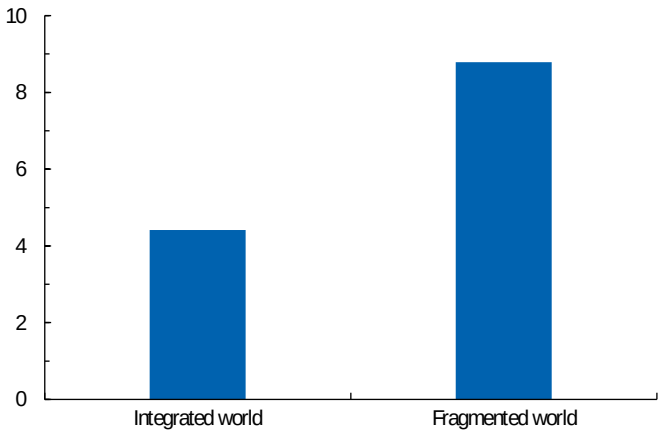
Fragmented commodity markets would lead to higher price volatility (see Jacks, O'Rourke, and Williamson 2011 for historical evidence). This challenges public finances and fiscal and monetary frameworks, giving rise to potential procyclicality of fiscal and monetary policies and

hurting economic stability (Cavalcanti, Mohaddes, and Raissi 2015; IMF 2023). Fragmentation can affect price volatility through at least two channels: smaller market sizes and countries switching blocs.[18]

Smaller Market Sizes

In a fragmented world, markets would become smaller and bloc-level prices more responsive to country-level shocks (see also Albrizio and others 2023). In the partial equilibrium model, the price response is proportional to the supply shock's size relative to the overall market. Thus, by restricting the set of countries they trade with, countries would face larger price increases in response to the same negative supply shocks.[19] In an illustrative example, Figure 3.6. compares the price impact of a three-standard-deviation shock to the US wheat harvest in an integrated market with that in a fragmented market.[20] The same supply shock doubles the impact on wheat prices when trade is fragmented into two smaller blocs. This is important, as climate change is expected to raise the variability of agricultural output. A fragmented world, in which the price response to supply shocks is amplified, would be less able to cope with this challenge.

Figure 3.6. Wheat Price Increase in the US-Europe+ Bloc Due to a Harvest Shock
(Percent)



Sources: Food and Agriculture Organization of the United Nations; and IMF staff calculations.
Note: The bars in the figure depict the change in the price of wheat in the US-Europe+ bloc (those countries that voted for Russia to withdraw from Ukraine in the 2022 UN vote on the Ukraine war) from a three-standard-deviation negative shock to US wheat production. The figure compares the price increases in the bloc in a free-trade world to those in a fragmented world.

Countries Switching Blocs

In a fragmented world, major commodity producers would face powerful incentives to switch geopolitical allegiances, representing a new source of supply shocks and price volatility. For highly concentrated commodity markets, a single exporting country switching to the other bloc could lead to a large supply gap and trigger hefty price changes. Uncertainty about a country's geopolitical alignment could itself lead to price volatility as traders update their priors regarding potentially large fragmentation-induced price swings.

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[18] Other channels could include the impact on the financial ecosystem linked to commodities, such as derivatives and insurance (FSB 2023).

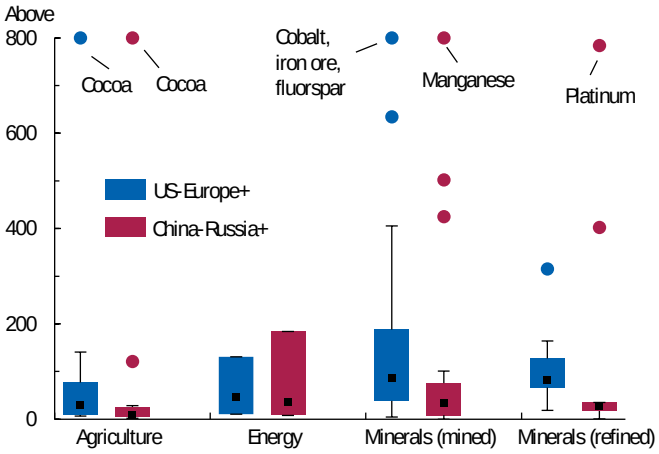
[19] In the single-commodity model, the price change in response to a supply shock is $Price\ Change = -\frac{Size\ of\ Supply\ Shock\ Relative\ to\ Market}{Elasticity\ of\ Supply - Elasticity\ of\ Demand}$, with $Elasticity\ of\ Demand < 0$ (Alvarez and others, 2023).

[20] The US accounts for about 7 percent of global and 15 percent of US-Europe+ bloc wheat production. A three-standard-deviation US harvest shock corresponds to about 60 percent of US wheat production, or 4 percent of global output, holding wheat prices constant. The exercise uses a price elasticity of supply of 0.2 and a price elasticity of demand of -0.85 (see Alvarez and others, 2023). Lower elasticities would lead to higher prices impacts, while fragmentation would still double the price impact in this example.

To illustrate price sensitivity to countries switching blocs, Figure 3.7. shows the distribution of the greatest price increases each commodity can experience in a bloc when a single exporting country switches alliance.[21] Minerals at the mining stage tend to be the most sensitive, given their highly concentrated production. For example, South Africa produces one-third of the world's manganese, a metal used in steelmaking and batteries. If South Africa switched to the US-Europe+ bloc, the price of manganese in the China-Russia+ bloc could rise more than 800 percent.

Figure 3.7. Largest Price Increases Induced by a Single Exporter Switching Blocs

(Percent)



Sources: British Geological Survey; Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Price effects are capped at 800 percent in the figure for readability. "Energy" refers to coal, natural gas, and crude oil. Each observation in the box plots represents the largest price increase that a commodity can experience in each bloc from a single exporting country's switching to the other bloc. So for each bloc, each data point in the figure refers to the price change of a commodity. Note also that the US (China) are not allowed to switch away from the US-Europe+ (China-Russia+) bloc. The black squares in the bars represent the median, the bars the interquartile range, and the whiskers the data points within 1.5 times the interquartile range from the 25th or 75th percentile across commodities in the group. The dots indicate outliers; the commodities representing the largest outliers are labeled. For the underlying complete information on commodity-specific price changes, see Online Annex Figure 3.6.2. The bloc including the countries that voted for Russia's withdrawal from Ukraine in the 2022 UN vote is labeled the "US-Europe+ bloc," and the remaining countries are included in the "China-Russia+ bloc."

Economic Impacts of Commodity Market Fragmentation

This section sheds light on the macroeconomic impacts of fragmentating commodity markets on individual economies, blocs, and the global economy. Three complementary analytical approaches are used.[22]

First, the partial equilibrium model discussed above is leveraged to compute changes in producer and consumer surplus due to fragmentation in individual commodity markets. The change in total surplus is used as an indicator of economic impact. This approach identifies the most macro-relevant commodities. It accounts for the changes in price and quantities consumed or produced of each commodity because of fragmentation. However, due to its partial equilibrium nature, the approach does not account for sectoral spillover effects, nor does it allow for the simultaneous disruption of trade in many commodities, which could have opposing or reinforcing effects within the same country.

Two general equilibrium models in the chapter overcome these shortcomings. A static multicountry, multisector trade model, which accounts for all input-output linkages across sectors, is used to simulate the long-term GDP losses associated with fragmenting all commodity

[21] Online Annex Figure 3.6.2. shows the 15 commodities whose price is most vulnerable to a single exporter switching blocs and underlies Figure 3.7 and the implied price changes.

[22] The Online Annex, Alvarez and others (2023) and Bolhuis, Chen, and Kett (2023) discuss the assumptions and calibration of each model. None of the approaches consider the impact of fragmentation on productivity and innovation. The role of the financial sector is also outside the scope of the chapter.

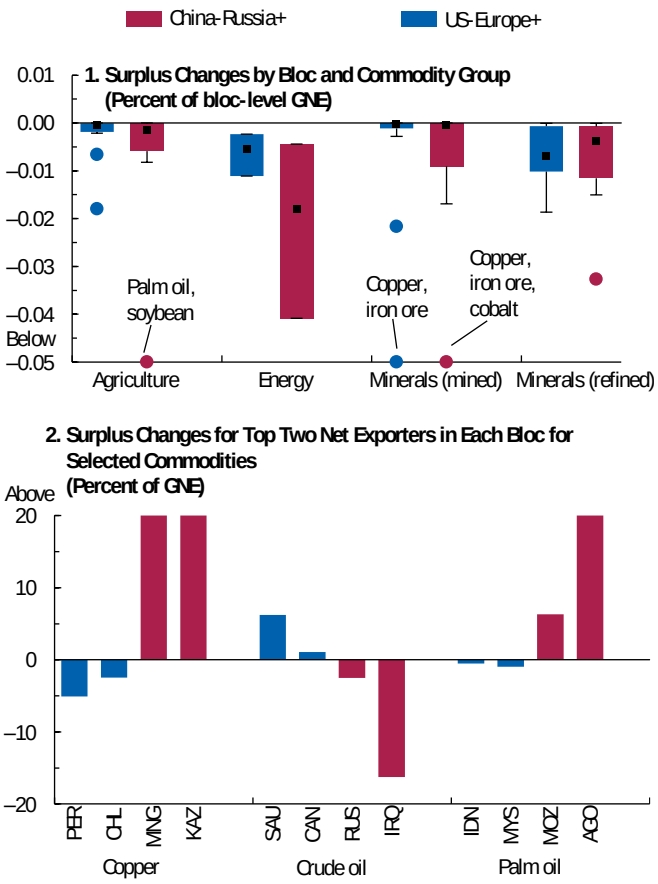
trade and to examine the role of neutral blocs (see Box 3.3.). Finally, the dynamic effects on GDP and inflation are examined in a multiregion dynamic stochastic general equilibrium (DSGE) model that includes energy and critical minerals.

Evidence from the Partial Equilibrium Model

Several findings emerge from the partial equilibrium approach. First, inefficiencies associated with restricting trade result in losses in bloc-level total surplus: the global economy is worse off from the fragmentation of trade in individual commodities (see Figure 3.8., panel 1).[23]

Second, bloc-level changes in total surplus are generally small (with some notable exceptions[24]), masking important heterogeneities across countries. Within each bloc, some countries experience an increase in surplus (net-exporting countries in a net-importing bloc and net-importing countries in a net-exporting bloc), and some experience a decline. Such changes are small for most countries as a share of gross national expenditure, but can be very sizable for a few commodity importers and exporters, as shown in Online Annex Figure 3.6.4. For instance, fragmentation of copper at the mining stage would reduce surplus by as much as 5 percent of gross national expenditure in Chile and Peru, both exporters of copper to the US-Europe+ bloc, where prices would fall. At the same time, it would lead to large surplus

Figure 3.8. Surplus Changes Due to Fragmentation in Individual Commodity Markets



Sources: British Geological Survey; Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: "Energy" refers to coal, natural gas, and crude oil. In panel 1, each data point in the box plots represents the total bloc-level surplus change from fragmenting trade in a single commodity. The black squares in the bars represent the median, the bars are the interquartile range, and the whiskers reflect the data points within 1.5 times the interquartile range from the 25th or 75th percentile across commodities in the group. Dots indicate outliers; the commodities associated with the largest surplus declines are labeled. The bloc including the countries that voted for Russia's withdrawal from Ukraine in the 2022 UN vote is labeled the "US-Europe+ bloc," and the remaining countries are included in the "China-Russia+ bloc." Data labels use International Organization for Standardization (ISO) country codes. GNE = gross national expenditure.

[23] For the analytic proof of this result see Alvarez and others (2023). In an integrated world, trade patterns reflect the efficient allocation of resources globally, with countries specializing in commodities for which they have comparative advantage (cost-effective deposits or suitable weather conditions). After fragmentation, trade patterns no longer reflect these comparative advantages.

[24] Online Annex Figure 3.6.3. shows the five largest surplus losses at the bloc level from the fragmentation of a single commodity. Such data points are marked as outliers in Figure 3.8., panel 1, capped at -0.05 percent of gross national expenditure. Under the baseline, trade fragmentation of palm oil or copper at the mining stage can lead to surplus losses in the China-Russia+ bloc of more than 1 percent of gross national expenditure, while trade fragmentation of iron ore or soybeans leads to surplus losses of more than 0.5 percent.

gains in Kazakhstan and Mongolia, which would scale up exports at higher prices to the copper-scarce China-Russia+ bloc (Figure 3.8., panel 2).

Third, restricting trade in commodities that are less price-vulnerable could still generate sizable surplus declines. For example, energy commodities are not particularly vulnerable under the baseline bloc configuration, but the associated declines in surplus are more significant since energy commodities are widely consumed and produced. In contrast, minerals experience strong price changes, but the surplus impact is more subdued, given their (so far) more limited relevance in countries' production and consumption.

Finally, surplus declines are generally larger in the China-Russia+ bloc. Commodities that are most vulnerable are more broadly consumed in this bloc (Online Annex Figure 3.6.3.).[25]

Evidence from the Trade Model

A general equilibrium multicountry, multisector trade model in Box 3.3. simulates long-term GDP effects from the disruption of all commodity trade. Broad differences are seen in the impact across countries, with some experiencing sizable losses. Low-income countries could suffer deeper losses than other countries, on average estimated at 1.2 percent, given their dependence on agricultural trade. Disruptions to trade in agricultural commodities would lead to losses of more than 2 percent of GDP for some of these countries. Consistent with the single-commodity exercise, the China-Russia+ bloc is more affected by fragmentation, yet the global GDP loss, at roughly 0.3 percent, is modest due to offsetting effects across countries.[26]

The economic impact can be greatly reduced if commodity trade is only partially restricted. Illustrative simulations in which countries that abstained from the vote on Ukraine are assumed to trade commodities freely point to much smaller effects of trade barriers between the US-Europe+ and the China-Russia+ blocs. Long-term changes in global GDP from this scenario are negligible, with meaningful losses only in Russia. This is in line with historical evidence on the ability of demand and supply of commodities to adjust in response to trade restrictions (Box 3.2.).

Evidence from the Macroeconomic Model

This section uses a DSGE framework to assess the dynamic GDP and inflation effects of commodity fragmentation. The model is based on an augmented version of the Global Macroeconomic Model for the Energy Transition.[27] The model includes the production, consumption, and trade of energy from fossil and renewable sources as well as four minerals critical to the energy transition. Commodities include crude oil, coal, natural gas, copper, nickel, cobalt, and lithium, capturing about 70 percent of the value of global commodity trade.

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[25] Sensitivity checks in Online Annex 3.6.2. show that this holds for a bloc configuration based on existing trade relationships. Alternatively, if all emerging market and developing economies, excluding India, Indonesia, and Latin American countries, are assigned to the China-Russia+ bloc, the US-Europe+ bloc could experience larger surplus losses, mainly due to oil market disruptions.

[26] Global GDP losses from restricting commodity flows between blocs comprise about 15 percent of the loss from restricting all trade. In comparison, commodities represent only 10 percent of total trade. The larger losses from fragmenting energy and agricultural markets in Bolhuis, Chen, and Kett (2023) stem from the assumption of full autarky compared with the no-trade-between-blocs scenario in the chapter.

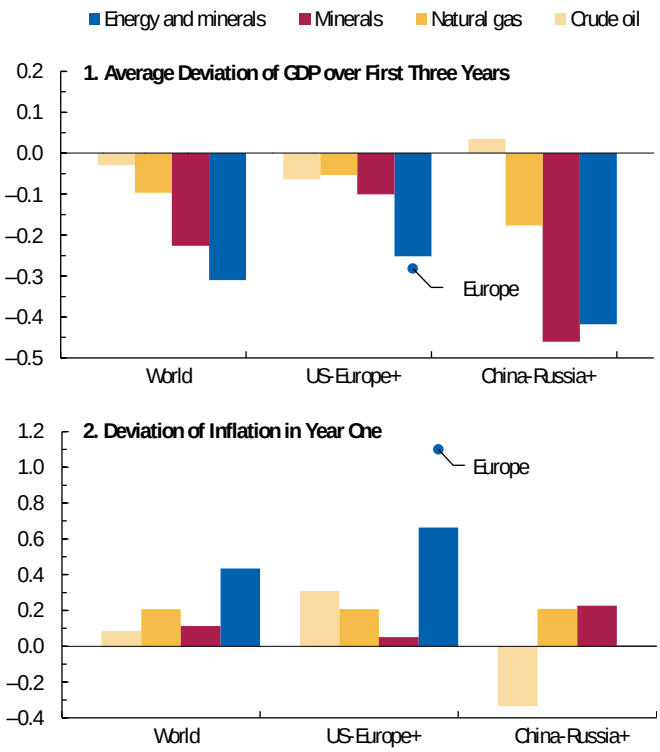
[27] The model was first used in Chapter 3 of the October 2022 WEO. It was augmented by (1) the possibility of segmenting tradable energy markets and (2) explicitly modeling two types of mineral aggregates composed of copper and nickel as well as cobalt and lithium. The augmented model has six regions: the US, the EU, US-EU–leaning countries, China, Russia, and China-Russia–leaning countries.

Fragmentation is modeled as a ban on trading these commodities between the two hypothetical blocs, which contain six different regions.

In the model, fragmentation impacts activity through several channels. First, the trade ban induces expenditure switching and trade diversion. Second, temporary imbalances between supply and demand within blocs emerge until prices adjust to clear markets. Such imbalances generate swings in commodity prices. Finally, rigidities affect the speed of adjustment of output, use, and trade, as well as overall macroeconomic effects.

The output and inflation effects vary significantly across regions, blocs, and commodities (Figure 3.9.). Comparison of the impact on individual commodities highlights the channels at play. The effects of fragmenting trade in oil and gas are quite different, even though the distribution of their consumption and production is similar across blocs. For oil, countries can quickly switch to trading partners within their bloc, with limited impact on GDP. By contrast, rigidities such as the need for pipelines or other structures constrain natural gas trade diversion, with more pronounced effects on GDP. GDP declines and inflation increases in both blocs.

Figure 3.9. Impact of Fragmentation on Real GDP and Inflation
(Percent deviation from baseline)



Sources: British Geological Survey; Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); Global Macroeconomic Model for the Energy Transition; OECD Inter-Country Input-Output Tables; United States Geological Survey; and IMF staff calculations.
Note: "Energy" refers to coal, natural gas, and crude oil. Region-level results are aggregated to the bloc and world levels using weights based on GDP at purchasing power parity. The bloc including the countries that voted for Russia's withdrawal from Ukraine in the 2022 UN vote is labeled the "US-Europe+ bloc," and the remaining countries are included in the "China-Russia+ bloc."

In the case of minerals, simulations highlight the importance of the geographic distribution of mining production and rigidities in scaling up refining capacity. On one hand, fragmentation could lead to a steep rise in prices in the China-Russia+ bloc and sizable declines in real GDP. Roughly 80 percent of the four minerals are mined in the US-Europe+ bloc, and minerals are used intensively in the China-Russia+ bloc's sizable manufacturing and construction sector. On the other hand, the US-Europe+ bloc would not be able to benefit from the relative oversupply of minerals at the mining stage since it would take several years to scale up refining capacity. That bloc would also experience a GDP decline from mineral market fragmentation.

Trade fragmentation in the seven commodities at the same time is associated with a global GDP loss of about 0.3 percent. However, as in the partial equilibrium and trade models, sizable differences are observed across and within blocs. The simulated losses are larger in the China-Russia+ bloc. Within the US-Europe+ bloc, Europe could experience a sizable impact on

inflation (as much as 100 basis points, or more) and GDP, driven mainly by the fragmentation of oil and gas markets.

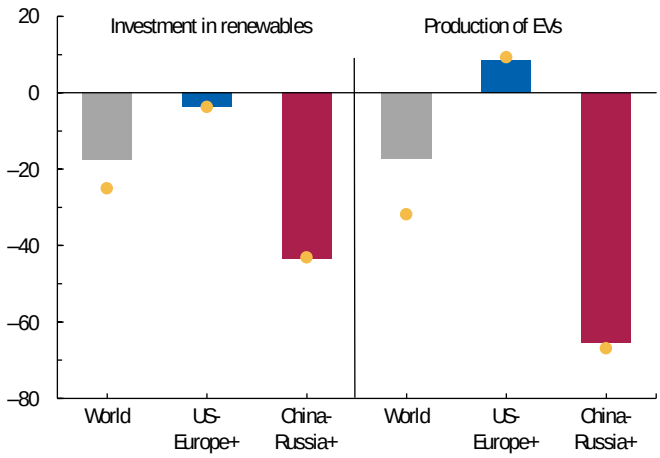
Several caveats are worth highlighting. Whereas the model provides regional granularity, it masks the heterogeneity of effects across countries given the highly concentrated nature of commodity production. Second, modeling and data constraints allow for the inclusion of only a subset of commodities. Third, the model does not capture the cost from a more volatile inflationary regime, which could make monetary policy more difficult. Finally, the model, like the two complementary analyses preceding it, uses prepandemic data on mineral usage and trade flows. Given the sizable projected increase in demand for these minerals throughout the green transition, the macroeconomic relevance of disrupting trade in these commodities will probably be greater—as discussed in the next section.

Implications for the Clean Energy Transition

Fragmentation of commodity markets could affect the cost of decarbonization. Minerals such as copper, nickel, cobalt, and lithium are key inputs for the green energy transition. They are used in EVs, in batteries and wiring, and in renewable energy technologies such as solar panels and wind turbines. Demand for these critical minerals could increase substantially (IEA 2023), and they could become as important to the world economy in a net zero emissions scenario as crude oil (Boer, Pescatori, and Stuermer, forthcoming).

Figure 3.10. Impact of Fragmentation of Critical Mineral Markets on Investment in Renewables and Electric Vehicles, 2030

(Percent deviation from net zero emissions scenario without fragmentation)



Sources: British Geological Survey; Gaulier and Zignago (2010); Global Macroeconomic Model for the Energy Transition; International Energy Agency; United States Geological Survey; and IMF staff estimates.
Note: The bars and dots in the figure report the change in real investment in renewable energy and the production of EVs in a fragmented world relative to the net zero emissions path, with demand for a cobalt, copper, lithium and nickel increase as projected by International Energy Agency's net zero emission scenario (in an integrated world). Country-level variables are aggregated to the bloc and world levels using weights based on GDP at purchasing power parity in the bars and on greenhouse gas emissions in the dots. The bloc including the countries that voted for Russia's withdrawal from Ukraine in the 2022 UN vote is labeled the "US-Europe+ bloc," and the remaining countries are included in the "China-Russia+ bloc." EVs = electric vehicles.

Under the net zero emissions by 2050 scenario, the IEA (2023) projects demand for copper to grow by a factor of 1.5, for nickel and cobalt to double, and for lithium to increase six times by 2030. This could raise prices substantially, as mining and refining are hard to scale up and are highly concentrated geographically (Figure 3.2., panel 1; Online Annex Figure 3.2.2.). For example, Chile and Peru produce about half of the world's copper, and Indonesia and the Philippines more than half its nickel.

Using the augmented Global Macroeconomic Model for the Energy Transition, this section illustrates the potential effects of mineral market fragmentation on energy transition dynamics.[28] The analysis focuses on minerals since they are key inputs for green technologies. The study of fragmentation of other commodity markets relevant for the green transition (such as oil and natural gas markets) is left to future research. The analysis uses projected increases in demand for key critical minerals in a net zero emissions scenario (IEA 2023) by assuming that policy incentives stimulate investment in renewable energy technologies and EVs. It first assumes free commodity trade. Leaving policies unchanged, it then compares the results with a counterfactual scenario of complete mineral market fragmentation across the two hypothetical blocs.

In the integrated world baseline, the model indicates that world prices of the four key minerals considered could rise by about 90 percent on average along the net zero emissions scenario path to 2030. If critical mineral markets are fragmented, the inability of the China-Russia+ bloc to import copper, nickel, lithium, and cobalt from countries such as Chile, Indonesia, or the Democratic Republic of the Congo would lead to an additional price increase in that bloc of 300 percent, on average. Acquiring minerals would be more expensive, which leads to lower investment in solar panels and wind turbines and fewer EVs (Figure 3.10.). In this net zero scenario, there would be about 70 percent fewer new EVs in the China-Russia+ bloc in a fragmented world than in an integrated world.[29]

Fragmentation causes an oversupply of minerals in the US-Europe+ bloc. However, the time needed to scale up mineral refining capacity is assumed to constrain the use of minerals in that bloc. Hence, fragmentation generates only small gains in the US-Europe+ bloc, with a slightly higher number of EVs produced but no gains in renewable energy capacity by 2030.

On balance, global net investment in renewable technology and production of EVs would be roughly 20 percent lower because of mineral market fragmentation.[30] This shortfall increases to about 30 percent if one uses greenhouse gas emissions to weigh the regional response of investment in renewables and EVs. The measure accounts for the greater emissions intensity of activity in the China-Russia+ bloc and hence the greater effort needed to achieve global emissions mitigation goals.[31] Decarbonizing the world economy would be more difficult if the market for minerals is fragmented.

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[28] Modeling the net effects of fragmentation on innovation and government policies in green technologies, in the more efficient use of commodities, in substitution, and extraction technologies is beyond the scope of this chapter. There could be competing long-term effects within and across blocs that are not captured by the supply and demand elasticities used in the model (see Acemoglu 2002; Acemoglu and others 2012; Goes and Bekkers 2022; Hassler, Krusell, and Olovsson 2021; Lemoine, forthcoming; Schwerhoff and Stuermer 2020).

[29] In the fragmentation scenario, China's fiscal cost of supporting investment to revert to the net zero emissions path is 1½–2 percent of GDP. Quantifying the impact of fragmentation on emissions reduction is outside the scope of this chapter.

[30] These findings are robust to assuming that technological progress would improve the substitutability of minerals with other inputs. Doubling the elasticity of substitution of the four minerals would reduce the decline in investment in renewable technology from 20 percent to 12 percent, for instance. The shortfall in global green investment because of fragmentation would be more muted, however, if key producers of minerals (Chile, Democratic Republic of the Congo, Peru) were assigned to the China-Russia+ bloc instead. See the exercise on countries switching blocs above and in Online Annex 3.6.

[31] The China-Russia+ bloc accounted for more than half of greenhouse gas emissions in 2020, but only a third of global GDP. Hence, global investment losses are significantly larger when bloc-level changes are aggregated using emissions (the yellow dots in Figure 3.10.) rather than purchasing-power-parity-weighted GDP (the bars in Figure 3.10.).

Summary and Policy Implications

Commodity markets are an important channel through which geopolitical fragmentation can affect the economy. Many features of commodities underpin their vulnerability to fragmentation: their highly concentrated and difficult-to-relocate production, hard-to-substitute consumption, and critical role as inputs for manufacturing and key technologies. Fragmentation in commodity markets is on the rise. Measures restricting commodity trade surged in 2022, price differentials across geographic markets have emerged for selected commodities, and FDI flows in commodity sectors are in decline—a trend that started before the war in Ukraine.

Model simulations suggest that fragmentation could cause large changes in commodity prices, depending on the resulting supply and demand imbalances and commodities' elasticities of supply and demand. Among the most vulnerable commodities are some minerals critical to the green transition and some highly traded agricultural goods.

A fragmented world would be more volatile. Commodity price volatility could intensify due to smaller market sizes and the incentives for producers to switch geopolitical allegiance. This could result in volatile inflation dynamics, making monetary policy more complex.

The potential impacts of fragmentation differ vastly across countries, with offsetting effects across consumer and producer countries resulting in modest output losses at the global level. Low-income countries, on average, would experience significantly deeper long-term output declines. Given the heavy reliance on agricultural imports by many low-income countries, fragmentation of agricultural commodities would raise important food security concerns. Baseline simulations suggest that a hypothetical China-Russia+ bloc could be more affected economically than a US-Europe+ bloc, though the economic impact would be reduced if commodity trade was only partially restricted or there was a nonaligned bloc. Overall, further fragmentation of commodity markets could throw an additional blow in an already challenging environment of slow global growth, tight financial conditions, and high debt; a blow that would be particularly harsh for some of the most vulnerable economies.

Fragmentation in critical mineral markets could make the clean energy transition more costly, raising the risks of delaying necessary climate change mitigation. It could add to the upward price pressure in the mineral-scarce bloc. The mineral-rich bloc could not reap the benefits from oversupply in the near term because it would be unable to scale up refining and processing capacity quickly. In the chapter's illustrative model simulation, fragmentation results in lower-than-needed global investment in renewables and EVs by 2030 by as much as 30 percent.

Given these findings, should advanced economies try to keep commodity trade open? Should emerging market and developing economies be concerned about the potentially higher cost of the green transition? For both questions, the answer is yes.

Even if the simulations suggest that commodity fragmentation would not result in very deep aggregate output losses in countries in a US-Europe+ bloc, the threat of derailing the global green energy transition should give advanced economies pause. With more than half of emissions generated by the hypothetical China-Russia+ bloc, averting climate disaster globally hinges on the ability of these economies to make successful and timely clean energy transitions.

On the other hand, many lower-income countries, whose main objective is raising living standards, should think twice, considering the threat of lower output and higher inflation from commodity market fragmentation.

All countries would suffer the greater volatility and uncertainty that fragmented commodity markets would bring. A protracted process of fragmentation, driven by complex and hard-to-predict policy measures and fluid implementation, would also heighten uncertainty, depressing private investment and potentially diverting scarce public resources toward a suboptimal reshoring of commodity supply.

Preventing fragmentation of commodity markets is the first-best response. Multilateral cooperation can provide guardrails and prevent a vicious spiral of countries imposing restrictions as a risk-management effort to mitigate the economic fallout from fragmentation. First-best multilateral solutions include enhanced rules within the World Trade Organization on quantitative restrictions, export tariffs, discriminatory subsidies, local content requirements, and other commodity-related trade measures (see Bown 2023). This is crucial for food commodities, as food insecurity affects a large swath of the population in low-income countries.[32]

Second-best solutions can also be considered. Given the potentially adverse effects of fragmentation on the energy transition, a minimum "green corridor" agreement should be established to preserve integrated markets for minerals that are critical for decarbonization. Safeguarding the flow of these minerals can be part of a foundational minimum agreement across countries. Without underestimating the political difficulties, such a corridor agreement could be easier to agree on because it would focus on a smaller set of commodities and countries. Similar "food corridor" agreements could provide guardrails in essential agricultural commodity markets, ensure equal access to food across countries of all income levels, and reduce the likelihood of humanitarian disasters in a world of more frequent supply shocks.

While many minerals used in clean energy technologies are bound to become critical for the global economy, the paucity of data on their consumption, production, and inventories raises uncertainty for producers and consumers and could hide potential risks for financial markets. In this respect, the international community could facilitate the green transition and support energy security by setting up a platform or organization to improve sharing and standardization of international data on mineral production, consumption, and inventories. The initiative could be similar to the Joint Organisations Data Initiative (JODI) for fossil fuels and the Agricultural Market Information System (AMIS) for food commodities.

Even as policymakers strive to mitigate the risk of fragmentation, countries can take steps to minimize the potential economic fallout. The geographic concentration of production and lack of diversification of commodity suppliers call for (1) fostering investment in domestic mining, exploration, and recycling of critical minerals; (2) diversification of supply sources; and (3) investing in infrastructure to reduce trade costs and improve market integration. Support for innovation to speed technological progress—and develop substitutes—would enhance efficiency

[32] On top of the usual distortionary effects, Giordani, Rocha, and Ruta (2016) show that trade-restricting measures for food can have multiplier effects. High food prices can trigger export restrictions while importers reduce import tariffs. These policies exacerbate tensions in world food markets and could generate another round of trade restrictions.

in the use and buildup of strategic reserves. Multilateral cooperation would enhance efficiency and prevent negative cross-country spillovers.

Broader policies that strengthen countries' resilience to shocks can help mitigate the effects of commodity shocks. These include strengthening macroeconomic, structural, and fiscal policy frameworks; building fiscal and financial buffers; and developing preparedness plans in case of sudden disruptions in commodity supply. Countries should also reinforce social safety nets to protect vulnerable households from higher commodity prices and volatility. Since fragmentation in physical commodity markets could exacerbate financial market volatility and result in sharp exchange rate adjustments, policy measures that prevent disruptions in commodity-derivatives markets and financial instability may be warranted (April 2023 GFSR).

Industrial policies are only the third-best approach and must be designed carefully to ensure equal treatment of firms across competitive markets to avoid adverse cross-country spillovers, minimize distortions and inefficiencies, and mitigate fiscal risks and harmful political economy outcomes. "Friend-shoring" policies can also be market-distorting and costly. Both sets of policies should be used only under particular conditions, such as in the presence of clear market failures or narrowly defined national security concerns. Domestic and global costs are more limited—and economies more resilient to shocks—if restriction-free trade applies to larger economic zones. Country-based restrictions on domestic content are suboptimal because they can interfere with price signals, reduce competition, and therefore lower productivity. Developing a framework for international consultations on friend-shoring practices could help identify negative cross-border spillovers and mitigate adverse consequences.

Box 3.1. Commodity Trade Tensions: Evidence from Tanker Traffic Data

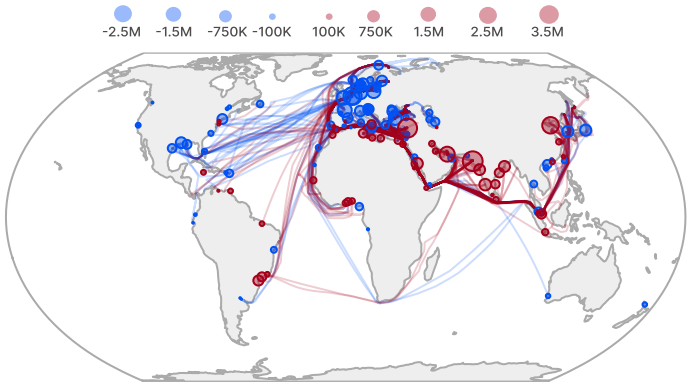
Since its invasion of Ukraine, Russia's oil exports have been subject to sanctions and have been voluntarily shunned by firms. What has been the impact on oil trade flows? Granular real-time data on tanker shipping patterns from the Automatic Identification System (AIS)[1] uncover significant shifts in routes, resulting in economic inefficiencies.

The European Union, United Kingdom, and United States banned most imports of crude oil and petroleum products from Russia after Russia's invasion of Ukraine. Western restrictions on US dollar payments have been reported to be a barrier to shipments. Group of Seven (G7) members also prohibited transportation and insurance services to tankers carrying Russian commodities above certain price thresholds.

AIS data reveal that the traffic patterns of Russia's tankers have changed substantially (Figure 3.1.1.). Tanker shipments from Russian ports to the US, Japan, and the EU declined between April–June 2023 and the same period in 2019. Other countries are now providing oil supplies. For example, the EU receives more shipments from countries such as the US, Norway, and the United Arab Emirates, but this extends the length of tanker routes by 20 percent.[2]

On the flip side, Russian oil shipments rose to countries such as China, India, Türkiye, and the United Arab Emirates. Almost 40 percent of India's oil imports came from Russia during April–June 2023, a stark rise from fewer than 5 percent before the war in Ukraine. While India's oil exports (mostly petroleum products) are small relative to its oil imports (mostly crude oil), India increased its oil exports to the EU substantially.

Figure 3.1.1. Changes in Tanker Shipments from Russia's Ports from 2019:Q2 to 2023:Q2
(Metric tons, decreases in blue and increases in red)



Sources: UN Global Platform; and IMF staff calculations.
Note: The bubble size indicates the magnitude of the change for the destination port. Lines indicate travel routes. The boundaries, colors, denominations, and any other information shown on the maps do not imply, on the part of the International Monetary Fund, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

The authors of this box are Seung Mo Choi and Alessandra Sozzi.

[1] The AIS is a mandatory self-reporting system for all ships above 300 gross tons. It is used to construct real-time trade indicators (examples are included in Arslanalp, Koepke, and Verschuur 2021; Arslanalp, Marini, and Tumbarello 2019; and Cerdeiro and others 2020). PortWatch (https://www.imf.org/portwatch) is an online platform that monitor trade disruptions and assesses spillovers through port-to-port links.

[2] UNCTAD (2022) documents a rise in tanker freight rates following the Russian invasion of Ukraine.

Box 3.2. Commodity Market Fragmentation in History: Many Shades of Gray

History points to a fluid range of experiences of fragmentation in commodity markets: from full trade disruption during World War II, to limited and controlled trade during the Cold War, to trade embargoes and other export restrictions. Fragmentation has rarely lasted, given commodities' fungibility and arbitrage opportunities.

During World War II, trade between the three major blocs—German-controlled Europe; Japanese-controlled Asia, and the rest of the world (the Allies) stopped (Findlay and O'Rourke 2007).[1] Some blocs faced commodity shortages—for example, crude oil in Germany and Japan (produced mostly by the Allies) and natural rubber in the Allies (produced mostly by Japan; Tuttle 1981). In both cases, governments worked with firms to alleviate shortages. Germany developed a coal-based synthetic fuel industry. By 1940, this fuel accounted for nearly half its oil supply and 95 percent of aviation fuel (Painter 2012). The US government stockpiled natural rubber and worked with industry to develop synthetic rubber (ACS 1998).

During the Cold War, trade between the US-led and the Soviet Union–led blocs was limited as a result of the Soviet strategy of self-sufficiency.[2] The Soviet Union traded crude oil, natural gas, and some metals for manufactured and agricultural goods, especially wheat. Traders often skirted government policies to facilitate this exchange (Farchy and Blas 2021). Political considerations also dominated trade. For example, after the Soviet invasion of Afghanistan, US President Jimmy Carter imposed a partial embargo on US grain exports to the Soviet Union.[3] The embargo, however, was ineffective due to the global nature of grain markets. While Soviet imports of US wheat fell sharply, they were replaced by imports from other countries, especially Argentina (Oki 2008).

Commodity market embargoes have often been used to apply political pressure. The Arab members of the Organization of the Petroleum Exporting Countries (OPEC) initiated an export embargo against the US and other countries in 1973 during the Arab-Israeli war and announced a 25 percent cut in output. Oil prices more than quadrupled between September 1973 and January 1974. The oil market was significantly disrupted; however, the disruption was short-lived as traders diverted oil to embargoed countries and production from non-OPEC countries rose (McNally 2017). Importers also took steps to reduce vulnerability; for example, by mandating efficiency improvements and creating strategic oil inventories (Baffes and Nagle 2022).

Another embargo example is South Africa during apartheid. Several governments implemented wide-ranging bans on exports to South Africa, particularly crude oil. However, sanctions were blunted by traders who were willing to risk violating sanctions to supply oil at high prices (Farchy and Blas 2021). Overall, the historical examples showcase the ability of fungible commodities to find their way from producers to consumers, absent near-absolute trade barriers.

The author of this box is Peter Nagle.

[1] Trade between blocs and neutral countries was affected by the war. For example, the UK and US bought much of the Spanish tungsten output to raise its price and limit availability for Germany. Between 1941 and 1943 the price of tungsten rose 13-fold (Caruana and Rockoff 2001).

[2] East-West trade was sharply reduced by the Cold War, from three-quarters of trade by the East in 1938 to 14 percent in 1953. In contrast, within-bloc trade and interdependence rose (Foreman-Peck 1995; Spulber and Gehrels 1958).

[3] In 1980, the Soviet Union planned to import 35 million metric tons of grain—25 million of that from the US. It ended up importing only 8 million tons, committed to under a previous treaty (JEC 1980).

Box 3.3. The Uneven Economic Effects of Commodity Market Fragmentation

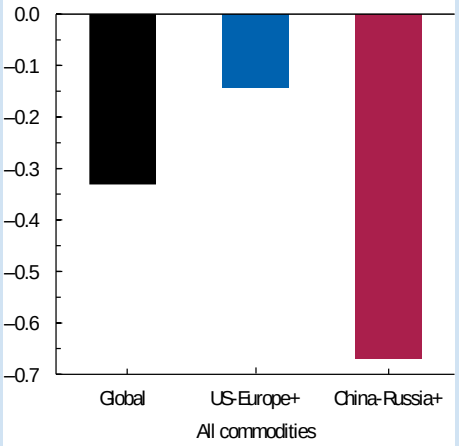
Fragmentation of commodity markets affects countries and households differently. This box demonstrates that low-income countries are more vulnerable to fragmentation, especially of agricultural commodities due to their greater reliance on food imports. The finding raises important food security concerns should further fragmentation materialize.

To quantify the impact on long-term GDP of fragmentating trade in multiple commodities simultaneously, a multicountry, multisector trade model is used, following Caliendo and Parro (2015). Bolhuis, Chen, and Kett (2023) augment the model to account for trade and production of 133 commodities across 145 countries. Labor is the only factor of production, and productivity is exogenous. Commodities are used as intermediate inputs with a long-term supply elasticity of one. The model accounts for the input-output structure of global trade and assumes low elasticity of substitution between commodities and other inputs in the production of manufactured goods. Trade costs are set such that there is no commodity trade between blocs.

Results show that the aggregate impact of commodity fragmentation would be moderate, with a global GDP loss of 0.3 percent (Figure 3.3.1.). However, there are large differences within and across blocs. Some economies may benefit from trade diversion as competitors lose access to export markets. Most experience permanent output declines. Losses are larger in countries where commodity trade with the other bloc was significant. The China-Russia+ bloc and low-income countries—whose economies are more commodity-intensive—would lose more.

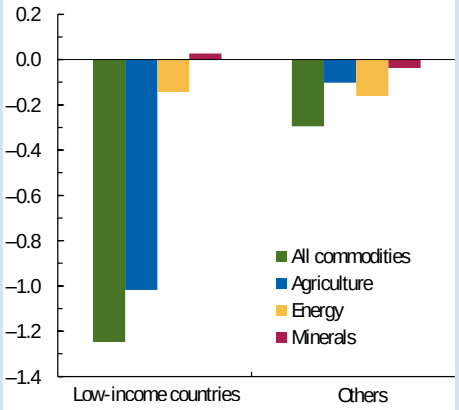
Low-income countries' high dependence on imports of agricultural goods makes them particularly vulnerable (Figure 3.3.2.). Disrupting trade in food commodities alone leads to losses of 1.1 percent of GDP. Commodity fragmentation could also have high social and humanitarian costs and would be particularly harmful for lower-income households, which spend a large share of income on food and fuel.

Figure 3.3.1. Estimated Output Losses
(Percent deviation from baseline)



Sources: British Geological Survey; Eora Global Supply Chain database; Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); US Geological Survey; and IMF staff calculations.
Note: The bars represent the losses in GDP relative to baseline from eliminating trade in groups of commodities across hypothetical blocs. Country-level losses are aggregated using weights based on GDP at purchasing power parity. For details, see Bolhuis, Chen, and Kett (2023).

Figure 3.3.2. Estimated GDP Losses in Low-income Countries and Others
(Percent deviation from baseline)



Sources: British Geological Survey; Eora Global Supply Chain database; Food and Agriculture Organization of the United Nations; Gaulier and Zignago (2010); US Geological Survey; and IMF staff calculations.
Note: The bars represent the losses in GDP relative to baseline from eliminating trade in groups of commodities across hypothetical blocs. Country-level losses are aggregated using weights based on GDP at purchasing power parity. For details, see Bolhuis, Chen, and Kett (2023).

The authors of this box are Marijn Bolhuis, Jiaqian Chen, and Benjamin Kett. See Bolhuis, Chen, and Kett (2023) for further details.

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CHAPTER 3

FRAGMENTATION AND COMMODITY MARKETS: VULNERABILITIES AND RISKS

Online Annexes

Online annexes 3.1.–3.6. present the data sources, additional stylized facts, methodology and complementary results referenced in the main text. Further details are in Alvarez and others (2023).

Online Annex 3.1 Data Sources, Sample Coverage, and Variable Definitions

Data sources are described below, while the list of economies included in the main exercises and country composition of blocs in the baseline scenario are provided in Annex Table 3.1.1.

3.1.1. Data Sources and Main Data Series

The chapter uses annual data on bilateral trade flows and production of 48 commodities at the country level. The data are linked through manually constructed concordances between HS codes and commodity production definitions. We initially built on Fally and Sayre (2018) but extended the concordances in major ways based on the literature on commodities as well as consultations with the British Geological Survey (BGS) (see Alvarez and others, 2023). Mined minerals (e.g., copper ore) are differentiated from refined mineral commodities (e.g., refined copper). The concordances also correct for errors in unit measurements. This is often overlooked in the literature.

The energy (coal, natural gas and crude oil), mineral, and agricultural commodities included are listed in Alvarez and others (2023) and Online Annex Figure 3.2.1. They were selected because they represent a large share of global trade, or are part of critical raw materials lists by the EU or US. Commodities with insufficient data were eliminated from consideration (e.g., uranium).

Bilateral trade data for minerals are from the Bilateral Commodity Trade Database (BACI), which draws on UN Comtrade. For agriculture, data are from FAO's trade matrix database.[1] Both sets provide standardized data on bilateral trade flows at the HS 6-digit product level, covering the 1986-2022 period, 220 countries and 49 commodities.

Production data for minerals are from the BGS, except for titanium, silicon, and potash, for which we use the US Geological Survey (USGS) data. Production of some minerals is expressed in metric tons of metal content, while trade data are reported in metric tons. To ensure comparability, adjustment factors are applied to convert trade flows of these minerals into equivalent metric tons of metal content. The adjustment factors are constructed based on the literature and in collaboration with BGS (see Alvarez and others 2023).

For agricultural commodities, output data are from the FAO Crops and Livestock Products Dataset, supplemented with the FAO Supply Utilization Accounts Dataset for rice and sugar. Energy commodities data is sourced from the International Energy Agency (IEA).

Cross-country Mergers and Acquisitions (M&A) are from Refinitiv Eikon.

[1] We apply the common mirroring technique to FAO bilateral trade data to calculate country specific exports based on reported imports from partner countries. This involves setting the exports from country "i" to country "j" equal to the imports of country "j" from country "i," thereby rectifying the mismatch and ensuring data consistency.

Greenfield Foreign Direct Investment (FDI) data are from fDi Markets, a service offered by the Financial Times. The database tracks and records new physical projects or the expansion of pre-existing investments using primarily public sources, such as media reports, industry organizations, investment promotion agencies, and news wires.

Commodity price data for mineral and energy commodities come from Bloomberg L.P., a global financial data provider. For agricultural and some mineral commodities, we calculate export prices using monthly trade quantity and value data from UN Comtrade. We estimate exports based on reported imports from trade partners (mirroring) to improve data coverage and quality.

Price elasticities of supply and demand are from Fally and Sayre (2018) and Dahl (2020), who provide a literature review of commodity elasticity estimates. The elasticities used in the chapter and their sources are reported in Alvarez and others (2023).

3.1.2. Economies Included and Definition of Blocs

The chapter includes all IMF World Economic Outlook economies for the exercises. If data is not available for a specific commodity in an exercise, the country is dropped from the sample. The countries are listed in Online Annex Table 3.1.1.

The baseline scenario divides countries into two geopolitical blocs, based on the March 2022 UN vote on the war in Ukraine (see Online Annex Table 3.1.1.). Countries, which abstained in the vote, are assigned to the China-Russia+ bloc. Different bloc configurations are also considered (Online Annex Table 3.6.1.).

Online Annex Table 3.1.1. Economies Included and Baseline Scenario Bloc Composition

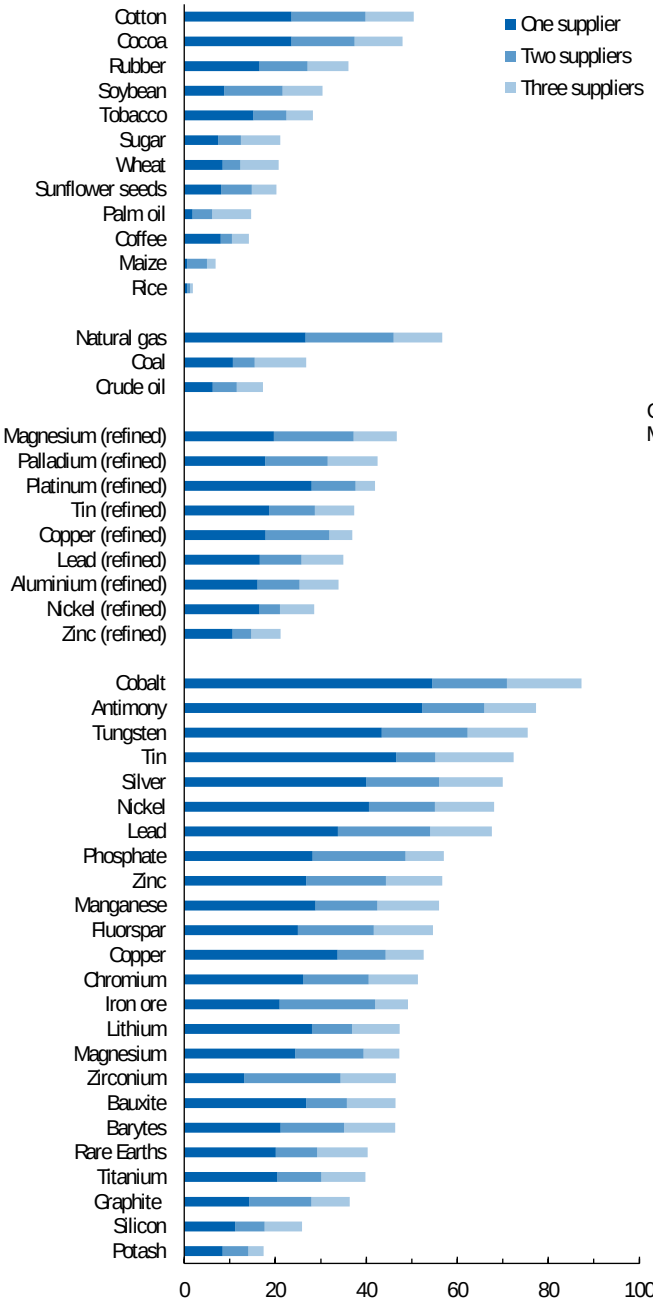
US-Europe+ Bloc	China-Russia+ Bloc
Afghanistan; Albania; Andorra; Antigua and Barbuda; Argentina; Aruba; Australia; Austria; Bahamas, The; Bahrain; Barbados; Belgium; Belize; Benin; Bhutan; Bosnia and Herzegovina; Botswana; Brazil; Brunei Darussalam; Bulgaria; Cabo Verde; Cambodia; Canada; Chad; Chile; Colombia; Comoros; Congo, Democratic Republic of the; Costa Rica; Côte d'Ivoire; Croatia; Cyprus; Czech Republic; Denmark; Djibouti; Dominica; Dominican Republic; Ecuador; Egypt; Estonia; Fiji; Finland; France; Gabon; Gambia, The; Georgia; Germany; Ghana; Greece; Grenada; Guatemala; Guyana; Haiti; Honduras; Hungary; Iceland; Indonesia; Ireland; Israel; Italy; Jamaica; Japan; Jordan; Kenya; Kiribati; Korea; Kosovo; Kuwait; Latvia; Lebanon; Lesotho; Liberia; Libya; Lithuania; Luxembourg; Malawi; Malaysia; Maldives; Malta; Marshall Islands; Mauritania; Mauritius; Mexico; Micronesia; Moldova; Montenegro, Rep. of; Myanmar; Nauru; Nepal; Netherlands; New Zealand; Niger; Nigeria; North Macedonia; Norway; Oman; Palau; Panama; Papua New Guinea; Paraguay; Peru; Philippines; Poland; Portugal; Puerto Rico; Qatar; Romania; Rwanda; Samoa; San Marino; São Tomé and Príncipe; Saudi Arabia; Serbia; Seychelles; Sierra Leone; Singapore; Slovak Republic; Slovenia; Solomon Islands; Somalia; Spain; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Suriname; Sweden; Switzerland; Thailand; Timor-Leste; Tonga; Trinidad and Tobago; Tunisia; Türkiye; Tuvalu; Ukraine; United Arab Emirates; United Kingdom; United States; Uruguay; Vanuatu; Yemen; Zambia	Algeria; Angola; Armenia; Azerbaijan; Bangladesh; Belarus; Bolivia; Burkina Faso; Burundi; Cameroon; Central African Republic; China; Congo, Republic of; El Salvador; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; Guinea; Guinea-Bissau; Hong Kong SAR; India; Iran; Iraq; Kazakhstan; Kyrgyz Republic; Lao P.D.R.; Macao SAR; Madagascar; Mali; Mongolia; Morocco; Mozambique; Namibia; Nicaragua; Pakistan; Russia; Senegal; South Africa; South Sudan; Sri Lanka; Sudan; Syria; Tajikistan; Tanzania; Togo; Turkmenistan; Uganda; Uzbekistan; Venezuela; Vietnam; Zimbabwe

Source: IMF staff compilation.

Online Annex 3.2. Additional Stylized Facts

Online Annex Figure 3.2.1. Share of Countries that Import from Only One, Two, or Three Suppliers

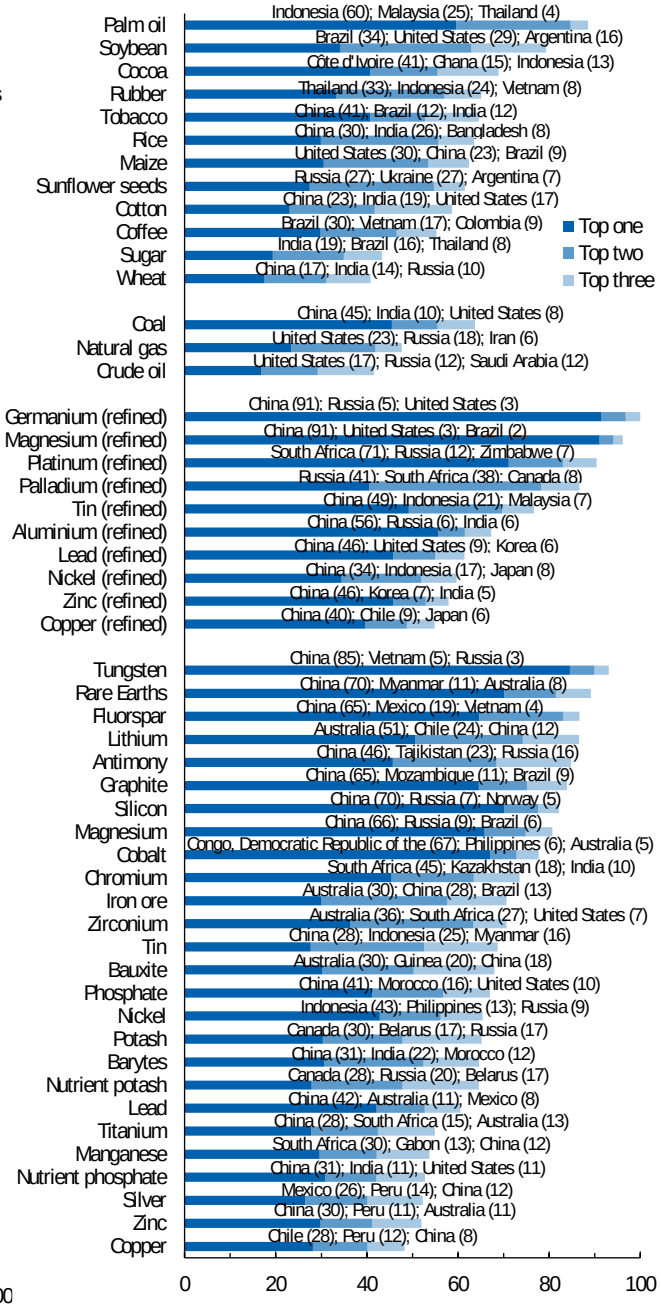
(Percent)



Sources: British Geological Survey; Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.

Online Annex Figure 3.2.2. Share of Top Three Countries in Total Commodity Production

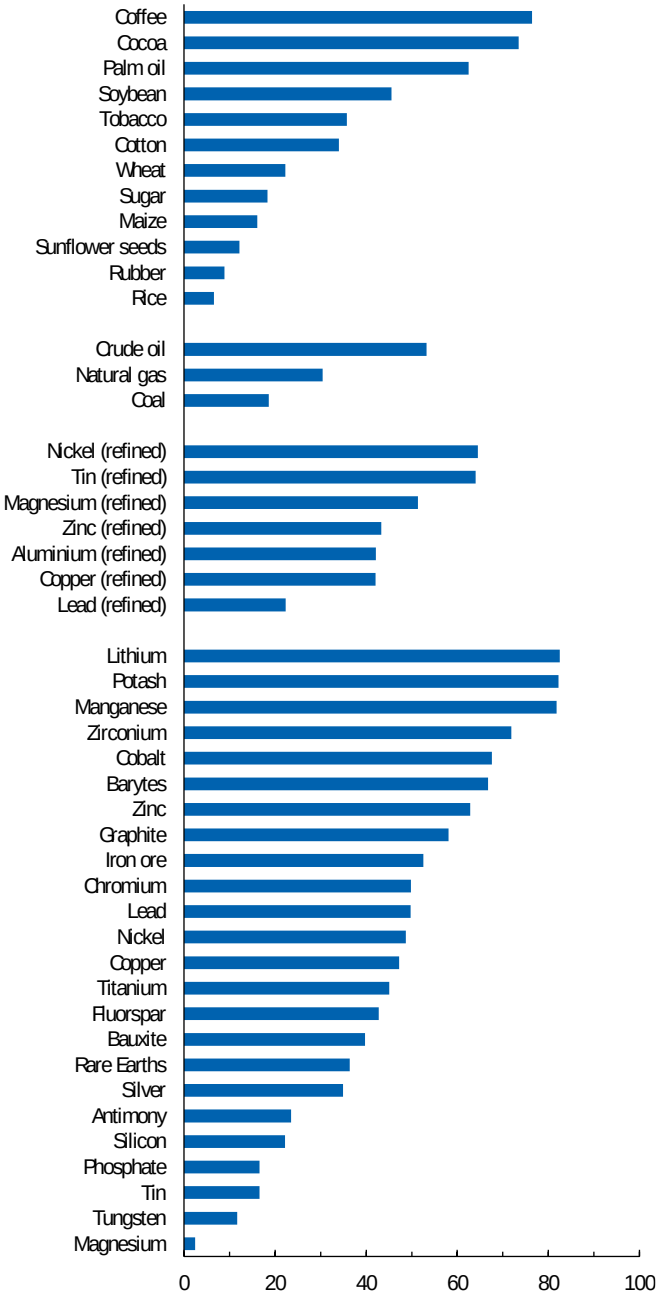
(Percent)



Sources: British Geological Survey; Food and Agricultural Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.

Online Annex Figure 3.2.3. Share of Traded World Production

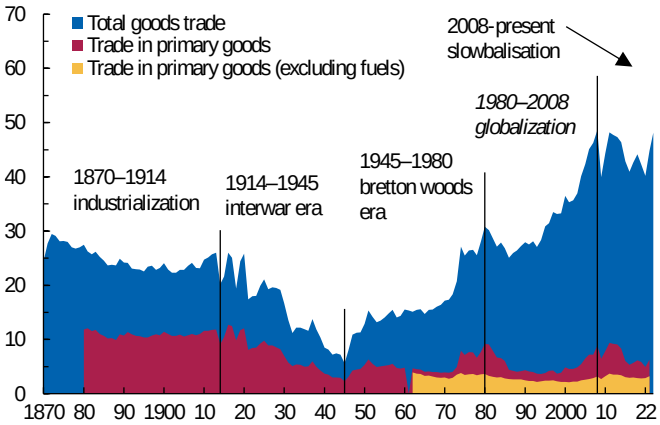
(Percent)



Sources: British Geological Survey; Food and Agricultural Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.

Online Annex Figure 3.2.4. Total and Primary Trade Openness

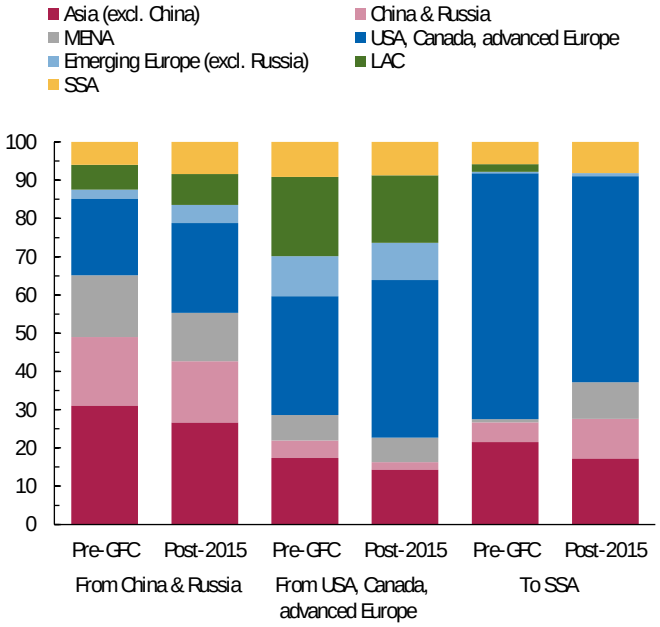
(Sum of goods exports and imports, percent of GDP)



Sources: International Trade Statitsics, 1900-1960; Jacks and Tang (2018); Jordà-Schularick-Taylor (JST) Macrohistory Database; UN Comtrade; and IMF staff calculations.
Note: Trade openness is measured as the ratio of exports and imports to GDP in nominal USD. Commodity trade is approximated by primary goods trade, using the Broad Economic Classification (BEC) Rev. 1. UN Comtrade data (1962-2022) is spliced with series from the UN International Trade Statistics, the JST Macrohistory database, and Jacks and Tang (2018).

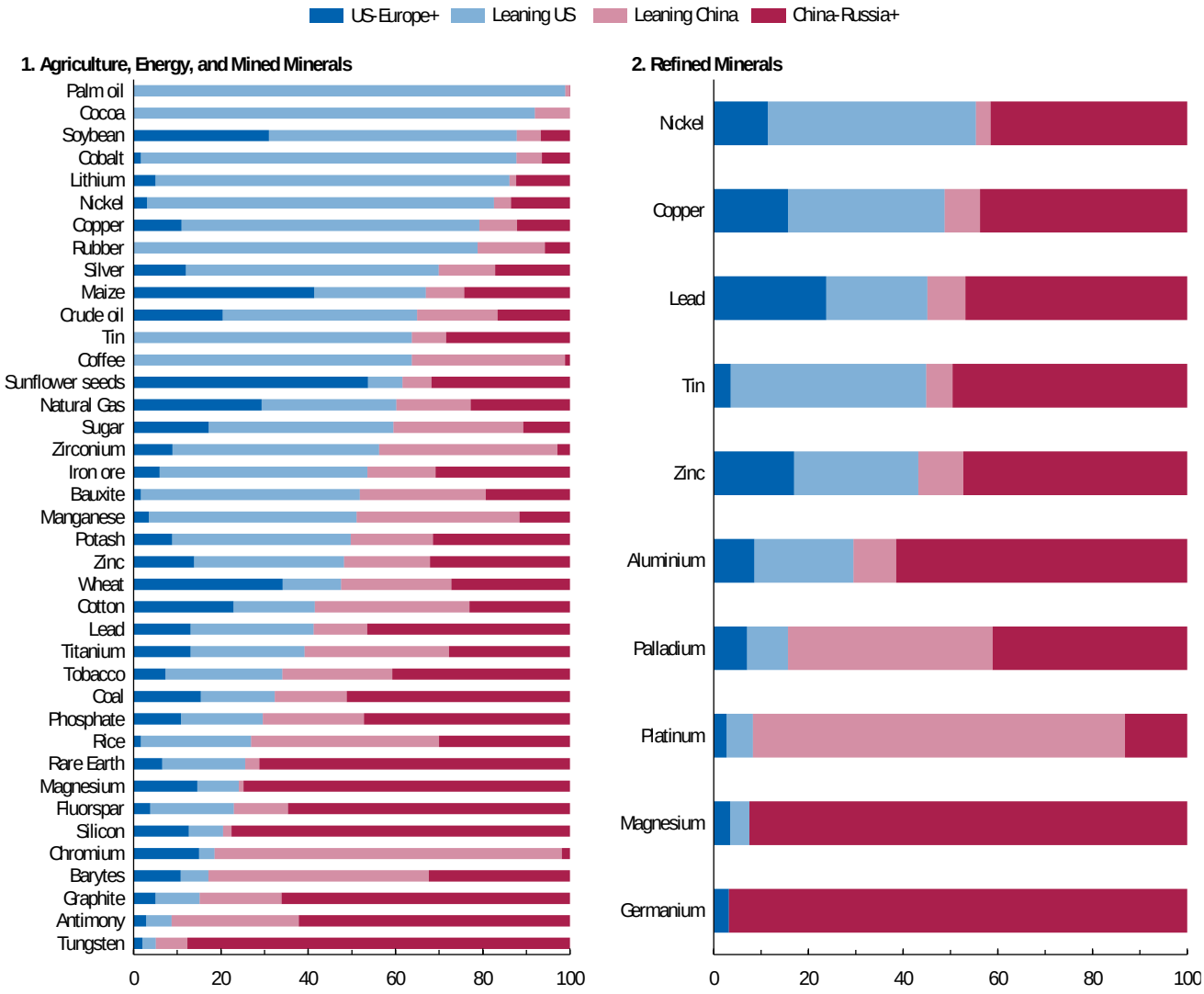
Online Annex Figure 3.2.5. Greenfield FDI and M&As in the Commodities Sector: Selected Sources and Destinations

(Percent of projects)



Sources: fDi Markets; and IMF staff calculations.
Note: FDI = foreign direct investment; GFC = global financial crisis; LAC = Latin America and the Caribbean; M&As = mergers and acquisitions; MENA = Middle East and North Africa; SSA = sub-Saharan Africa.

Online Annex Figure 3.2.6. Commodity Global Production: Distribution across Blocs
(Percent of global production, 2019)



Sources: British Geological Survey; Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.

Online Annex 3.3. Gravity Equation

To estimate the gravity equation that relates geopolitical distance to bilateral commodity trade, bilateral trade values from BACI and FAO are used. Other gravity covariates, such as geographical distance between pairs of countries, common language, among others, are obtained from CEPII GeoDist database (Mayer and Zignago, 2011). The Alliance Treaty Obligations and Provisions (ATOP) database (Leeds and others, 2002) provides information on each country's portfolio of military alliances. ATOP is used to calculate the similarity of portfolios of each country pair following Signorino and Ritter's (1999) s-score, s_{ijt}, for country i and country j in

year t. The measure of distance of military alliances is $MD_{ijt} = 1 - s_{ijt} \geq 0$. For ease of interpretation, MD_{ijt} is normalized so that its standard deviation is 1 in every year.

The gravity equation is estimated for each commodity type using 2010-18 data according to

$$y_{cijt} = \alpha_c MD_{ijt} + \beta_c X_{ijt} + E_{cit} + I_{cjt} + \varepsilon_{cijt}$$

where y_{cijt} is the value of exports of commodity type c from country i to country j in year t. Gravity covariates, X_{ijt}, include the geographical distance between the most populated cities in a country pair; whether countries are contiguous; speak a common language; have a colonial relationship; share a colonial history; are a current colony; and whether either country is a member of the World Trade Organization.[2] E_{cit} and I_{cjt} are fixed effects that capture importer- and exporter-specific trends in the trade of commodity c.

To account for country pairs having no trade flows in specific commodities, y_{cijt} is measured as an inverse hyperbolic sine of the trade value.[3] Two other specifications are run for robustness, where the gravity equation is estimated as a Poisson regression. The first specification is

$$v_{cijt} = \exp\left(\alpha_c MD_{ijt} + \beta_c X_{ijt} + E_{cit} + I_{cjt} + \varepsilon_{cijt}\right).$$

The second specification follows Hakobyan and others (2023) and first estimates the *undirected* propensity that a country pair trades goods, δ_{cijt} such that $\delta_{cijt} = \delta_{cjit}$ for any i, j

$$v_{cijt} = \exp\left(E_{cit} + I_{cjt} + \delta_{cijt} + \varepsilon_{cijt}\right),$$

and in a second stage estimates how distance of military alliances can impact this propensity

$$\delta_{cijt} = \alpha_c MD_{ijt} + \beta_c X_{ijt} + u_{cijt}.$$

The regression results can be found in Online Annex Table 3.3.1. Across all specifications, military distance is negatively associated with commodity trade flows. There are differences in the strength and consistency of this association across commodity types, with the negative effect of geopolitical distance on trade typically being the most pronounced for minerals.

[2] Because most of those variables do not vary over time, a static version of the gravity equation is also estimated for each year. There is no clear trend in the coefficients on geopolitical distance estimated in that manner.

[3] The inverse hyperbolic sine is defined as $y_{cijt} = \log\left(v_{cijt} + \sqrt{1 + v_{cijt}^2}\right)$, where v_{cijt} is the value of trade. This function is well defined at $v_{cijt} = 0$, but quickly converges to $\log(2 \times v_{cijt})$ as v_{cijt} grows. The coefficients α_c can thus be interpreted as elasticities when there is trade.

Online Annex Table 3.3.1. Gravity Equation Coefficients on Military Distance

Specification	Commodity Type			
	All Commodities	Agriculture	Energy	Minerals
	(1)	(2)	(3)	(4)
Baseline (inverse hyperbolic sine)	–0.2306***	–0.2298***	–0.1532***	–0.3789***
	(0.0372)	(0.0376)	(0.0259)	(0.0416)
Poisson (one stage)	–0.151	0.1052**	–0.4492***	–0.2449***
	(0.1007)	(0.053)	(0.1499)	(0.0716)
Poisson (two stages)	–0.1186*	–0.0558	–0.0957	–0.1575***
	(0.0621)	(0.0418)	(0.1014)	(0.057)

Source: IMF staff compilation.
Note: All specifications include exporter-by-year and importer-by-year fixed effects. Standard errors are shown in parenthesis and clustered at the importing country level. *, **, and *** indicate coefficients are statistically different from 0 at the 10%, 5%, and 1% levels, respectively.

Online Annex 3.4. A Multi-country, Partial Equilibrium Commodity Market Model

Based on Alvarez and others (2023), consider a single-commodity model with multiple countries that face country-specific supply (s) and demand (d) curves of the following form:

$$\ln(q_c^s) = \eta^s \ln(p_c) + \gamma_c^s$$
$$\ln(q_c^d) = \eta^d \ln(p_c) + \gamma_c^d ,$$

where c denotes the country, q_c^s and q_c^d are quantities supplied and demanded, p_c is the commodity price, and $\eta^s > 0$ and $\eta^d < 0$ are the price elasticities of supply and demand of the commodity. For simplicity, all countries are assumed to have the same supply and demand elasticities, but have unique demand and supply shifters, γ_c^s and γ_c^d.

Countries are in one of two blocs $B\epsilon\{USA - Europe+, China - Russia +\}$. Aggregating all countries within a single bloc B, we get the following bloc-level demand and supply curves.

$$\ln(Q_B^s) = \eta^s \ln(p_B) + \gamma_B^s$$
$$\ln(Q_B^d) = \eta^d \ln(p_B) + \gamma_B^d$$

where $Q_B^s = \sum_{c\epsilon B} q_c^s$, $Q_B^d = \sum_{c\epsilon B} q_c^d$, $\gamma_B^s = \log(\sum_{c\epsilon B} e^{\gamma_c^s})$ and $\gamma_B^d = \log(\sum_{c\epsilon B} e^{\gamma_c^d})$. This defines two market equilibria: one that allows for trade between blocs and one that does not.

Integrated market equilibrium. The integrated market equilibrium must fulfill market clearing and non-arbitrage conditions such that $Q_{USA-EU+}^s + Q_{CHN-RUS+}^s = Q_{USA-EU+}^d + Q_{CHN-RUS+}^d$ and $p_{USA-EU+} = p_{CHN-RUS+} = p_w$, where p_w is the world price. The equilibrium world price can then be written as a function of supply and demand parameters. That is

$$\ln(\mathrm{p_w}) = \frac{1}{\eta^s - \eta^d} * (\Omega^{\mathrm{d}} - \Omega^{\mathrm{s}})$$

where $\Omega^{\mathrm{d}} \equiv \ln(e^{\gamma_{USA-EU+}^d} + e^{\gamma_{CHN-RUS+}^d})$ and $\Omega^{\mathrm{s}} \equiv \ln(e^{\gamma_{USA-EU+}^s} + e^{\gamma_{CHN-RUS+}^s})$. The equilibrium world price can be substituted into bloc- or country-specific demand and supply curves to obtain the corresponding quantities demanded, supplied, and net exports/imports.

Fragmented market equilibrium. The fragmented market equilibrium assumes no trade between blocs, while trading costs within a bloc are zero. The equilibrium prices and quantities must then fulfill bloc-level market clearing conditions. The new market equilibrium prices in a bloc *B* is

$$\ln(p_B) = \frac{(\gamma_B^d - \gamma_B^s)}{\eta^s - \eta^d}$$

Bloc- and country-level quantities and net exports can be obtained by substituting bloc level prices, p_B, into the corresponding supply and demand curves.

Fragmentation impact. In the model, the impact of fragmentation is the difference in country- or bloc-level quantities and prices between the fragmented and integrated market equilibria. The change in price is given by:

$$\ln(p_B) - \ln(\mathrm{p_W}) = \frac{1}{\eta^s - \eta^d} * [(\gamma_B^d - \gamma_B^s) - (\Omega^{\mathrm{d}} - \Omega^{\mathrm{s}})]$$

In our calibration, $\mathrm{p_W}$ is standardized to 1, so that

$$\gamma_c^d = \ln(q_c^d) = observed\ initial\ quantity\ demanded$$
$$\gamma_c^s = \ln(q_c^s) = observed\ initial\ quantity\ supplied$$

From initial equilibrium conditions, $\Omega^{\mathrm{d}} = \ln(e^{\gamma^d_{USA-EU+}} + e^{\gamma^d_{CHN-RUS+}}) = \ln(q^d_{USA-EU+} + q^d_{CHN-RUS+}) = \Omega^{\mathrm{s}},\ \text{so}\ \Omega^{\mathrm{d}} - \Omega^{\mathrm{s}} = 0$. The effect of fragmentation on prices is given by:

$$\ln(p_B) - \ln(\mathrm{p_w}) = \frac{\gamma_B^d - \gamma_B^s}{\eta^s - \eta^d}$$

Consumer, producer and total surplus changes. The simple model can be used to analyze changes in producer and consumer surplus. These are calculated as the change in areas under the demand curve (above equilibrium prices), for consumer surplus changes, and the change in the areas above the supply curve (under equilibrium prices), for producer surplus changes. More specifically, changes in consumer and producer surplus for country c are given by:

$$\Delta \mathrm{CS_c} = -\int_{p_w}^{p_c} e^{\eta^d \ln(p\ \ )+\gamma^d} dp = -p_w^{1+\eta^d} q_{c,w}^d \frac{\left(\frac{p_c}{p_w}\right)^{1+\eta^d} - 1}{\eta^d + 1}$$

$$\Delta \mathrm{PS_c} = \int_{p_w}^{p_c} e^{\eta^s \ln(p\ \ )+\gamma^s} dp = p_w^{1+\eta^s} q_{c,w}^s \frac{\left(\frac{p_c}{p_w}\right)^{1+\eta^s} - 1}{\eta^s + 1}$$

where $p_c = \mathrm{p_B}$, is the price faced by country *c* (which equals the bloc-level price in the fragmented equilibrium), and $p_w q_{c,w}^d$ and $p_w q_{c,w}^s$ are the quantities, in dollars, demanded and supplied in the integrated market equilibrium. Surplus changes are larger in countries that experience a larger price change in a largely consumed or produced commodity. Total surplus is the sum of consumer and producer surplus in a particular economy.

Calibration of the model

The model is calibrated so that the pre-fragmentation economy matches observed country and bloc-level trade flows for 2019, prior to the onset of the COVID-19 pandemic.[4]

Demand and supply shifters (γ_c^d, γ_c^s)

Standardizing the integrated market price to one ($\mathrm{p_w} = 1$), γ_c^d and γ_c^s are calibrated to match the log of the initial quantity demanded and supplied of a particular commodity. The quantity produced is the volume in metric tons of content of a commodity. The quantity demanded is calibrated as the quantity produced minus net exports volume for each commodity.[5]

Elasticity parameters (η^d, η^s)

The calibration of elasticity parameters is informed by empirical estimates from the literature, as documented in the survey by Fally and Sayre (2018) and Dahl (2020). The calibration of η^d and η^s, namely the demand and supply elasticities, uses the following algorithm. First, it relies on the short-run median demand and supply price elasticity estimates for a commodity from Dahl (2020), where available. Second, if missing[6], estimates from static models from Dahl (2020) are used. Third, for commodities with still missing values, the average short-run elasticities from Fally and Sayre (2018) is taken. Fourth, for those commodities where no estimate is available, the average elasticity across commodities in the broad group is used (e.g., food, minerals). The elasticities used for each commodity can be found in Alvarez and others (2023).

Online Annex 3.5. GMMET Model

This section provides details on the Global Macroeconomic Model for Energy Transition (GMMET), the extensions implemented for the chapter, data sources, and simulations.

3.5.1. Description of GMMET

GMMET is a general equilibrium multi-region multi-sector model configured here for six regions. The regional specification is designed to restrict trade between two hypothetical blocs, the US-Europe+ bloc and the China-Russia+ bloc as described in Online Annex Table 3.1.1. The six regions are: the US; the EU; a region comprising countries leaning toward the US and the EU; China; Russia; and a region comprising countries leaning toward China and Russia. The model belongs to the class of large-scale structural New-Keynesian dynamic general equilibrium models that are traditionally used for the quantitative short- and medium-term analysis of monetary and fiscal policy. Its core macroeconomic structure is described in Carton and others (2023) and Kumhof and others (2010).

The Core Structure

Each period corresponds to a calendar year. The model features liquidity-constrained households, who consume all income each period, and overlapping-generations households, who decide how much to consume and save and how much to work. Households consume

[4] Due to data quality considerations, the calibration of crude oil and zirconium uses data from 2018.
[5] Note that storage is not included in the analysis.
[6] Demand (supply) price elasticity estimates with positive (negative) values are treated as missing.

standard goods and services, energy for residential purposes (natural gas and electricity) and transportation services. Transportation services are provided with conventional cars burning gasoline (that comes from oil) and electric vehicles (EVs) running on electricity. The choice of whether to purchase a conventional car or an EV depends on their relative prices.

Both types of households exhibit non-Ricardian behavior, which allows fiscal policy to have an impact on macroeconomic variables even in the long run (Blanchard, 1985). Firms in non-energy sectors produce tradable and nontradable goods based on energy inputs (from fossil fuel and renewable sources) and labor and capital.

In each region, there are governments and central banks, which follow specific budgetary and monetary rules. As in standard New-Keynesian models, nominal and real rigidities in domestic production, labor market and trade make monetary and fiscal policy have notable near-to-medium-term effects.

In the model, all markets clear in each period at the equilibrium prices and the prices for all good and services are reflected in CPI indexes in each region.

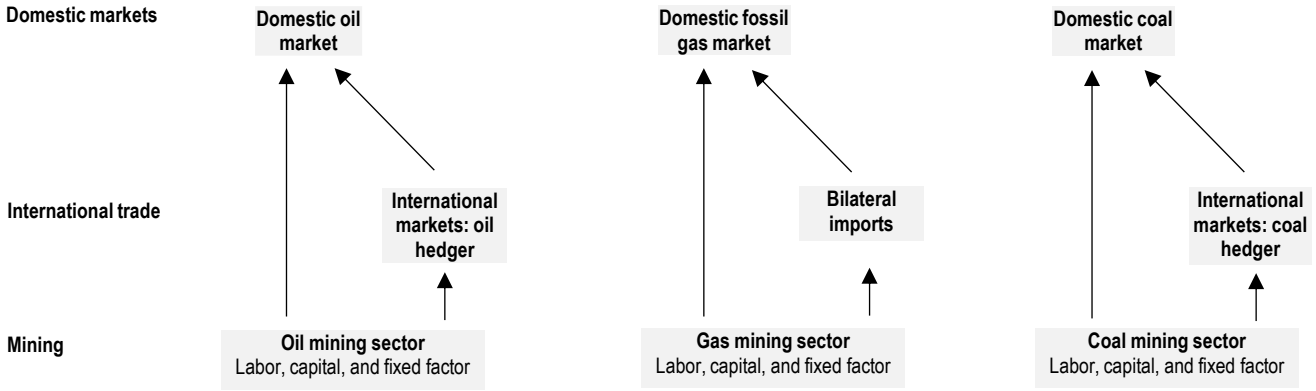
Fossil Fuel Energy Sectors

Energy production originates from three fossil fuel mining sectors – coal, gas, and crude oil – each combining capital and labor with a resource, which is fixed in each period, but scalable over time, accounting for limited possibilities to adjust mining capacity in the short run (coal mines, gas or oil wells). All three fuels are sold to the tradable sector as an intermediate input. Oil and gas are also consumed by households (as car gasoline and fuel for home heating, respectively); natural gas and coal are also sold as fuel for electricity generation.

There are domestic and international markets for oil. The model extends Carton and others (2023) by allowing for international trade of oil in perfectly integrated markets as well as in segmented markets as detailed in Online Annex Figure 3.5.1.

There is a hedger that aggregates oil exports from producing regions and sells to importing region according to their demand. In the absence of restrictions, markets are perfectly integrated, and the hedger sets commodity prices such that markets clear at the global level. In case of

Online Annex Figure 3.5.1. Fossil Fuels Markets



Source: IMF staff compilation.

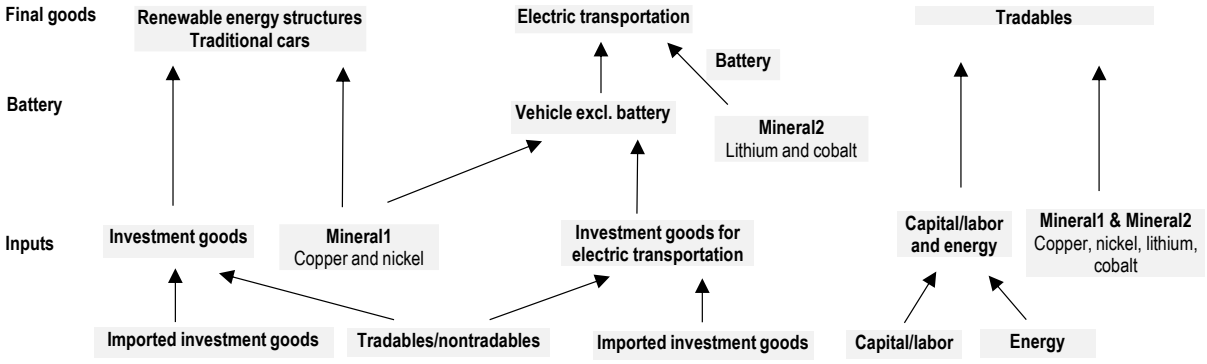
restrictions of trade across blocs, the hedger sets prices in each bloc such that the market clears at the single bloc market level.

Coal markets operate in a similar fashion. Natural gas markets, however, are structured differently. Segmentation in gas markets arises from the need of pipelines and other structures (e.g., LNG terminals) for transportation. Thus, international trade of natural gas is modelled as a bilateral flow between regions.

Minerals Sector

Relative to the GMMET in Carton and others (2023), the model is augmented with minerals sectors key for the green energy transition: copper, nickel, lithium, and cobalt. Copper, which is used in cables and conductors, is essential for the turbines and panels in solar and wind electricity generation (renewables). Nickel is used in the bearings, shafts, gears, and hydraulic components of wind turbines. Lithium and cobalt form an essential part of the lithium-ion batteries used in EVs.

Online Annex Figure 3.5.2. Use of Minerals



Source: IMF staff compilation.

Minerals enter the model in two mineral composites sectors; copper and nickel (*mineral1*); and lithium and cobalt (*mineral2*). Besides being crucial inputs for the green transition, the mineral composites are used in other production processes, such as for manufacturing goods and building structures, combined in a unique tradables bundle, and for conventional cars (CC). The use of minerals in the production of tradables and CC represents another extension of GMMET relative to Carton and others (2023).

To produce CCs and EVs, *mineral1* is combined with an investment good to construct the bulk of the vehicle (Online Annex Figure 3.5.2.). Additionally, for EVs, *mineral2* is added, as a proxy for the battery component at a second stage. Investment goods are either produced with a bundle of domestically produced tradables and non-tradables or entirely imported. Structures for renewable energy (solar panels, wind turbines) are produced with a technology that resembles the one for CCs using a bundle of investment goods and *mineral1*. EVs are produced in each region and are bundled and traded together with other final products. Finally, to produce tradable goods, the model combines *mineral1* and *mineral2* with a capital/labor and energy bundle. As shown in Online Annex Figure 3.5.2., availability of minerals affects the production of solar panels, wind turbines and cars either directly or indirectly, through the tradables inputs.

The model focuses on minerals at the mining stage, as the geographical location of endowments is important for the impact of fragmentation. Mining of the two mineral composites is structured in the same way – each combining capital and labor with a resource, which is fixed in each period. Minerals can be traded in integrated international market as well as in segmented markets, following the same structure of oil and coal (Online Annex Figure 3.5.1).

Data and Parameter Specification

Production technologies in the model are CES and feature constant return to scale. The calibrated model reproduces empirical estimates of the supply elasticity of fossil fuel commodities and the four critical minerals (Fally and Sayre, 2018; Dahl, 2020). The production and trade intensities of fossil fuels commodities and minerals are calibrated using the BGS, US Geological Survey, Bilateral Commodity Trade Database, IEA, and Eurostat.

Online Annex Table 3.5.1. Mineral Use, Supply and Trade
(Percent of region GDP, unless noted otherwise)

	United States	European Union	Countries learning toward USA-Europe+	China	Russia	Countries leaning toward China-Russia+
	(1)	(2)	(3)	(4)	(5)	(6)
GDP (percent of world)	24.60	18.10	27.60	16.50	1.80	11.40
Mineral1 (copper and nickel)	0.03	0.07	0.28	0.41	0.61	0.10
Production	0.04	0.04	0.48	0.08	0.53	0.16
Net imports	–0.01	0.03	–0.19	0.33	0.07	–0.06
Mineral2 (lithium and cobalt)	0.00	0.01	0.01	0.03	0.02	0.01
Production	0.00	0.00	0.03	0.00	0.01	0.00
Net imports	0.00	0.01	–0.02	0.03	0.01	0.00

Sources: British geological survey; Gaulier and Zignano (2010); Global macroecomic model for the energy transition; and IMF staff calculations.
Note: Accounting errors due to rounding. Minerals data are at the mined stage.

All key parameters, including for the fossil fuel sectors, are in line with Carton and others (2023). Annex Table 3.5.1 focuses on the calibration of the mineral sector. The extraction and use of *mineral1* and *mineral2* are based on 2018 and 2019 data. Annex Table 3.5.2. outlines the key values in the benchmark calibration for the use of minerals as well as alternative calibrations. Generally, both *mineral1* and *mineral2* cannot easily be substituted by other minerals or intermediate goods (Fally and Sayre, 2018; Dahl, 2020). Further, the use of *mineral1* in the production of renewables is also assumed to be inelastic, with an elasticity of substitution of 0.1. Robustness of the findings is tested using higher elasticity of substitution (0.4 in Table 3.5.2.). This would imply that, for instance, technological progress allows for more substitutability of minerals with other inputs.

Online Annex Table 3.5.2. Minerals' Elasticities of Substitution

	Benchmark	Higher
	(1)	(2)
Elasticity between:		
Minerals and other factors in manufacturing	0.2	0.4
Minerals in the production of electric transport	0.2	0.4
Mineral1 in the production of conventional transport	0.2	0.4
Mineral1 and production of renewables	0.1	0.4

Source: IMF staff compilation.

3.5.2. Fragmentation Scenarios: Main Channels

The model starts from a steady-state equilibrium, where markets are fully integrated. Then, fragmentation is introduced by eliminating trade in each of the key commodities between the two blocs.

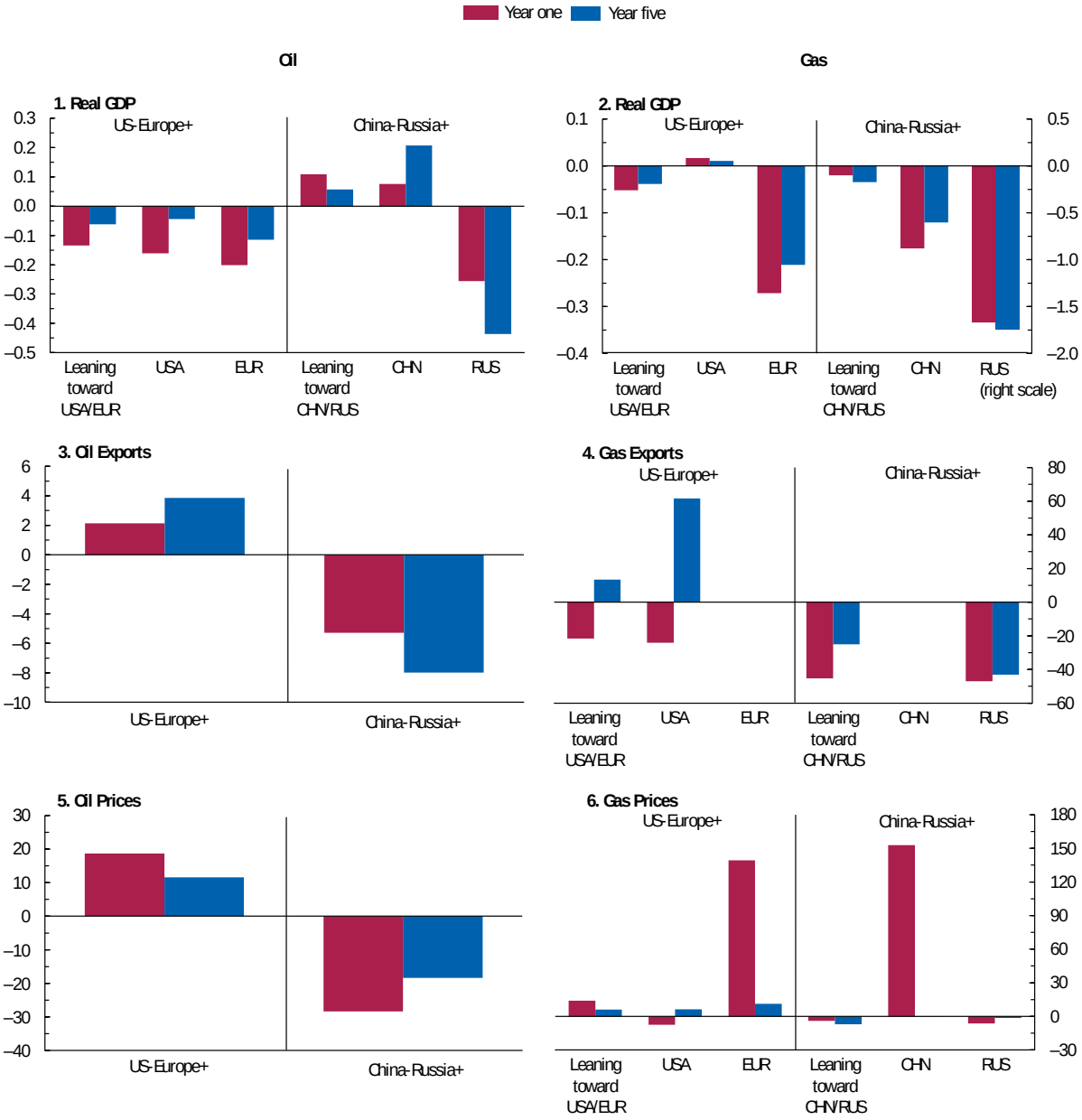
Trade restrictions generate a reallocation of commodity demand across blocs, making trade diversion one of the main propagation channels. When trade across blocs is restricted, the hedger reallocates trade within each bloc, such that the supply and demand of commodities clear at the bloc level at new equilibrium prices. In the case of gas, fragmentation is implemented by restricting trade bilaterally between regions that belong to opposite blocs. The bloc with relatively higher initial supply of each commodity relative to the demand within the bloc (ex-ante net exporting bloc) experiences a decline in the price of the specific commodity.

The opposite occurs in the other bloc (ex-ante net importing bloc). Therefore, commodity prices represent another channel through which fragmentation affects economic activity. Finally, trade diversion could be limited in the near term by the presence of rigidities that could slow the adjustment of trading volumes, with more profound effects on prices and aggregate output. To describe the operation of those channels, in Annex Figure 3.5.3., the effects of fragmentation in oil and natural gas markets are compared.

Starting with fragmentation of the oil market, on impact (year 1) oil prices increase by about 18 percent in the US-Europe+ bloc and decline by about 28 percent in the China-Russia+ bloc, as initial oil demand is larger than supply in the US-Europe+ bloc, while the opposite occurs in the other bloc. Prices then slightly decline as production and trade adjust. The adjustment happens quite fast as there are no material frictions to oil trade. Traded oil volumes already adjust substantially in the first year, with contained impacts on GDP and inflation. Exports of oil increase within the US-Europe+ bloc, where there is an undersupply of oil, and decrease in the China-Russia+ bloc. Within the same bloc, there are important differences across regions. Ex-ante exporters in an ex-ante exporting bloc, such as Russia and some countries leaning toward the China-Russia+ bloc (e.g., Iraq, Iran), lose from fragmentation because oil prices decline.

Russia faces the largest losses in terms of GDP, as oil exports represent about 50 percent of its total exports, while China and other countries in the same bloc (which, excluding a few, are mostly oil importers) benefit from oil becoming cheaper. In the US-Europe+ bloc, the European Union faces larger losses, as it is a net importer in an ex-ante net importing bloc, where prices increase after fragmentation.

Online Annex Figure 3.5.3. Fragmentation of Oil and Gas Markets
(Percent deviation from baseline)



Sources: Global Macroeconomic Model for the Energy Transition; and IMF staff calculations.
Note: Region-level results are aggregated to the bloc and world levels using weights based on GDP at purchasing power parity. The bloc including the countries that voted for Russia's withdrawal from Ukraine in the 2022 UN vote is labeled the "US-Europe+ bloc," and the remaining countries are included in the "China-Russia+ bloc."

A potential fragmentation of gas markets has a more marked negative impact on GDP and inflation in both blocs. This is because rigidities, such as pipelines, limit trade diversion. This is the case for example with gas supplies from Russia to Europe. The assumption is that in the near term most of the gas provided through pipelines cannot be redirected toward other regions in the China-Russia+ bloc after the fragmentation shock. China also imports more that 60 percent of its gas from countries belonging to the opposite bloc (e.g., Australia) that cannot be quickly replaced with gas supplies from Russia. As a result, the impact on trade flows and

inflation are larger with a marked negative impact on GDP in the near-term in both the European Union and China. Russia faces more pronounced losses relative to the case of oil because of a larger role of rigidities.

3.5.3. Fragmentation in Mineral Markets: Impact on the Clean Energy Transition

The fragmentation of mineral markets highlights the importance of the distribution of demand and supply across blocs and at the same time elevated costs and time to build necessary capacity to process and refine minerals. The elevated concentration of minerals supply in the US-Europe+ bloc leads to steep increases in prices and inflation in the China-Russia+ bloc. The heavy use of these minerals, especially *mineral1*, in the manufacturing and construction sectors in countries like China generates a large fall in GDP in the China-Russia+ bloc. The oversupply of those minerals in the US-Europe+ bloc cannot be quickly used in that bloc as processing and refining capacity requires long time to build and scale up. This peculiar rigidity is captured in the model by assuming that after the fragmentation, the US-Europe+ bloc cannot replace immediately the large mineral processing sector in the China-Russia+ bloc. To account for this, a shock to the productive use of minerals is fed through the model. The magnitude of the shock is proportional to the China-Russia+ imports of minerals from the US-Europe+ bloc in the initial equilibrium before fragmentation.[7] As a result, the impact of fragmentation on the US-Europe+ bloc is also a decline in GDP.

Given the projected importance of minerals for the green transition, the increase in prices after a potential fragmentation can be even more relevant in the medium run. Thus, the model is used to examine how fragmentation could affect the green transition. To start, the demand for copper, nickel, cobalt, and lithium is assumed to increase in the future as projected by the IEA (2023) Net Zero Emission scenario (NZE baseline). An increase in investment in renewable structures and EVs consistent with this higher demand up to 2030 is simulated, keeping track of the resulting endogenous increase in the prices of these minerals. The increase in renewable investment and EVs is stimulated through green subsidies in all regions. The baseline assumes that minerals can be traded freely. The fragmentation scenario bans minerals trade across blocs, while leaving the green subsidies unchanged from the baseline. Fragmentation leads to an increase in mineral prices in both blocs in the initial years as the China-Russia+ bloc cannot access minerals mined in the US-Europe+ bloc, while at the same time the US-Europe+ bloc does not have built-up refining capacity to reap the benefits from the relative oversupply of those minerals. As refining capacity builds up in the US-Europe+ bloc, prices fall consistent with an oversupply of minerals in that bloc. By 2030, prices are over 20 percent lower in the US-Europe+ bloc and over 200 percent higher in the China-Russia+ bloc, relative to the NZE baseline. On the whole NZE transition path 2023-2030, prices of minerals are 300 percent

[7] After fragmentation a shock to the productive use of mines is set to mimic the difficulty to use minerals without a previously built-up refining capacity. The shock is set to generate a decline in mineral1 and mineral2 production to mimic the fact that the share of those minerals that cannot be exported to the China-Russia+ bloc after the fragmentation cannot be used in the US-Europe+ bloc. The magnitude of the shock is therefore proportional to the China-Russia bloc import share of those minerals in the initial steady state when markets are perfectly integrated. The shock gradually diminishes to bring the productive use of minerals in the US-Europe+ bloc to the full level of supply by year 10. This simulates the time that it takes to set up a refinery plant (5 to 10 years).

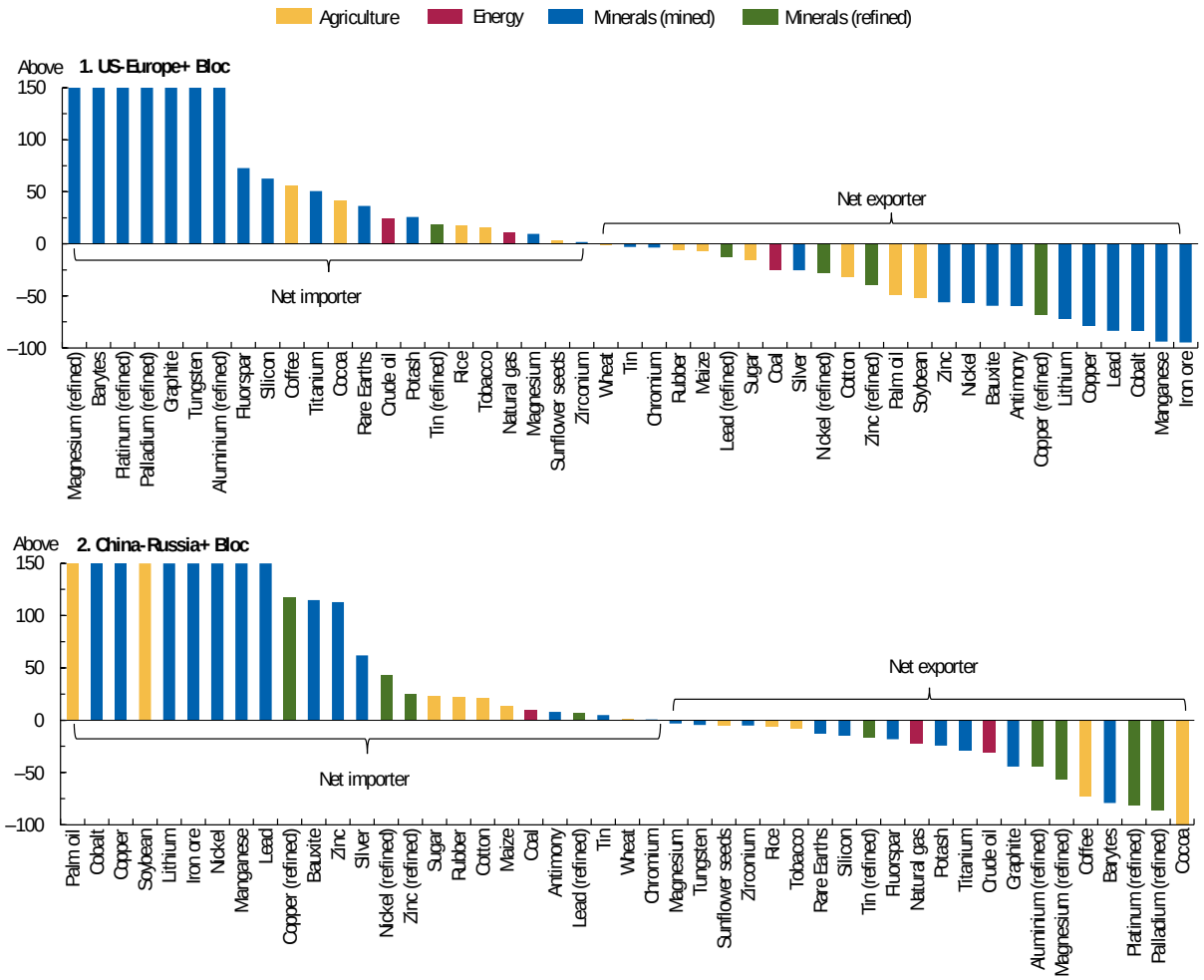
higher on average relative to the NZE baseline in the China-Russia+ bloc, accounting for the spike in prices in initial years. Fragmentation leads to a decline in investment in renewables and EVs in at the global level, with much bigger losses, relative to the baselines, in the China-Russia+ bloc.

A key assumption is the constant-return-to-scale technology in the production of renewables and EVs. If their production exhibited increasing returns to scale, the US-Europe+ bloc could scale up investment faster than in the baseline. Both effects deliver a decline in renewables and EVs in the US-Europe+ bloc of the magnitude assumed in the benchmark model.

Online Annex 3.6. Partial Equilibrium Model: Additional Results

This section presents additional results from the single-commodity partial equilibrium model. It draws on Alvarez and other (2023).

Online Annex Figure 3.6.1. Price Changes Due to Fragmentation in Individual Commodity Markets
(Percent)

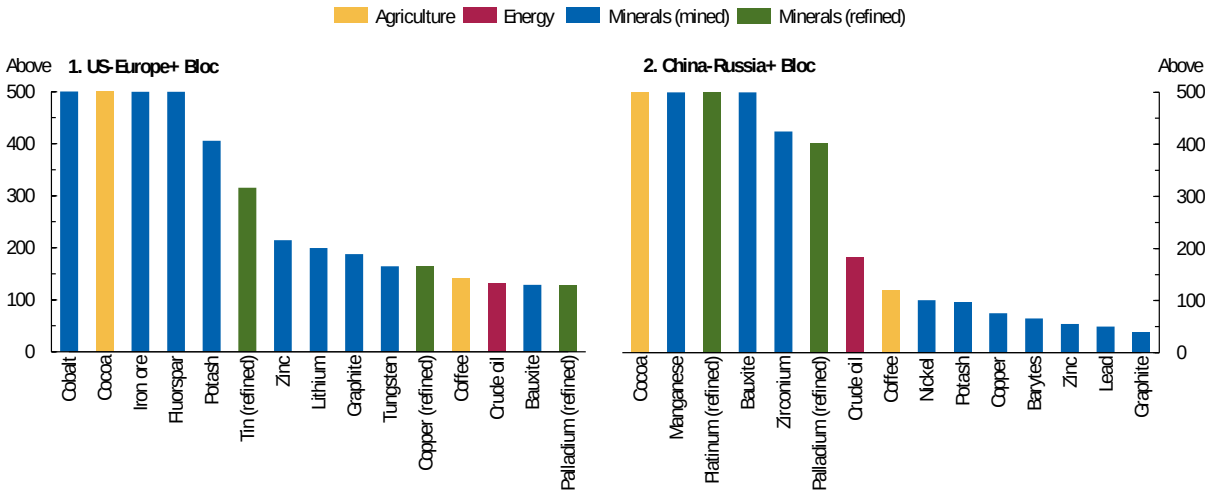


Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the commodity price change in each bloc induced by fragmentation of commodity trade. Price effects are capped at 150 percent for ease of exposition.

3.6.1. Baseline Specification: Additional Results

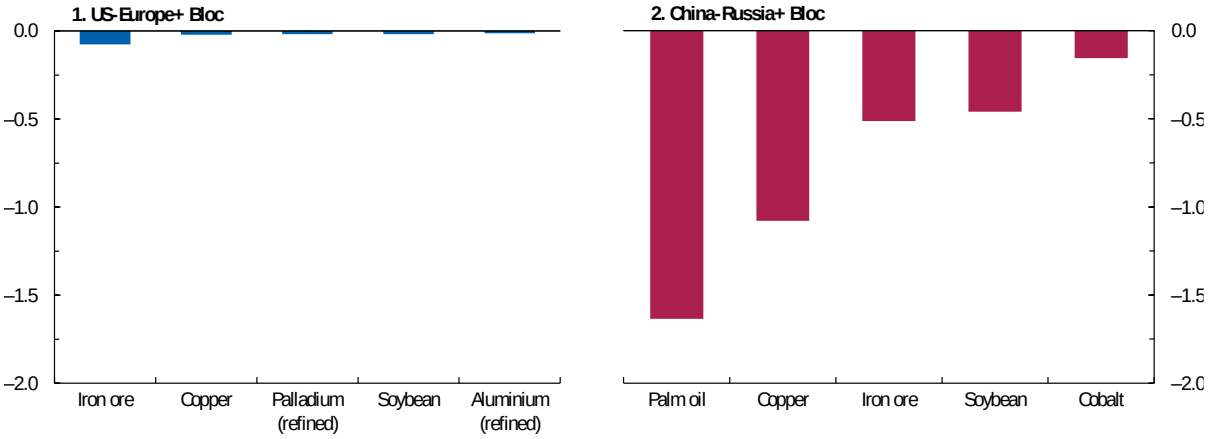
This subsection provides additional commodity-specific results for the baseline scenario. Annex Figure 3.6.1. presents the fragmentation-induced changes in prices in the baseline

Online Annex Figure 3.6.2. Top 15 Largest Price Increases from a Single Exporter Switching Blocs
(Percent)



Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agricultural Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the largest bloc-level price increase that the corresponding commodity experiences from a single exporting country switching to the other bloc.

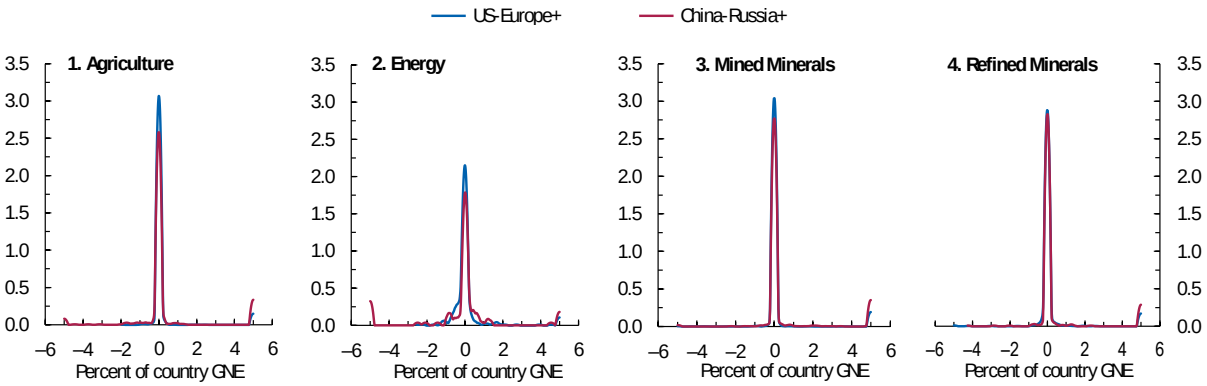
Online Annex Figure 3.6.3. Top Five Largest Changes in Bloc-Level Total Economic Surplus
(Percent of bloc-level GNE)



Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agricultural Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the decline in bloc-level total economic surplus from fragmenting trade of the corresponding commodity in the axis. GNE = gross national expenditure.

scenario for each commodity in the two blocs. Annex Figure 3.6.2. elaborates on the price effects from individual countries switching blocs. For each bloc, it shows the 15 largest price increases that would be induced by an exporter switching trade allegiances. Annex Figure 3.6.3. highlights the 5 commodities that generate the largest changes in total bloc-level surplus in each

Online Annex Figure 3.6.4. Distribution of Country-Level Changes in Total Surplus Due to Fragmentation in Individual Commodity Markets
(Density)



Sources: British Geological Survey; Dahl (2020), Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Changes in total economic surplus at the country level are capped at +/– 5 percent of GNE for readability. Each observation represents the total economic change in the surplus of a country due to the fragmentation of a single commodity market. The *y*-axis is the probability density function for the kernel density estimation. GNE = gross national expenditure.

bloc. Finally, Annex Figure 3.6.4. plots the distribution of the country-level changes in total surplus from fragmentation across countries and commodities.

3.6.2. Alternative Bloc Configurations

This subsection discusses the implications on price and total economic surplus changes across the two blocs due to trade fragmentation under different bloc configurations (see Table 3.6.1. for the alternative bloc configurations considered). We examine two alternatives to the baseline. In bloc configuration A, like Chapter 4 of the April 2023 World Economic Outlook, all emerging and developing economies, excluding India, Indonesia and Latin American countries, are assigned to the China-Russia+ bloc. In Bloc Configuration B, a country is assigned to the US-Europe+ bloc if it trades more with the US and the EU combined than with China and Russia combined. A country is assigned to the China-Russia+ bloc if it trades more with China and Russia combined than with the US and EU combined.[8,9]

[8] Trade shares are calculated using 2019 data from UN Comtrade.
[9] Note that the single-commodity partial equilibrium exercise cannot accommodate bloc configurations in which some countries remain neutral, as was instead done in Chapter 4 of the April 2023 World Economic Outlook chapter.

Online Annex Table 3.6.1. Alternative Blocs Configurations

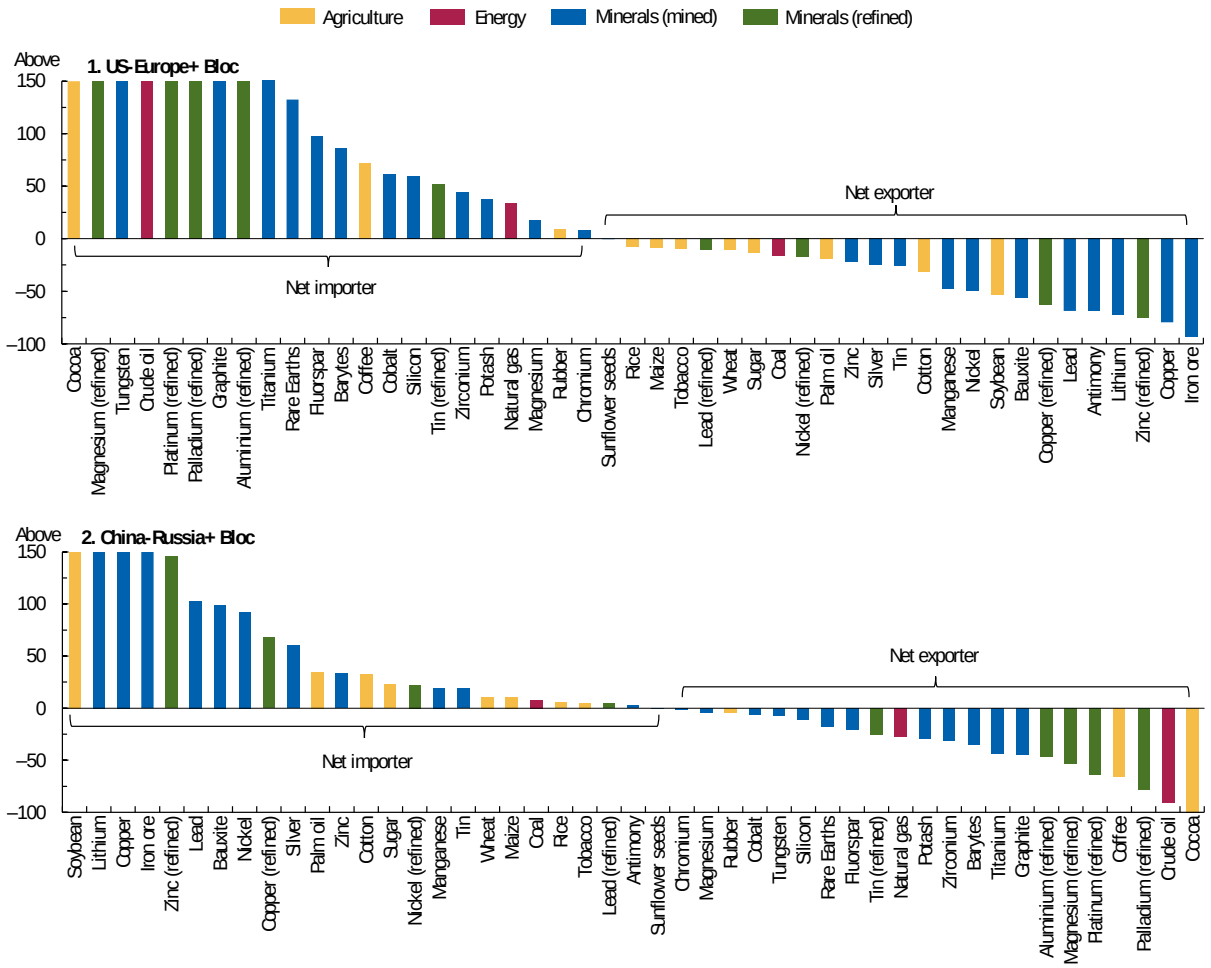
	US-Europe+ bloc	China-Russia+ bloc
Bloc configuration A	Andorra; Argentina; Aruba; Australia; Austria; Belgium; Brazil; Bulgaria; Canada; Chile; Colombia; Costa Rica; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; India; Indonesia; Ireland; Israel; Italy; Japan; Korea; Latvia; Lithuania; Luxembourg; Malta; Mexico; Netherlands; New Zealand; Norway; Peru; Poland; Portugal; Puerto Rico; Romania; Serbia; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; Tuvalu; United Kingdom; United States	Afghanistan; Albania; Algeria; Angola; Antigua and Barbuda; Armenia; Azerbaijan; Bahamas, The; Bahrain; Bangladesh; Barbados; Belarus; Belize; Benin; Bhutan; Bolivia; Bosnia and Herzegovina; Botswana; Brunei Darussalam; Burkina Faso; Burundi; Cabo Verde; Cambodia; Cameroon; Central African Republic; Chad; China; Comoros; Congo, Democratic Republic of the; Congo, Republic of; Côte d'Ivoire; Djibouti; Dominica; Dominican Republic; Ecuador; Egypt; El Salvador; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; Fiji; Gabon; Gambia, The; Georgia; Ghana; Grenada; Guatemala; Guinea; Guinea-Bissau; Guyana; Haiti; Honduras; Hong Kong SAR; Iran; Iraq; Jamaica; Jordan; Kazakhstan; Kenya; Kiribati; Kosovo; Kuwait; Kyrgyz Republic; Lao P.D.R.; Lebanon; Lesotho; Liberia; Libya; Macao SAR; Madagascar; Malawi; Malaysia; Maldives; Mali; Marshall Islands; Mauritania; Mauritius; Micronesia; Moldova; Mongolia; Montenegro, Rep. of; Morocco; Mozambique; Myanmar; Namibia; Nauru; Nepal; Nicaragua; Niger; Nigeria; North Macedonia; Oman; Pakistan; Palau; Panama; Papua New Guinea; Paraguay; Philippines; Qatar; Russia; Rwanda; Samoa; San Marino; São Tomé and Príncipe; Saudi Arabia; Senegal; Seychelles; Sierra Leone; Singapore; Solomon Islands; Somalia; South Africa; South Sudan; Sri Lanka; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Sudan; Suriname; Syria; Tajikistan; Tanzania; Thailand; Timor-Leste; Togo; Tonga; Trinidad and Tobago; Tunisia; Türkiye; Turkmenistan; Uganda; Ukraine; United Arab Emirates; Uruguay; Uzbekistan; Vanuatu; Venezuela; Vietnam; Yemen; Zambia; Zimbabwe
Bloc configuration B (main trading partner)	Albania; Algeria; Andorra; Antigua and Barbuda; Argentina; Aruba; Austria; Azerbaijan; Bahamas, The; Bahrain; Bangladesh; Barbados; Belgium; Belize; Bhutan; Bolivia; Bosnia and Herzegovina; Botswana; Brazil; Bulgaria; Burkina Faso; Burundi; Cabo Verde; Cambodia; Cameroon; Canada; Central African Republic; Chile; Colombia; Comoros; Costa Rica; Côte d'Ivoire; Croatia; Cyprus; Czech Republic; Denmark; Dominica; Dominican Republic; Ecuador; Egypt; El Salvador; Equatorial Guinea; Estonia; Eswatini; Ethiopia; Fiji; Finland; France; Georgia; Germany; Greece; Grenada; Guatemala; Guinea-Bissau; Guyana; Haiti; Honduras; Hungary; Iceland; India; Ireland; Israel; Italy; Jamaica; Japan; Jordan; Kosovo; Latvia; Lebanon; Lesotho; Libya; Lithuania; Luxembourg; Madagascar; Mali; Malta; Mauritius; Mexico; Micronesia; Moldova; Montenegro, Rep. of; Morocco; Mozambique; Namibia; Nauru; Netherlands; Nicaragua; Niger; Nigeria; North Macedonia; Norway; Pakistan; Palau; Panama; Paraguay; Peru; Poland; Portugal; Puerto Rico; Qatar; Romania; San Marino; São Tomé and Príncipe; Saudi Arabia; Senegal; Serbia; Seychelles; Sierra Leone; Slovak Republic; Slovenia; South Africa; Spain; Sri Lanka; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Suriname; Sweden; Switzerland; Trinidad and Tobago; Tunisia; Türkiye; Uganda; Ukraine; United Arab Emirates; United Kingdom; United States; Venezuela	Afghanistan; Angola; Armenia; Australia; Belarus; Benin; Brunei Darussalam; Chad; China; Congo, Democratic Republic of the; Congo, Republic of; Djibouti; Eritrea; Gabon; Gambia, The; Ghana; Guinea; Hong Kong SAR; Indonesia; Iran; Iraq; Kazakhstan; Kenya; Kiribati; Korea; Kuwait; Kyrgyz Republic; Lao P.D.R.; Liberia; Macao SAR; Malawi; Malaysia; Maldives; Marshall Islands; Mauritania; Mongolia; Myanmar; Nepal; New Zealand; Oman; Papua New Guinea; Philippines; Russia; Rwanda; Samoa; Singapore; Solomon Islands; Somalia; South Sudan; Sudan; Syria; Tajikistan; Tanzania; Thailand; Timor-Leste; Togo; Tonga; Turkmenistan; Tuvalu; Uruguay; Uzbekistan; Vanuatu; Vietnam; Yemen; Zambia; Zimbabwe

Sources: UN Comtrade data; and IMF staff compilation.

Bloc configuration A

This configuration leads to price increases for a larger number of commodities in the US-Europe+ bloc than under the baseline. Key differences relative to the baseline are as follows: (1) The price of crude oil increases by more in the US-Europe+ bloc as major oil producers are now in the China-Russia+ bloc (UAE, Libya, Nigeria, Qatar, Saudi Arabia, Kuwait); (2) the price of cocoa increases in the US-Europe+ bloc, as Ivory Coast, the largest world producer of cocoa, becomes part of the China-Russia+ bloc; (3) the Democratic Republic of Congo, the world largest producer of cobalt, has been moved to the China-Russia bloc, leading to a rise in the price of cobalt in the US-Europe+ bloc; (4) the China-Russia bloc experiences milder price increases for palm oil and manganese. The former is because important palm oil producers such as Malaysia and Thailand are now assigned to the China-Russia+ bloc. Manganese becomes less

Online Annex Figure 3.6.5. Price Changes from Trade Fragmentation by Commodity under Bloc Configuration A
(Percent)

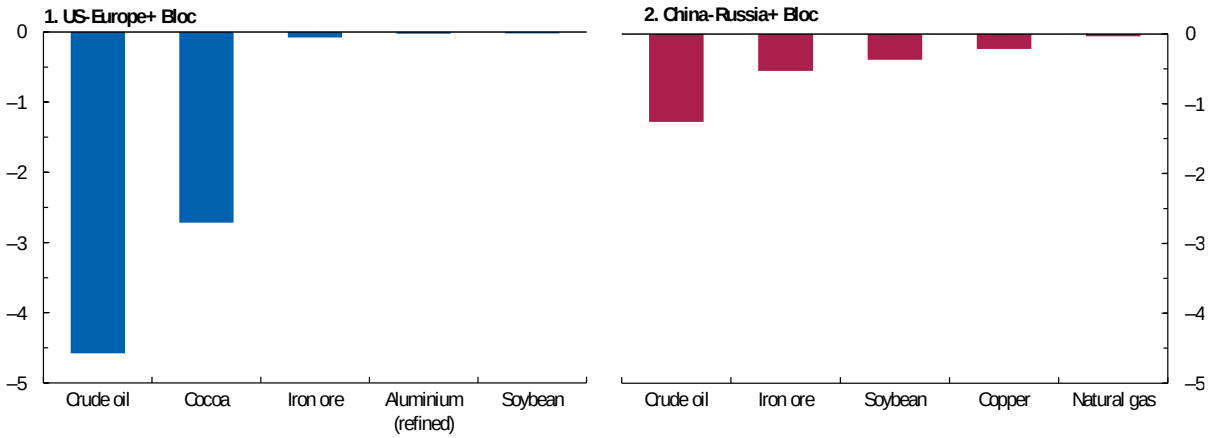


Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the commodity price change in each bloc induced by fragmentation of commodity trade. Price effects are capped at 150 percent for ease of exposition.

vulnerable in the China-Russia+ bloc because India, a major importer of this commodity, is now assigned to the US-Europe+ bloc.

Turning to the implications of fragmentation for changes in total surplus across blocs, crude oil and cocoa are now the commodities causing the largest surplus declines in the US-Europe+ blocs. They imply surplus losses in the US-Europe+ bloc between 2.5 and 4.5 percent of GNE. This is because both commodities experience large price increases, while also being widely consumed. Crude oil is also causing relevant surplus declines in the China-Russia bloc (over 1 percent of GNE). In this case, it is due to producers surplus declining, as exporting countries in this bloc experience large reduction in prices.

Online Annex Figure 3.6.6. Top Five Largest Changes in Bloc-Level Total Economic Surplus under Bloc Configuration A
(Percent of bloc-level GNE)



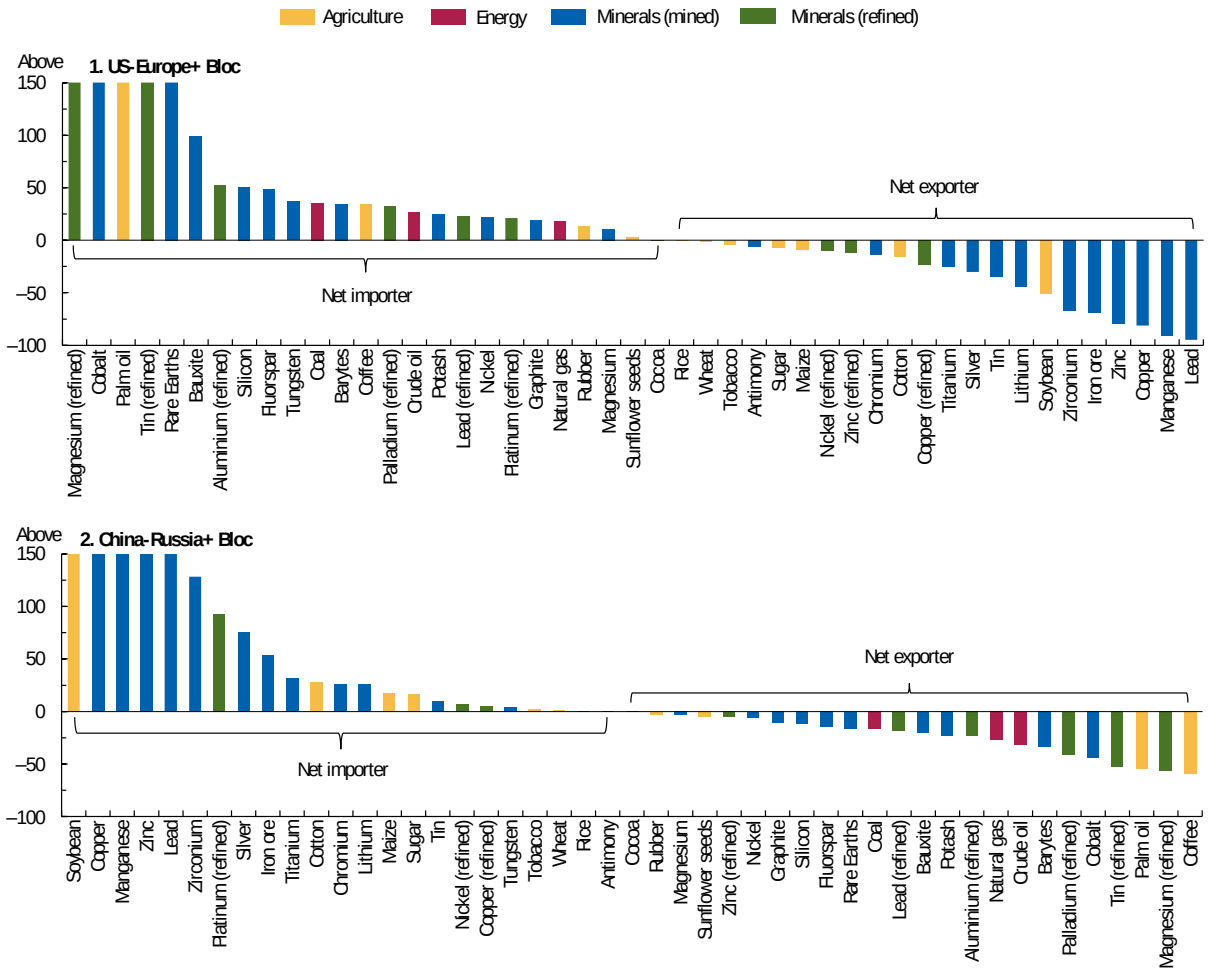
Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the decline in bloc-level total economic surplus from fragmenting trade of the corresponding commodity in the axis. GNE = gross national expenditure.

Bloc configuration B (major trade partner)

Relative to the baseline specification, the major changes are represented by the assignment of India, Mozambique, South Africa to the US-Europe+ bloc, and of Australia, the Democratic Republic of the Congo, Indonesia, Korea, Malaysia, New Zealand, Philippines, and Thailand to the China-Russia+ bloc. Under this specification, the US-Europe+ bloc experiences large price increases in palm oil (given the shift of Indonesia and Malaysia, which account for 80 percent of global production) and cobalt (given the shift of the DRC), but is less vulnerable to trade fragmentation of graphite, refined platinum, and refined palladium (given that Mozambique and South Africa are now in the US-Europe+ bloc). As in the baseline, the China-Russia bloc still experiences large price increases of soybeans, copper, manganese, zinc, and lead, but not of iron ores and lithium (given the assignment of Australia to the China-Russia+ bloc), or of palm oil

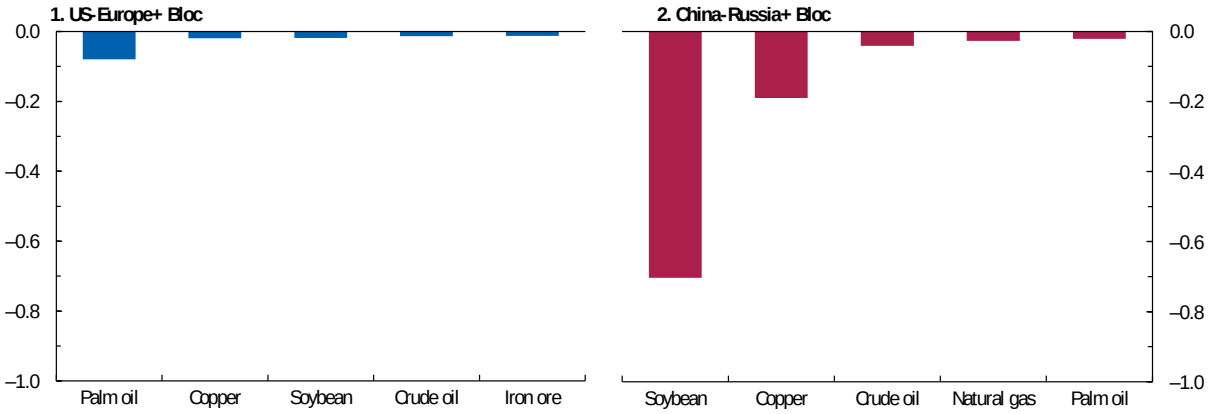
(Figure 3.6.7). Changes in total economic surplus remain larger in the China-Russia+ bloc, but lower in magnitude relative to the baseline (Figure 3.6.8).

Online Annex Figure 3.6.7. Price Changes from Trade Fragmentation by Commodity under Bloc Configuration B
(Percent)



Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the commodity price change in each bloc induced by fragmentation of commodity trade. Price effects are capped at 150 percent for ease of exposition.

Online Annex Figure 3.6.8. Top Five Largest Changes in Bloc-Level Total Economic Surplus under Bloc Configuration B
(Percent of bloc-level GNE)



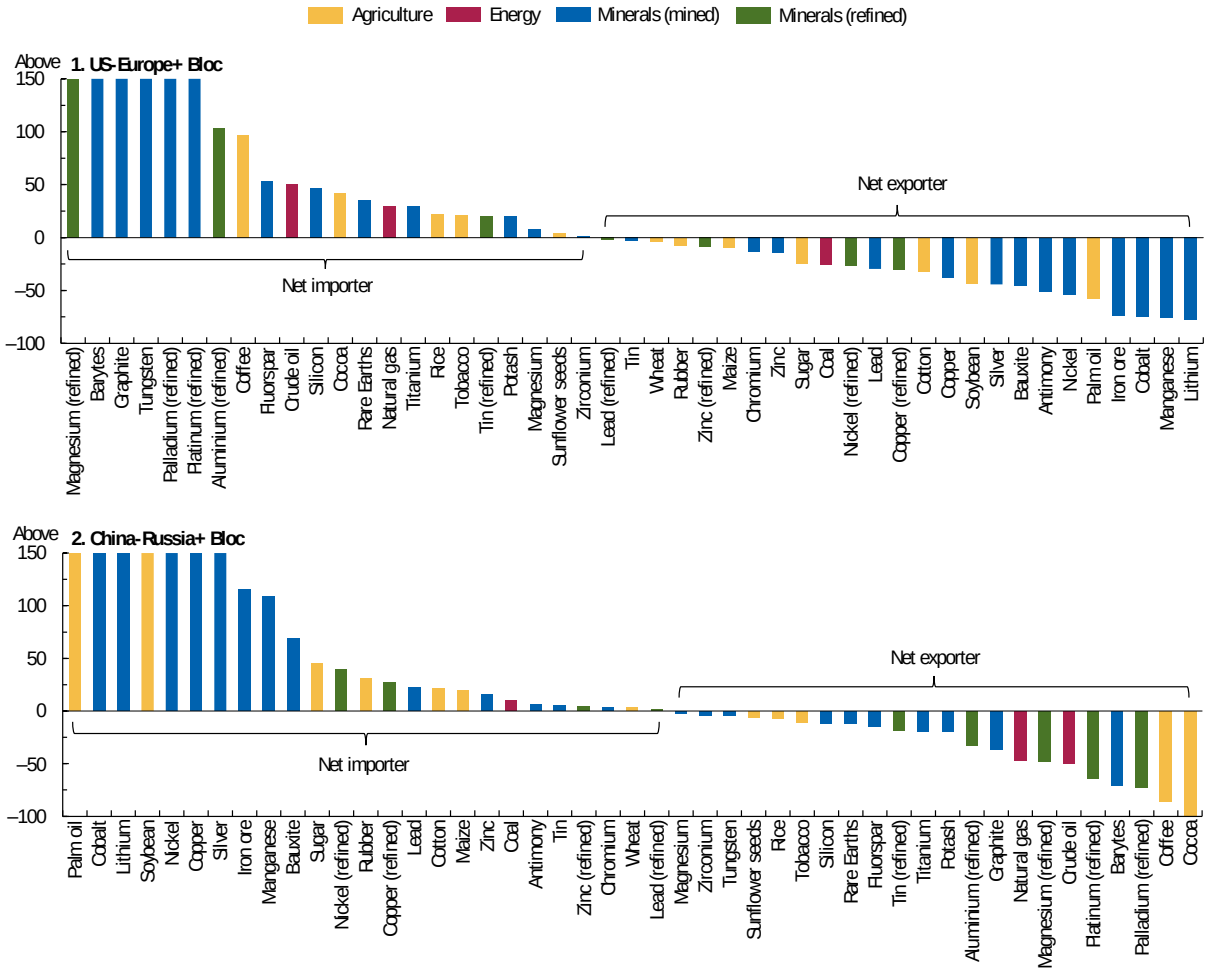
Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the decline in bloc-level total economic surplus from fragmenting trade of the corresponding commodity in the axis. GNE = gross national expenditure.

3.6.3. Alternative Elasticities

This subsection shows the sensitivity of the results to different elasticities (for the alternative elasticities considered see Alvarez and others, 2023). Under this alternative specification the demand and supply elasticities are set as the median values among the estimates listed in the literature review in Fally and Sayre (2018). Missing information on the supply and demand elasticities of a commodity are replaced with the average elasticity by broader categories.

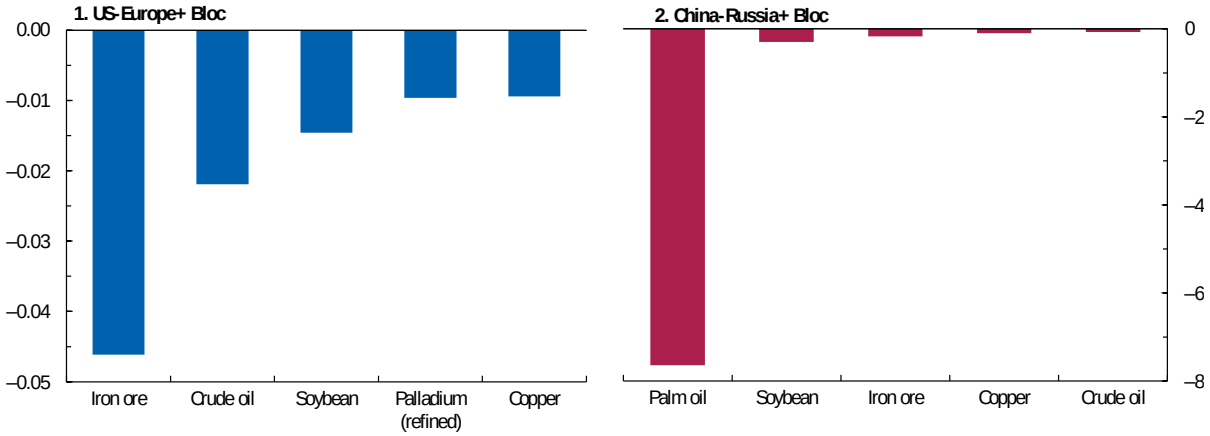
As shown in Figure 3.6.9, the ranking of commodity price vulnerability to fragmentation is overall in line with the baseline (illustrated in Figure 3.6.1). The results on the five largest surplus changes across blocs in Figure 3.6.10 are also broadly in line the baseline (in Figure 3.6.2).

Online Annex Figure 3.6.9. Price Changes from Trade Fragmentation by Commodity under an Alternative Elasticities Configuration
(Percent)



Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the commodity price change in each bloc induced by fragmentation of commodity trade. Price effects are capped at 150 percent for ease of exposition.

Online Annex Figure 3.6.10. Top Five Largest Changes in Bloc-Level Total Economic Surplus under an Alternative Elasticities Configuration
(Percent of bloc-level GNE)



Sources: British Geological Survey; Dahl (2020); Fally and Sayre (2018); Food and Agriculture Organization of the United Nations; Gaulier and Zignano (2010); International Energy Agency; United States Geological Survey; and IMF staff calculations.
Note: Each bar represents the decline in bloc-level total economic surplus from fragmenting trade of the corresponding commodity in the axis. GNE = gross national expenditure.

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