GROUP OF TWENTY

G-20 Background Note on The Macroeconomic Impact of Food and Energy Insecurity

2023

Prepared by Staff of the

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*Does not necessarily reflect the views of the IMF Executive Board

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CONTENT

EXECUTIVE SUMMARY

The surge in food and energy prices during the past few years has fueled inflation and hurt growth. Prices of food and energy commodities increased steadily following the onset of the pandemic and reached historic highs after Russia's invasion of Ukraine. While international prices have since moderated, they have nonetheless contributed to upward pressure on domestic inflation. Moreover, high energy prices have increased input and transportation costs, weighing on economic activity and feeding into higher food prices through production linkages. The result has been a cost-of-living crisis, with the most vulnerable economies and people particularly hard-hit and with a marked increase in food insecurity. In addition, empirical estimates highlight that the increased *volatility* of commodity prices is likely to weigh on medium-term growth and increase inflation volatility.

The current challenges could worsen if risks to the outlook materialize. A further erosion of real incomes could lower household spending and spark social unrest, harming livelihoods and growth. An extended disruption of the energy supply in Europe poses further downside risks. Moreover, unfavorable inflation developments could necessitate a sudden tightening of financial conditions from larger-than-expected further policy interest rate increases, raising borrowing costs for many economies that are already dealing with elevated debt levels. Further geoeconomic fragmentation could restrict trade and increase concentration risks in the energy supply, exacerbating food and energy security concerns.

Policymakers have responded amid difficult policy tradeoffs. Monetary policy has been tightened markedly in most G-20 economies to help bring down inflation. At the same time, fiscal measures have been implemented to ease the cost-of-living pressures, especially in Europe. However, in many economies, these measures have often been untargeted and aimed at suppressing the pass-through of higher international prices. Restrictions on trade have also been imposed in the attempt to ensure the domestic food supply. To address energy security concerns, some economies have scaled up reliance on fossil fuels, setting back the green transition.

Policy action is needed to tackle the on-going crisis and prepare for future shocks.

- *Domestic policies must stay focused on bringing down inflation and elevated debt levels while supporting the most vulnerable*. This requires continued monetary policy tightening until inflation is brought down durably. Fiscal measures should be temporary and targeted, allowing price signals to operate to the extent possible, while avoiding acting against monetary policy. Measures aimed at ensuring energy security should be compatible with the green transition.
- *Multilateral efforts are urgently required to prevent further geopolitical fragmentation and strengthen the multilateral trade system*. The removal of food export restrictions is necessary to ensure global food security. The green transition will also rely on the free flow of trade to avoid disruptions in markets for key transition-related primary inputs. And strengthening the global financial safety net is essential for building resilience against future shocks.

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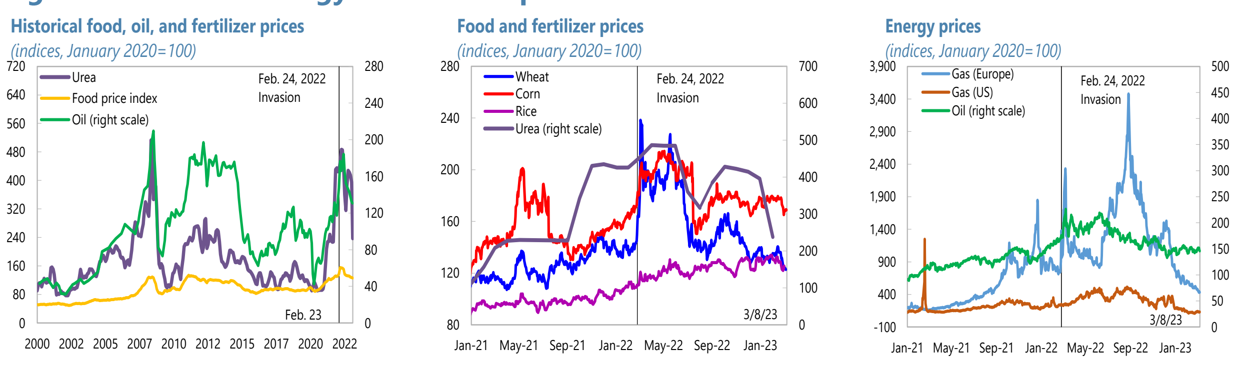
HIGH FOOD AND ENERGY COSTS ARE TAKING A TOLL

A. Surging Food and Energy Prices Have Fueled Inflation and Hurt Growth

Food and energy prices surged toward record highs over the past few years, owing to global shocks related to the COVID-19 pandemic and the war in Ukraine, prompting significant supply disruptions. This contributed to inflationary pressures and a cost-of-living crisis. Moreover, global growth remains subpar and commodity terms of trade volatility has likely had further adverse impact. While food and fuel price inflation has recently moderated, price levels remain uncomfortably high for people around the world.

1. Global food and energy prices have risen markedly since the start of the COVID-19 pandemic. International food commodity prices rose 38 percent between January 2020 (prior to the global pandemic) and February 2022 and rose sharply again following *Russia*'s invasion of Ukraine, before peaking in March 2022 (Figure 1). Global wheat prices jumped 38 percent between February and March 2022. At the same time, energy prices increased, with oil prices approximately doubling between January 2020 and their peak in March 2022. Moreover, the price of gas in Europe rose to unprecedented highs during the summer of 2022, as the supply of Russian gas to Europe was sharply reduced. At their peak in August 2022, European gas prices were nearly 30 times higher than in January 2020. Prices of some fertilizers (e.g., urea) nearly quintupled between January 2020 and their peak in April 2022 and, despite some recent declines, were still four times as high in December 2022. While both food and energy commodity prices have moderated from their peaks, they remain elevated. Moreover, while international commodity prices were at similar highs during the global financial crisis, the current cost-of-living crisis is particularly challenging as it is occurring on the back of a global pandemic and in the context of persistent broad-based inflationary pressures in most economies.

Figure 1. Food and Energy Price Developments



Sources: Haver Analytics; Food and Agriculture Organization of the United Nations; IMF, *Primary Commodity Price System* Database; IMF, *World Economic Outlook*; and IMF staff calculations.

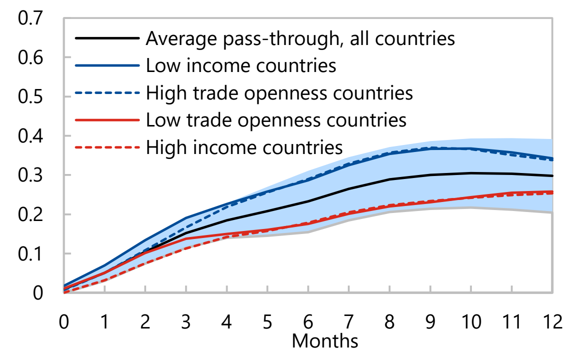
2. In general, increases in international food prices pass through to domestic food prices. While fiscal measures during the past several months in some economies were directed at limiting the domestic impact of higher international prices (see below), an increase in international prices generally leads to an increase in domestic prices. Based on monthly data for more than 100 countries over

1991–2020, IMF staff estimates suggest that a 1 percent increase in international food prices is associated with an about 0.3 percent increase in domestic food prices approximately one year later (Figure 2). Moreover, the pass-through from international to domestic food prices during this period was larger for lower-income countries than for advanced economies and tends to be larger for economies with higher degrees of trade openness—as greater cross-border arbitrage opportunities raise the responsiveness of domestic prices to changes in international food prices.[1]

3. In turn, higher domestic food and energy prices put upward pressure on headline inflation. In 2022, headline inflation picked up strongly in most G-20 economies, with several of these recording inflation above double-digit levels (Figure 3). While a large share of the increase in headline inflation related to the direct importance of food and energy in the consumption basket, core inflation also picked up in many economies amid second-round effects of earlier cost shocks, the strong demand recovery in 2021, and tight labor markets. In 2022, core inflation was between 1.5 and 3 times higher than in 2020 across G-20 economies. Moreover, core inflation has yet to ease in many G-20 economies—and while headline inflation has started to ease, it remains elevated.

Figure 2. Passthrough From International to Domestic Food Prices

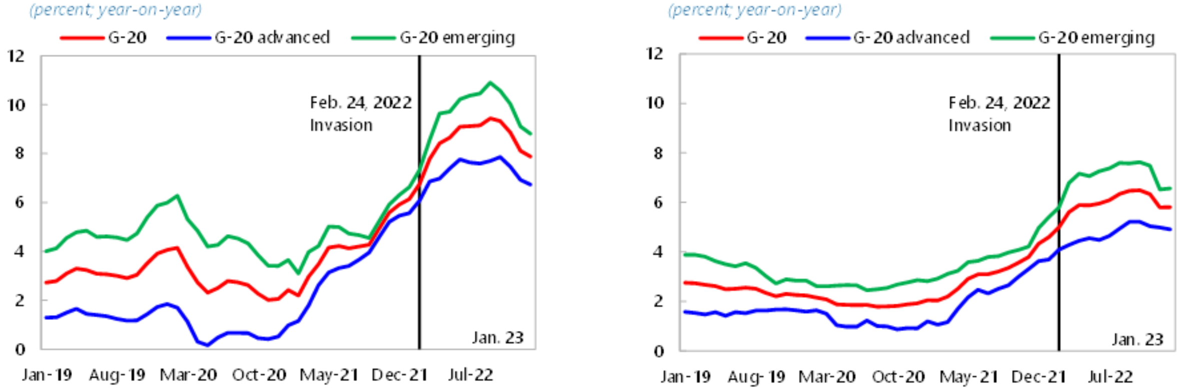
Response of food CPI to international food price shock
(percent)



Sources: Haver Analytics; IMF; World Bank; IMF staff est.
Note: Response of domestic food CPI to a 1 percent shock to international food prices. 90-percent confidence bands. High- (low-) income economies are those above (below) +1 (-1) standard deviation of the global average.

Figure 3. G-20: Headline and Core Inflation

Headline CPI 1/ *(percent; year-on-year)* | **Core CPI 2/** *(percent; year-on-year)*

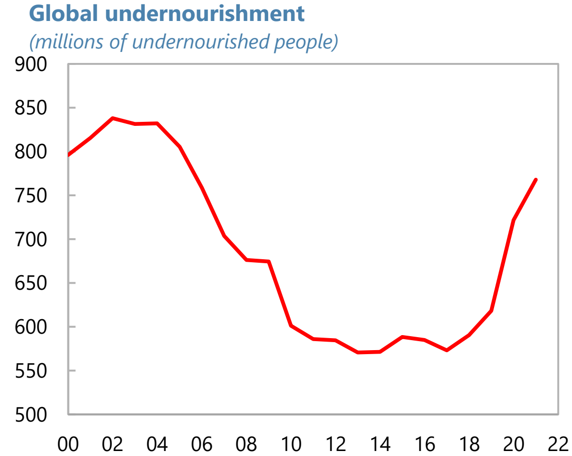


Sources: Haver Analytics; IMF, *World Economic Outlook*; IMF staff calculations.
Note: ESP: permanent invitee.
1/ G-20 advanced excludes AUS.
2/ G-20 advanced excludes AUS; G-20 emerging excludes ARG, SAU.

[1] IMF, 2022b.

4. The result has been a cost-of-living-crisis, with the most vulnerable households and economies disproportionately exposed to the increase in prices. The rise in inflation has weighed on household budgets everywhere. However, households in low-income and emerging market economies tend to spend a larger share of their budgets on food items than households in advanced economies, making them more exposed to changes in food prices.[2] As such, while food insecurity has been on the rise since 2018, it worsened markedly during 2020–21, with underlying factors including higher food prices, conflicts, natural disasters, as well as pandemic-related disruptions in food markets. In fact, between 2019 and 2021, the number of undernourished people globally increased by more than 150 million (Figure 4). Moreover, the World Food Program estimates that about 345 million people across a sample of 79 countries will be food insecure in 2023—almost 200 million more people than in early 2020.[3] In addition, while fuel typically accounts for a larger share of expenditures in high-income households, low-income households are also negatively impacted by energy price increases. For example, higher energy prices lead to higher prices of other goods in the supply chain and push up prices more broadly via second-round effects.[4]

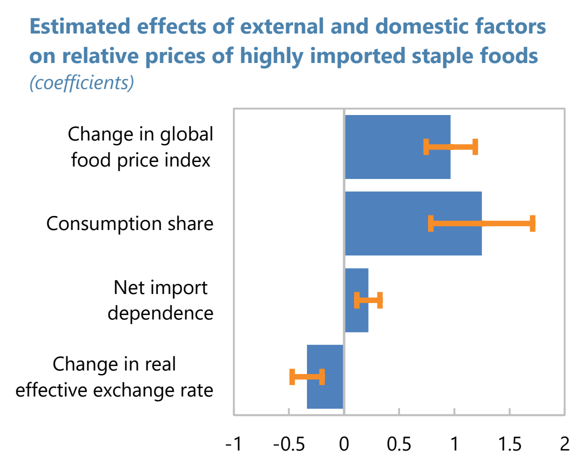
Figure 4. Food Insecurity



Sources: Bloomberg Finance, L.P.; The Integrated Food. Security Phase Classification (IPC); United Nations Food and Agriculture Organization; and IMF staff calculations.

5. In some regions, the surge in global food prices has led to particularly acute challenges. Many economies in Sub-Saharan Africa, the Middle East, and Central Asia face acute cost-of-living pressures amid elevated local food prices. For example, in Sub-Saharan Africa, about 12 percent of the population was estimated to be acutely food insecure in 2022, with staple food prices in the region rising on average by close to 24 percent during 2020–22. This denotes the sharpest increase since the 2008 global financial crisis. In this respect, IMF staff estimates for Sub-Saharan Africa suggest that in the case of highly imported staples, the pass-through of changes in global to local food prices is one-to-one (Figure 5). In addition, higher import costs of

Figure 5. Drivers of Food Price Inflation in Sub-Saharan Africa



Sources: FAO; C. Okou, J. Spray, and F. Unsal, 2022, "Staple Food Prices in Sub-Saharan Africa: An Empirical Assessment."
Note: Estimated effects on staple food prices of a 1 percent increase in listed factors. Highly imported staples: those with net import dependence above 75 percent. Sample: 15 countries (accounting for 70 percent of the SSA population).

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[2] In low-income countries, the share of food in household spending is about 40 percent (see Rother and others, 2022).

[3] World Food Program, 2023.

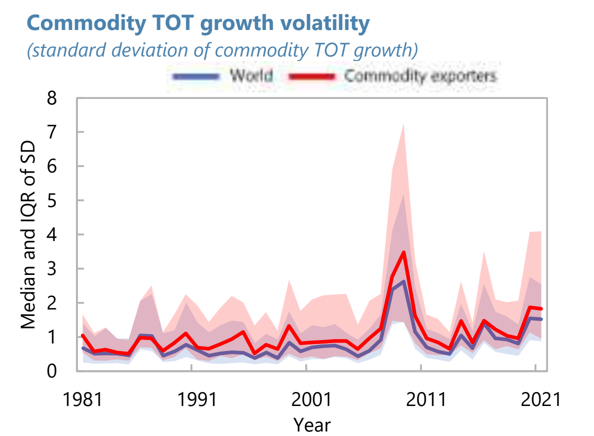
[4] Amaglobeli and others (forthcoming).

agricultural inputs such as fertilizers, seeds, and fuel contributed indirectly to food price inflation. Beyond fluctuations in global food prices, changes in local food prices in economies in the region also depend on cross-country variation in import shares and other factors:

- *Import share: Economies in Sub-Saharan Africa rely heavily on imports of staple foods*. Between 50 and 85 percent of wheat, palm oil, and rice are sourced from outside the region. Moreover, IMF staff has estimated that an increase in a country's net import dependence by 1 percentage point increases the local relative prices of a highly imported staple by 0.2 percentage points.[5]
- *Exchange rates: Currency depreciation can inflate the cost of imported staples*. A 1 percentage point real effective exchange rate depreciation is on average associated with a 0.3 percentage point increase in the relative price of highly imported staples. Moreover, higher input costs (e.g., fertilizers, seeds) induced by weaker local currencies in some economies (e.g., *Ghana*, *Nigeria*), including in the context of a stronger US dollar, also raised the prices of locally produced staples (in addition to the effect of domestic supply disruptions).
- *Consumption share: A higher share of imported staple foods in food consumption is associated with higher relative prices of staples*. A 1 percentage point higher consumption share of a highly imported staple is associated with an average 1.2 percentage point higher relative local price.

6. **At the same time, elevated energy costs have weighed on global economic activity**. Global growth projections for 2022 and 2023 have been revised down significantly during the past year, from 4.4 percent and 3.8 percent, respectively, in the January 2022 World Economic Outlook (WEO) Update to 3.4 and 2.9 percent, respectively in the January 2023 WEO Update. The impact of the war in *Ukraine* on key global energy markets has been an important force contributing to the weaker outlook for global growth, particularly in Europe.[6] That said, as higher energy prices prompted an increase in the supply of gas from outside *Russia* and a reduction in energy demand—and as sizable fiscal support was also provided—the overall impact on GDP in Europe has so far been contained.[7] In addition, tighter global financial conditions from necessary monetary policy tightening in most economies to bring down inflation is cooling demand and economic activity.

Figure 6. Terms of Trade Growth Volatility



Sources: Gruss and Kebhaj (2019), and IMF staff calculations.
Note: Median and interquartile range of standard deviation of year-on-year growth rates of the commodity TOT, which has increased since 2019, and more so for commodity exporters.
Sample: 182 countries (62 commodity exporters, defined as in Cavalcanti and others, 2015). TOT: terms of trade.

7. **In addition to elevated price levels, heightened volatility in commodity terms of trade growth has likely adversely impacted growth** (Figure 6). During the past 2 to 3 years,

[5] Okou and others, 2022. A highly imported staple is defined as one with net import dependence exceeding 75 percent.

[6] IMF, 2022a.

[7] Flanagan and others, 2022.

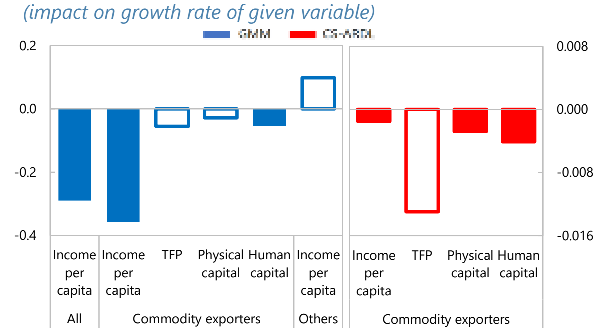
volatility in changes to the commodity terms of trade has risen markedly, including due to more extreme weather events such as droughts and floods.[8] In turn, it has reached levels not seen since the volatile period during the global financial crisis. This has likely further weighed on growth in commodity exporting economies. In fact, IMF staff estimates point to a negative and significant association between higher commodity terms of trade growth volatility and per capita income growth among commodity exporting economies. In contrast, there is no significant association among economies that do not rely on commodity exports (Figure 7). Further, the likely impact on income per capita appears to be through the capital accumulation channel, including both physical and human capital. In part, this may reflect the harmful impact of volatility on fiscal revenues in commodity exporting countries. Indeed, evidence suggests that institutions designed to cope with such revenue volatility in commodity exporters—such as sovereign wealth funds—can dampen the negative impact on growth.[9]

8. Higher volatility of changes to the commodity terms of trade may also increase volatility in headline inflation. IMF staff estimates suggest that economies with more volatile commodity terms of trade growth experience greater headline inflation volatility over the medium term (Figure 8). For example, the volatility in commodity terms of trade growth may be linked to greater volatility in the prices of imported goods, which may cause more volatility in domestic prices, as volatility in import prices passes through to domestic price changes.

Figure 7. Impact of Commodity Terms of Trade Volatility on Activity

Regression coefficients on CTOT growth volatility

(impact on growth rate of given variable)

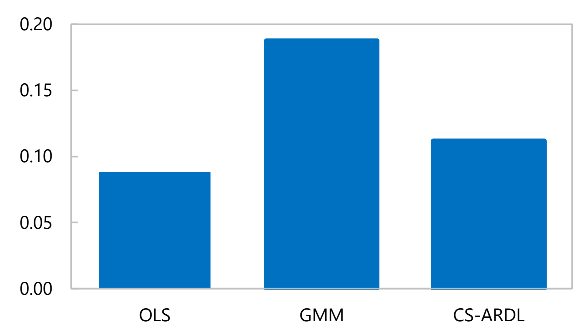


Sources: IMF staff estimates.

Note: Coefficients from GMM (blue), and cross-sectional ARDL (red) regressions using 5-year interval (GMM) and annual (CS-ARDL) data from 1970-2019. Solid bars: statistically significant. GMM sample: 118 countries, of which 62 commodity exporters. CS-ARDL sample: 62 commodity exporters. CTOT: commodity terms of trade. See Appendix.

Figure 8. Long-Run Impact of Commodity Terms of Trade Growth Volatility on Headline Inflation Volatility

Regression coefficients on CTOT growth volatility



Sources: IMF staff estimates.

Note: CTOT: commodity terms of trade. Statistically significant coefficients; regression of headline inflation volatility (logs in OLS and GMM cases) on (log) volatility of CTOT growth. GMM example: 1 percent increase in the standard deviation of CTOT growth increases the standard deviation of headline inflation by about 0.2 percent. OLS and GMM: control for openness, lagged inflation, and time and country fixed effects. GMM: instruments for openness and lagged inflation. OLS and GMM panel sample: 118 countries, 5-year non-overlapping intervals, 1972-2022. CS-ARDL panel sample: 81 countries, annual, 1979–2019. See Appendix.

[8] This note focuses on the volatility in terms of trade growth following the resource curse literature, which considers the impact on GDP growth of both the *level* of commodity terms of trade growth, and the *volatility* of commodity terms of trade growth (e.g., Cavalcanti, Mohaddes, and Raissi, Journal of Applied Econometrics, 2015). The results on the impact of commodity terms of trade growth volatility on per capita GDP growth shown in the note extend the aforementioned study beyond its original sample period (1970–2007). See Figure 7 and Appendix 1 for details.

[9] Mohaddes and Raissi, 2017.

B. Energy Price Inflation has Fed into Food Price Inflation

While both energy and food price inflation has seen upward pressures from supply constraints and other disruptions, there are also important interlinkages between the two. Notably, higher energy prices drive food prices higher as they increase the cost of food production.

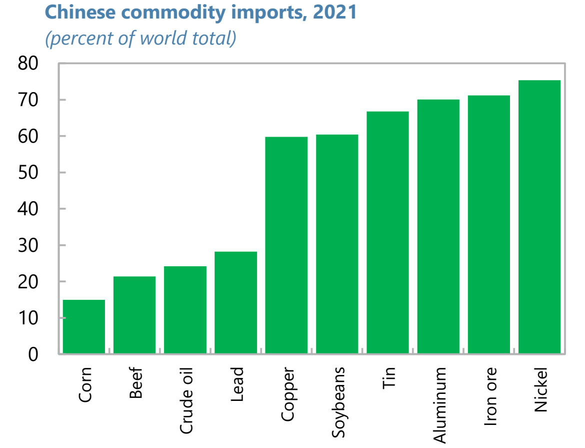
9. Global energy and food prices often co-move, in part as energy price inflation feeds into food price inflation. During the period between 1970 and 2022, food and oil prices have been in the same phase (boom or bust) about 66 percent of the time—and this concordance increases to 75 percent for the period since 2004. Three reasons behind this co-movement are particularly notable:

- *Global economic activity is a common driver of demand for several global commodities*. For example, global activity directly impacts demand for commodities that are an input into production—and is particularly relevant for energy. Notably, growth in *China* is a major driver of demand for commodities—and hence their prices—in light of its large share of global metal imports (Figure 9).

- *Fluctuations in oil and gas prices feed into food prices given the importance of energy in food production*. For example, oil is used directly as fuel for farm equipment and transportation. As such, estimates suggest that a negative supply shock that increases international oil prices by 10 percent leads to an increase in international cereal prices by about 2 percent after three quarters. In addition, gas is the main input to nitrogen-based fertilizers and pesticides used in farming, thereby impacting food prices. It is estimated that a 10 percent increase in fertilizer prices due to higher natural gas prices is associated with a 2 percent increase in international cereal prices after three quarters (Figure 10).

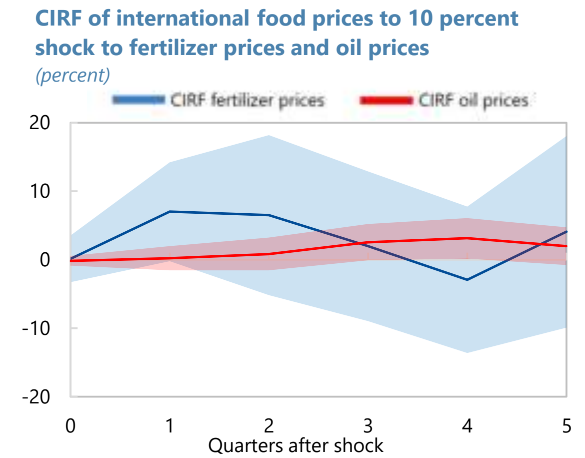
- *Higher oil prices increase food prices through energy substitution toward biofuels in production*. Some agricultural products are used as biofuels, most prominently corn. When oil prices increase, this prompts substitution away from expensive oil and toward cheaper biofuels to keep fuel prices down. In turn, this increases demand for biofuels and, thus, also increases the demand for and price of the underlying

Figure 9. China and Commodity Imports



Sources: UN Comtrade; and IMF staff calculations.

Figure 10. Passthrough from Energy to International Food Prices



Sources: Haver Analytics; IMF; World Bank; Bogmans and others, 2022.
Note: CIRF: cumulative impulse response function; shaded areas: 90-percent confidence bands.

crops. In addition, it prompts an increase in the price of other non-biofuel crops (e.g., because the use of land is diverted toward the production of crops for biofuel and away from other crops).[10] In this respect, the correlation between oil and cereal prices increased notably after the introduction of biofuel mandates in the *European Union* and the *United States* in the mid-2000s, which obliged oil refiners to blend a certain share of biofuels such as ethanol to be mixed into the economy's final fuel mix.

C. Risks of Renewed Surges in Food and Energy Prices Remain

While commodity price pressures have somewhat receded, they remain high by historical standards and inflation continues to weigh on purchasing power. Moreover, disruptions in these markets could reappear, posing a further threat to food and energy security. Rising geoeconomic fragmentation and climate change are adding to risks.

10. Continued elevated food and energy costs or further shocks to these markets could have severe macroeconomic consequences. In the near term, upward pressure on energy prices could arise due to both demand and supply shocks, albeit with different implications for global economic activity and attendant policy challenges. For example, a strong economic recovery in *China* would lead to a marked increase in global demand for energy, including amid positive spillovers to trading partners. However, higher prices could also result from further supply disruptions in food and energy markets in the event of an intensification of the war in *Ukraine*, which could also weigh on global economic activity.

- *Persistent cost-of-living pressures pose risks to the outlook*. Key risks relate to the further erosion of real incomes and, hence, demand. Moreover, attendant social unrest stemming from cost-of-living pressures can also harm growth. IMF staff estimates suggest that material social unrest can lead to significant declines in GDP. On average, in a sample of 89 economies, the level of GDP remains about 1 percent below the level prior to an unrest event for a year and a half after the event.[11]
- *Unanticipated additional policy tightening could further weigh on growth*. While monetary policy tightening is underway to bring down inflation in many economies, unfavorable inflation developments could force central banks to hike policy interest rates beyond expectations, including if cost-of-living pressures feed into wage-price spirals. Resulting higher borrowing costs would be particularly challenging for vulnerable economies with elevated debt burdens.
- *Europe remains exposed to energy security risks.* A harsher winter in Europe this year as compared to the mild winter in 2022 poses upside risks to energy demand and, hence, prices. Moreover, this could occur at a time of higher gas prices associated with a pickup in growth in *China* and an attendant increase in energy demand.

[10] The range of estimates in the literature on the impact of biofuels on crop prices is wide. Over the long run, estimates suggest a 2–3 percent increase in corn prices for each billion gallon in corn ethanol production. See US Environmental Protection Agency, "Economics of Biofuels."

[11] Hadzi-Vaskov and others, 2021.

- *Over the longer term, food insecurity can be detrimental to growth.* For example, malnourishment can hold back human capital development and productivity. In the past, micronutrient deficiencies in *China* and in *India* may have cost up to 0.4 percent of GDP annually during the early and mid-1990s.[12]

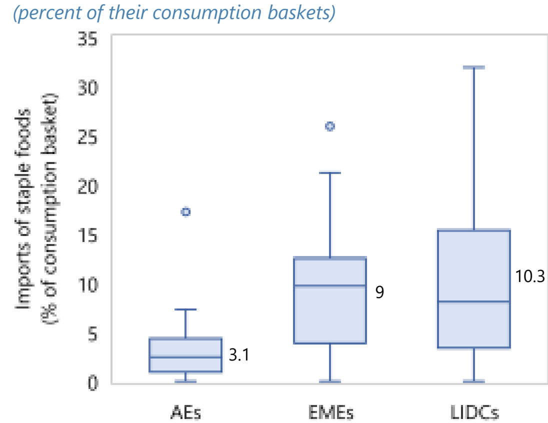
11. Further geoeconomic fragmentation could also exacerbate food and energy concerns. Recent estimates suggest that geoeconomic fragmentation could have sizable negative effects on the world economy.[13] It could directly impact food and energy markets, as seen in the dislocations caused by the war in *Ukraine* and the imposition of sanctions by western countries on *Russia* and *Belarus*. In addition, the production of key commodities has become increasingly concentrated over time, heightening exposure to fragmentation risks. In the context of energy security, these fragmentation risks exist both in conventional fossil-fuel supplies and in the supplies of key raw materials needed for renewable energy (Box 1).

12. People and economies highly dependent on trade for basic food needs are particularly exposed to disruptions in commodity trade. IMF estimates from a sample of 174 advanced, emerging market, and low-income economies show that most populations in the world rely on few staples such as maize, wheat, and rice to achieve minimum levels of dietary energy requirements. For example, the median share of wheat in satisfying the minimum caloric requirement among people in advanced and emerging economies is about 30–35 percent. In low-income economies, rice and maize play a prominent role, satisfying about 20 percent of minimum caloric requirements for the median low-income country. Moreover, on average in low-income developing and emerging market economies, 10 percent of consumption of such food staples is imported—an import share that is three times higher than in advanced economies (Figure 11).[14] As such, millions of people are highly vulnerable to adverse external food supply shocks. The recent challenges related to the Black Sea grain trade highlights the relevance of such risks.

Figure 11. Import Dependence for Staples

Import of staple food by country classification 1/

(percent of their consumption baskets)



Sources: FAOSTAT Food Balances, WB Consumption Database, and Passadore and others (forthcoming).
1/ Box and whiskers: interquartile range and 5th and 95th percentile bounds. Floating numbers: unweighted averages.

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[12] World Bank, 2006. There have been important improvements in this area. For example, India has made notable progress in improving the nutritional status of children and adults over time, as seen in lower rates of stunting in physical growth of children, and lower rates of below-normal body-mass indices among adults (National Family Health Survey 5, 2019–21).

[13] Recent literature on the topic has produced a range of estimates of the impact of geoeconomic fragmentation on the global economy. While point estimates are sensitive to modeling assumptions, some key takeaways are that the costs are higher the greater the fragmentation; that low-income and developing countries stand to lose more; and that transition costs are likely to be sizable. See Aiyar and others, 2023. "

[14] Within countries, the poorest households depend more on imports of staple foods required for subsistence, and this pattern holds for emerging market economies and low-income developing countries.

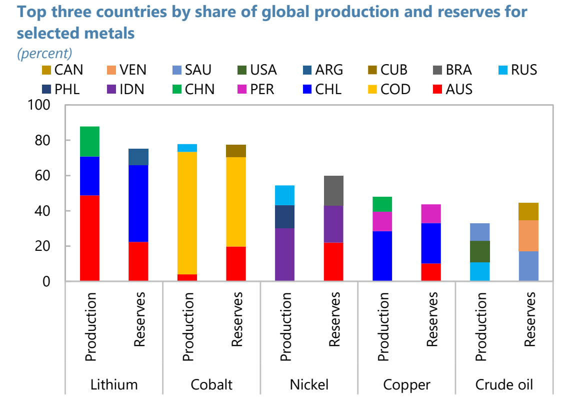
Box 1. The Role of Critical Minerals for Energy Security and the Green Transition

Critical minerals such as lithium, cobalt, or nickel are key inputs to green energy technologies and, hence, energy security. However, these minerals could become bottlenecks for the green transition, with substantially higher prices, owing to high market concentration and the long time it takes to open new mines. While critical minerals could become highly important for the global economy (as oil is today), insufficient data on minerals consumption, production, and inventories are causing uncertainty for producers and consumers. In this respect, the G-20 can facilitate the green transition and energy security by supporting international data sharing.[1]

Critical minerals are key inputs into green technologies. The green energy transition implies a significant increase in minerals demand, as renewables and electric cars are more minerals-intensive than their conventional counterparts. For example, under the International Energy Agency's (IEA) net zero emissions scenario, lithium and cobalt consumption increases more than 20- and 5-fold, respectively, over the next two decades. Alongside, energy security becomes less dependent on fossil fuels and more so on critical minerals.

However, critical minerals markets are highly concentrated—more so than oil markets—making them vulnerable to geoeconomic fragmentation. For example, about 70 percent of the global cobalt production is in the Democratic Republic of the Congo (Box Figure 1). In comparison, the global production share of the top three crude oil producers is only about 30 percent. Moreover, supply is very inelastic, as opening new mines can be a decade-long process. Overall, these factors make the production of critical minerals vulnerable to disruptions from natural catastrophes, wars, and fragmentation in investments and trade.

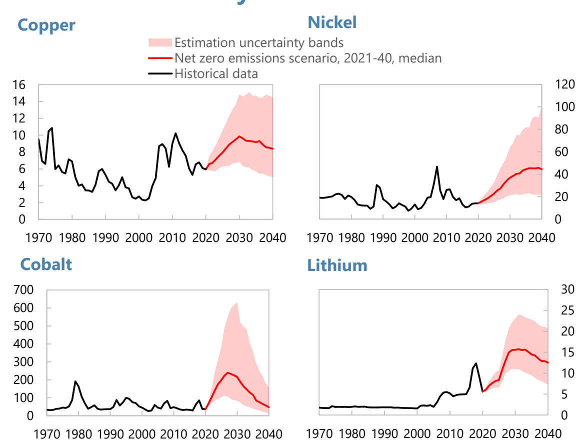
Concentration of Minerals



Sources: UN Comtrade; United States Geological Survey (USGS); and IMF staff calculations.

In addition, a lack of international sharing of data on the consumption, production, and inventories of many critical minerals creates uncertainty. While there are ample data for fossil fuels and established minerals and metals such as copper and nickel, there is much less information about the supply of and demand for critical minerals such as lithium, graphite, and cobalt. This makes it difficult to assess market imbalances and creates unnecessary price volatility, making investment for both producers and consumers challenging.

Price Scenario Analysis



Source: Boer and others (2021a).
Note: Prices are adjusted for inflation using the U.S. consumer price inflation index.

Looking ahead, a marked increase in the demand for critical minerals along the green transition could lead to substantial upward pressure on their prices and, hence, on the cost of inputs for green technologies. In a net zero emissions scenario, IMF staff estimates show that prices for critical minerals could reach previous historical peaks—and for an unprecedented length of time (Boer and others, 2021a). Cobalt, lithium, and nickel prices could rise several hundred percent from 2020 levels before peaking around 2030 (Box Figure 2).

While there is data uncertainty, estimates suggest that, amid sizable price increases, the global market value of critical minerals could rival that of oil. In a net-zero emission scenario, the combined production value of copper, nickel, cobalt, and lithium could climb from roughly USD 130 billion in 2020 to more than USD 700 billion in 2040—well above the estimated total value of oil production of about USD 400 billion in 2040 (assuming an oil price of 30 US$ per barrel; Boer and others, 2021a, 2021b). This would be macro relevant for several G-20 economies. For example, the value of nickel production in *Indonesia* could increase to an annual average of more than USD 40 billion over the next two decades. For *Australia*, the average annual value of lithium production could climb to USD 70 billion (Bems and Stuermer, 2022).

Policymakers can facilitate energy security and the green transition by putting increased focus on critical minerals and taking actions to help expand their supply.

A data sharing initiative would strengthen international cooperation on critical minerals. Essential actions include:

- *Launch an international institution or initiative to share data on critical minerals markets*. This could, for example, be analogous to the Joint Organizations Data Initiative on Oil and Gas (JODI) or the International Energy Agency (IEA) and would allow a clearer market outlook and a reduction in uncertainty.
- *Ensure broad participation in data sharing.* As both advanced economies as well as emerging market and developing economies are key producers and consumers of critical minerals, broad participation is key.
- *Share data on several frequencies and purposes*. Shared data should ideally include annual and quarterly frequencies and cover data on production, consumption, and inventories of key minerals for the green energy transition. In addition, national geological surveys and international organizations could provide guidance, building on statistical standards and reporting templates that exist for some of the metals.

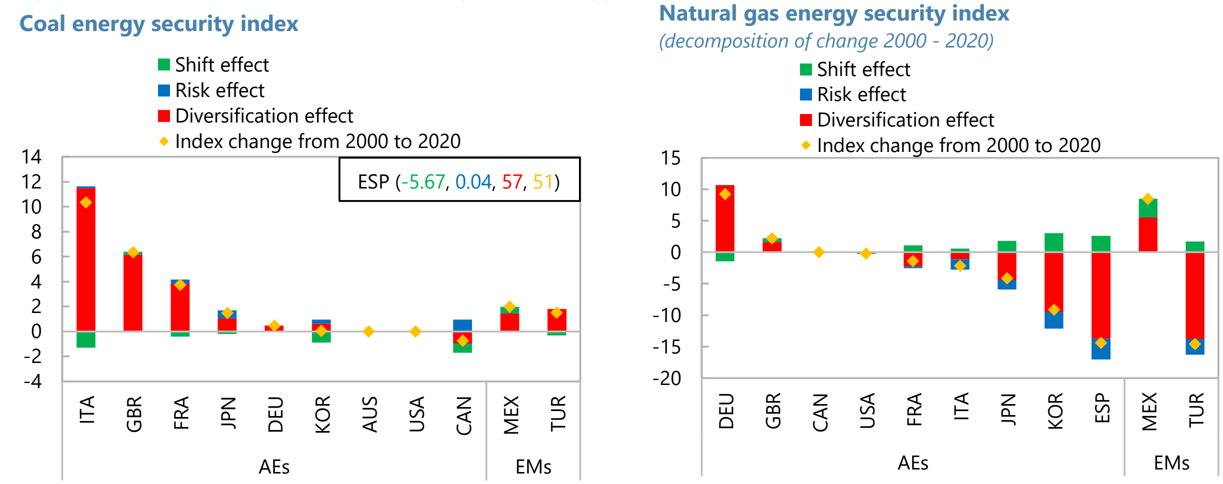
Several additional actions can help increase the global supply of critical minerals, which will be essential amid the rising needs along the green transition. Several measures can help promote efficient market functioning, encourage direct investment to expand the supply of critical minerals, and mitigate upward pressures on the cost of low-carbon technologies—not least as some countries have significant reserves of critical minerals (Box Figure 1).

- *Strengthen rules on multilateral trade*. Multilateral trade policy needs to reflect more strongly the shift from fossil fuels to critical minerals. As such, more stringent rules related to export restrictions would help prevent fragmentation of mineral markets.
- *Ensure appropriate social, labor, and governance standards.* Strong social, labor, and governance standards for mining are essential to ensure safe and sustainable production methods.
- *Reduce policy uncertainty*. Policy uncertainty, including related to the green transition, adds uncertainty for investors, thereby weighing on mining investment and heightening risks of a delay in the energy transition. A credible, globally coordinated climate policy could help to reduce such uncertainty.

[1] This box has been prepared by Lukas Boer, Andrea Pescatori, and Martin Stuermer.

13. Economies highly dependent on imports of energy from a few large external suppliers are particularly exposed to concentration risks in the energy market. Some economies (e.g., *Spain* for coal, *Germany* for natural gas, *Mexico* for oil) have increased their dependence on imports from a few large energy producers during the past couple of decades. Indeed, greater diversification (greater concentration) in energy import sources is the main driver of increases (decreases) in energy security among G-20 economies. Figure 12 shows a shift-share decomposition of a political-risk-adjusted energy security index. The index measures energy import concentration, adjusted for political risks in the energy exporting country (capturing the degree of energy supply uncertainty related to political instability or the lack of democratic freedom). The Figure shows that changes to diversification or concentration of import sources are the main determinant of changes in energy security between 2000 and 2020.[15] For example, in the case of coal, the increase in concentration of import sources in *Italy*, *United Kingdom*, and *France* drove a decrease in energy security, amid rising market shares of a few large coal producers (e.g., *Indonesia*, *China*) in these countries. In contrast, diversification improved energy security related to natural gas in several G-20 economies, except *Germany* and *Mexico* where concentration risks rose, owing to their increased reliance on *Russia* for natural gas during the given period.

Figure 12. Decomposition of Change in Energy Security Index



Sources: J. Kim, A. Panton, and G. Schwerhoff (forthcoming) "Energy Security and the Green Transition."
Note: An increase in the index value reflects a deterioration of energy security. The index is a Herfindahl-Hirschman aggregation of energy suppliers' market shares, weighted by the political risk of each supplying country. By taking the index value at two points in time (2000 and 2020), changes in energy security can be attributed to 3 effects: (i) a diversification effect, which indicates the degree of import concentration, capturing a move away from or towards a single dominant supplier (red segments); (ii) a risk effect, which results from changes in the risk scores of individual energy supplying countries (blue segment); and (iii) a shift effect, which results from shifts in energy imports between countries with different risk ratings (green segment).

14. In addition, temperature and precipitation anomalies owing to climate change are adversely affecting livelihoods and food security. This is particular the case in poorer parts of the

[15] Kim and others (forthcoming). Note that this decomposition only captures changes in energy import concentration, and not the levels. Further, the composition of natural gas suppliers for *Germany* (and many other European countries) changed in 2022 amid *Russia*'s gas shutoff to Europe and as European countries found alternative suppliers.

world where resources for adaptation are limited and reliance on rain-fed agriculture is high.[16] For example, with less than 1 percent of arable land equipped with irrigation in Sub-Saharan Africa, most people in that region that are relying on subsistence agriculture are vulnerable to adverse weather events. In addition, in some economies, many people are highly reliant on only one staple food for almost all their caloric requirements (e.g., Afghanistan relies predominantly on wheat and Bangladesh mainly on rice) and may be particularly vulnerable to climate-related shocks to food supply.[17] A lack of climate-resilient food supplies could put large swathes of the populations at higher risk of hunger.

EARLY ACTION MUST ALSO BE SMART ACTION

A. Policymakers Have Responded to the Cost-of-Living Crisis

Both monetary and fiscal policies have essential roles in the response to the cost-of-living crisis but face complex trade-offs amid elevated debt and high borrowing costs for many. Some external sector measures, adopted by governments, such as added restrictions on trade flows, are counterproductive.

15. In most G-20 economies, high inflation has necessitated monetary policy tightening. During 2022, policy interest rates among many G-20 economies rose quickly and in a highly synchronized manner across emerging market and advanced economies. Exceptions include *Japan* and *China*, which did not adjust key policy interest rates, and *Russia* and *Türkiye*, which reduced rates. Across tightening G-20 economies, policy interest rates were hiked in 2022 by between 200 and 400 basis points in advanced economies and between 180 and 470 basis points among emerging market economies, not including *Argentina*, where policy interest rates were lifted by more than 35 percentage points. And although there are substantial lags before the full effects of policy tightening play out, early signs suggest that tighter monetary policy has begun to cool demand and inflation.[18,19]

16. Meanwhile, fiscal authorities have announced a wide variety of measures to ease the cost-of-living pressures. An IMF survey of 182 countries shows that most economies announced at least one measure during 2022. The survey indicates that most measures aimed at reducing the passthrough of international prices to domestic prices.[20] Such measures included price freezes and reductions in consumption taxes. Other measures included cash and in-kind transfers, subsidies, and below-the-line fiscal support. Among G-20 economies, 17 percent of the implemented measures related to food prices and 48 percent of the measures to energy prices. Moreover, nearly a quarter of the implemented measures in the G-20 were untargeted. A number of G-20 emerging market and advanced economies relied on price subsidies and price freezes as well as on subsidies to specific industries. In addition, several economies made extensive use of cash transfers and reduced

[16] IMF, 2020.

[17] Passadore and others (forthcoming).

[18] IMF, 2023b.

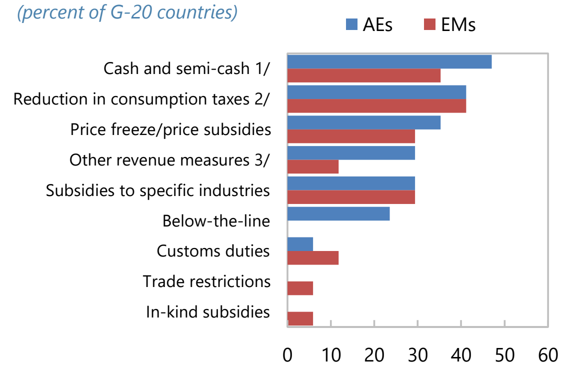
[19] For example, Havranek and Rusnak (2013) estimate that monetary policy lags average about 3 years (+/-1.5 years), with somewhat longer lags than 3 years in advanced economies and shorter than 2 years on average in emerging market economies.

[20] Updated results of the DEFPA IMF Country Desk Survey from Amaglobeli and others (forthcoming).

consumption taxes (Figure 13). In general, many of these measures could have adverse implications for fiscal sustainability and the green transition. For example, unless they are designed to be temporary and targeted, measures such as subsidies and tax cuts are costly, regressive, and unsustainable responses to a persistent shock. In addition, lower consumption taxes on energy can dampen the price signal from higher energy prices that help encourage more energy efficiency.

Figure 13. G-20: Fiscal Measures

Recently announced measures in response to high energy and food prices
(percent of G-20 countries)



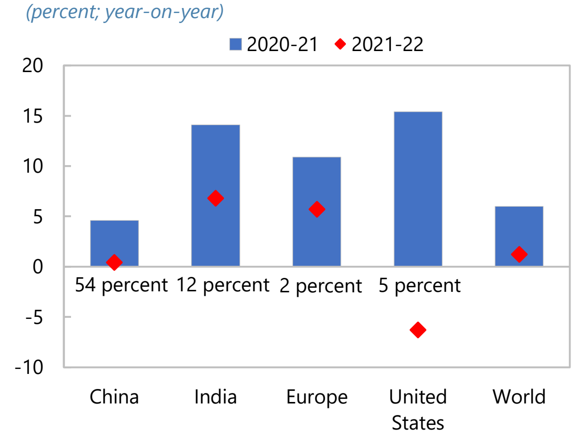
Sources: Based on updated results of the DEFPA IMF country desk survey from Amaglobeli and others (forthcoming), conducted in January/February 2023, on measures announced by governments since the beginning of 2022 in response to rising food and energy prices.
Note: Includes ARG, AUS, BRA, CAN, CHN, FRA, DEU, IND, IDN, ITA, JPN, KOR, MEX, ZAF, TUR, GBR, USA.
1/ Includes cash transfers and semi-cash, such as vouchers and utility bill discounts.
2/ Includes value-added and excise taxes.
3/ Includes income tax changes and other revenue measures.

17. **Many economies, typically food exporters, have also reverted to protectionism in the face of the food shock**. As of September 2022, close to 30 economies worldwide had imposed restrictions on food and fertilizer exports in the period following Russia's invasion of Ukraine. This included several G-20 emerging market economies (*Argentina, China, India, Indonesia, Russia, Türkiye*) that imposed at least one export restriction on food and fertilizers in 2022.[21] And while some of these restrictions have been subsequently reversed, they remain in place on a number of food items, accounting for about 8 percent of total calories traded internationally.[22]

18. **The increase in fossil fuel prices—in particular natural gas prices—has prompted a shift in the sources of energy supply, including away from gas and toward other fuels such as coal**. This shift may reflect firms' decisions to switch energy sources under changing supply conditions as well as policy actions to actively promote a switch to alternative energy sources, including for energy security reasons. For example, many European economies have increased reliance on gas storage while also seeking to establish alternative gas sources (e.g., additional pipeline gas imports from *Norway*; LNG imports from the *United States*, *Qatar*, and *Algeria*). That said, while global coal consumption growth decelerated in 2022, it nonetheless grew by 1.2 percent, surpassing 8 billion tons of consumption for the first time in history (Figure 14). In addition, in some

Figure 14. Coal Consumption

Coal consumption growth
(percent; year-on-year)



Source: International Energy Agency; IMF staff calculations.
Note: Numbers below bars: 2020 global consumption shares.

[21] Rother and others, 2022.

[22] IFPRI Food Security Portal data as of February 2023.

economies, while moderating, coal consumption growth remained strong (e.g., *India*, where it provides 75 percent of electricity generation, though amid increasingly accessible renewables that are also adding to electricity generation; and Europe, where coal demand rebounded in the last two years following a steady decline over the last decade).[23] If left unaddressed, the increased reliance on fossil fuel-based energy could be detrimental to achieving climate change mitigation objectives. In this respect, some of the recently announced fiscal support measures that suppress the price signal of higher energy prices may also be counterproductive, as they would not sufficiently discourage reliance on carbon-intensive fossil fuels.

B. Short-Term Actions must be Aligned with Medium-Term Priorities

Overall, the macroeconomic policy mix should remain contractionary in most economies. While inflation is expected to moderate as monetary policy tightening takes effect, it is essential to stay the course, including amid continued pressures on core inflation. At the same time, fiscal policy can provide targeted support to the most vulnerable within the overarching aim of restoring fiscal sustainability. Remaining on a tightening path will also ensure that fiscal policy does not work against monetary policy's efforts to bring down inflation.

19. Monetary policy must remain focused on bringing inflation down durably. Securing global disinflation remains a key priority. Monetary policy needs to stay the course where inflation is elevated, keeping real policy rates above neutral levels until a decline in underlying inflation is clearly visible. Not tightening enough, or reversing course too early, runs the risk of costlier adjustments down the line if inflation does not durably decline. At the same time, central banks will need to stand ready to act (e.g., with temporary, well-targeted liquidity support) in the event financial stress should arise from higher interest rates.

20. Meanwhile, fiscal policy should aim for gradual and steady tightening, and thus reduce the pressure on monetary policy to combat high inflation, while supporting the most vulnerable. Where debt levels are high, fiscal policy must be contractionary and remain focused on ensuring fiscal sustainability. This implies that costly broad-based measures to limit the pass-through of high international commodity prices to domestic prices—adopted by some economies to mitigate the impact from higher food and energy prices—need to be unwound and replaced by targeted measures to support vulnerable households. This will help preserve the price signal and ensure fiscal sustainability. A clear, well-communicated strategy is required. In addition, as volatility in commodity terms of trade growth could pose macro-fiscal risks and potentially jeopardize debt sustainability, many economies would benefit from enhancing governance and public financial management by improving fiscal transparency and establishing medium-term fiscal frameworks. Some key principles to help guide appropriately designed fiscal support include the following.[24]

- *In all economies and to the extent possible, fiscal support measures should preserve the price signal from higher energy prices*. All economies have an important role to play in allowing price signals to

[23] International Energy Agency, 2022.

[24] Amaglobeli and others (forthcoming).

help rebalance the global demand and supply of food and energy. In this respect, when providing fiscal support, transfers that are independent of the consumption of energy or food are preferred as they do not distort relative prices, allowing higher energy prices to encourage greater energy efficiency going forward. That said, second best measures may be unavoidable in economies lacking an adequate social safety net. As such, other measures that preserve some or all of the price signals could also be considered, including (i) lump-sum bonuses linked to consumption reduction by households; and (ii) block pricing, providing lower prices for consumers below a minimum level of energy consumption and at market prices above that minimum level.

- *Where energy or food price subsidies are in place, international prices should gradually be allowed to pass through to retail prices*. The pace of pass-through should be carefully calibrated based on the gap between retail and international prices, the available fiscal space, and the ability to put measures in place to mitigate the impact on vulnerable households. Commitment to eliminating subsidies over the medium term is essential.
- *In general, reducing taxes on food and fuel is not advisable*. An across-the-board reduction in such taxes implies providing relief to all, including the most affluent households, and results in the loss of significant revenues when these are most needed. For fuel taxes, such as excises, there are several additional considerations, as fuel taxes address environmental externalities and are required for climate change mitigation. Temporary tax reductions for food may be considered where social safety nets are weak, with clear exit timelines.
- *Untargeted measures entail high fiscal costs.* Hence, moving to targeted transfers would lower fiscal costs, which is particularly relevant for economies facing high debt burdens. For example, in Europe, estimates suggest that fiscal measures implemented between the summer of 2021 and end-2022 exceeded 1.5 percent of GDP in some economies (averaging around 1 percent). In contrast, targeted measures aiming to fully offset consumption losses of the bottom 20 percent of households would have had an average annual cost of 0.4 percent of GDP (albeit with variation across economies).[25]
- *Strengthening social security networks would help more effectively protect vulnerable households from food and fuel price shocks.* Strong social security networks are characterized by benefit programs that have high coverage of the poor, adequate benefit levels, good benefit incidence (proportion of the benefits received by the poor as a share of total benefits), are effective at reducing poverty, and have good infrastructure to scale up transfers in response to shocks. Greater digitalization and financial integration would also be helpful in this regard by making it easier to identify and target beneficiaries and transfer benefits quickly when needed.

21. **Moving toward more renewable energy will have the dual benefits of increasing energy independence and security and facilitating the green transition**. The cost-of-living crisis as well as higher prices of fossil fuels offer an opportunity to enhance energy security and advance climate

[25] Ari and others, 2022. Estimated fiscal costs exclude loan guarantees.

change reforms, including by transitioning away from fossil fuels and towards renewables.[26] Notably, these goals can be pursued at the same time if the expansion of energy capacity is done in a way that is consistent with climate change mitigation goals while ensuring sufficient energy supply during the transition. Moreover, diversification of energy sources as part of the green transition is consistent with greater energy security.

C. Multilateral Cooperation is Needed to Safeguard the World Economy

Cooperation among countries is urgently needed to ensure open and rules-based trade, avoid further geoeconomic fragmentation, and maintain resilient global financial safety nets.

22. Multilateral efforts are essential to ensure unimpeded trade and thereby support food security and the green transition. Efforts to ensure the continued flow of food such as through the Black Sea Grain Initiative has been helpful. In addition, the approval of the IMF's new Food Shock Window provides additional access to emergency financing for economies facing urgent balance-of-payment needs related to the global food crisis, and where a multi-year program is either not feasible or not necessary. The IMF has also been supporting countries strongly affected by the global food crisis through new UCT-quality programs or augmentation of existing ones.[27] However, further efforts are needed.

- *Avoid disruption to trade in food commodities*. In the short-run, countries that are reliant on food imports from *Russia* and *Ukraine* remain vulnerable to renewed disruptions in the grain market. Restrictions on exports of key food items distort production incentives and, as such, are harmful for global food security over the longer run.
- *Support the green transition through the free flow of trade in key transition-related primary inputs*. The production of transition minerals is more concentrated than the production of oil and gas. For copper, nickel, cobalt, rare earths, and lithium, the largest producers have a market share of more than 25 percent.[28] Some of the key source countries for critical transition minerals such as cobalt and rare earths are subject to relatively high levels of risk, as mining is dominated by countries with high political risk values (as measured by ICRG risk indices).[29] Therefore, diversifying sources of supply will be important. The ongoing increase in the share of liquefied natural gas may help diversify gas supply and reduce concentration risks. Data transparency and dissemination could play a pivotal role in reducing uncertainty and enhancing impact analysis related to the supply of critical minerals (Box 1).
- *Strengthen the multilateral trade system*. More broadly, progress on addressing concerns related to trade distorting practices (e.g., industrial subsidies, market access barriers), the increasing use

[26] Past crises (e.g., 1970s fuel price shocks) are thought to have played a role in expanding public support for policies to reduce dependence on oil and promote renewable energy in the U.S. (see Aklin and Urpelainen, 2018). IMF research suggests that concern for climate change and support for green recovery policies increased during COVID-19 (Mohommad and Pugacheva, 2022).

[27] IMF Press Release No. 22/335.

[28] Kim and others (forthcoming).

[29] ICRG risk indices provide risk ratings for 141 countries and offshore financial centers, across political, economics, and financial risks.

of trade policy for non-trade objectives (e.g., national security, labor protection, climate change), and the dispute settlement impasse is critical to restore faith in the international trade policy architecture. In this regard, the package agreed at the 12th Ministerial Conference of the WTO was a step in this direction, but more is needed.[30]

23. Addressing further geoeconomic fragmentation is important for reaching strong, sustainable, balanced, and inclusive growth. For several decades, trade and technology linkages have been important channels for beneficial spillovers arising from greater global economic integration. Preserving them is critical for future prosperity. However, with geopolitical tensions escalating and multilateral consensus on many issues proving elusive, a pragmatic approach is needed. This approach can be tailored to the extent of consensus on various issues: [31]

- *Multilateral efforts should continue to be emphasized and remain the best approach in making progress toward common goals.* Areas where multilateral efforts are particularly essential include climate change mitigation, food security, and pandemic preparedness.
- *Plurilateral initiatives could be a practical way forward in areas where countries' preferences are not well aligned and when multilateral negotiations stall*. That said, it will be important that such initiatives are open and non-discriminatory. In the context of trade policy, plurilateral agreements within the WTO can help make progress on outstanding issues. Deep, open regional trade agreements can also help support multilateral integration. Throughout, it will be important that food corridors are kept open.
- *"Guardrails" may be needed in areas where preferences are not aligned, and countries increasingly resort to unilateral actions.* Such guardrails may be needed to mitigate global spillovers and protect the vulnerable and could include multilateral consultations as well as commonly agreed norms of conduct.

24. Enhancing the resilience of the global financial safety net will help provide safeguards in times of need. A strong global financial safety net can help mitigate the effects of future shocks, including commodity supply shocks. Ensuring a sufficiently large and coherent global financial safety net is crucial to be able to provide rapid and adequate support to countries in times of need. In this regard, it is vital that the IMF remain representative of its global membership and be adequately resourced to serve as the anchor of the global financial safety net. Successful completion of the 16th General Review of Quotas will be a key step in this direction.

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[30] The 12th Ministerial package included outcomes related to fisheries subsidies, the WTO response to the pandemic, food insecurity, e-commerce, WTO reforms, and other issues.

[31] Aiyar and others, 2023.

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Appendix I.

This Appendix describes the exercises from the which the regression coefficients shown in Figures 7 and 8 in the main text are obtained.

A. CTOT Growth Volatility and Per Capita GDP Growth

1. Following Cavalcanti and others (2015), we examine the economic impact of Commodity Terms of Trade (CTOT) growth and CTOT growth volatility (henceforth CTOT volatility). We focus on per-capita GDP growth, changes in Total Factor Productivity (TFP), physical capital accumulation, and human capital acquisition. We estimate the following dynamic panel data model:

$$g_{y,is} = (\varphi - 1)y_{is-1} + \gamma_1 gCToT_{is} + \gamma_2 \sigma_g CToT_{is} + \gamma_3 EXPY_{is} + \boldsymbol{\beta}' \boldsymbol{z}_{is} + c_{yi} + \eta_s + \varepsilon_{is} \quad (1)$$

Here, $i = 1 \ldots N$ and $s = 1 \ldots S$; $S = T/5$ (where T is the interval between 1970 and 2019); $g_{y,is}$ is the geometric average growth rate of Y={real GDP per capita, or TFP, or physical capital, or human capital} between period s and $s-1$; y_{is-1} is the log of Y in the first year of each 5-year interval; $gCToT$ is the growth rate of the CTOT index; $\sigma_g CToT$ is the standard deviation of the growth rate of the CTOT index in each 5-year interval; $EXPY$ is a measure of export sophistication; and $\boldsymbol{z}_{is}$ is a set of additional control variables from the growth literature including education levels, trade openness, government consumption expenditure, and lack of price stability. c_{yi} is a country-specific fixed effect, η_s is a period-specific time effect, and ε_{is} is an idiosyncratic error term.

2. The model is estimated with a system GMM estimator. We employ the Windermeijer (2005) approach to correct for the small sample bias. The system GMM approach accounts for the joint endogeneity of explanatory variables and the problems induced by unobserved country-specific effects.

3. Appendix Table 1 shows the results of the system GMM regressions. The results indicate that in the full sample of 118 countries, CTOT volatility is negatively associated with growth in per capita GDP. Looking at commodity exporters and other countries separately, this is effect is observed only among commodity exporters. Moreover, the negative association with GDP growth among commodity exporters appears to be driven by the negative association of CTOT volatility with human capital accumulation for this group of countries.

Appendix I. Table 1. Effects of CTOT Growth and Volatility on GDP per Capita Growth and its Determinants, 1970-2019: GMM Regressions

Sample:	All	Commodity exporters				Others
Dependent variable (growth rate of):	Income per capita	Income per capita	TFP	Physical capital	Human capital	Income per capita
CTOT growth	0.247*	0.0931	-0.108	0.315***	0.0662	0.382
	(0.135)	(0.163)	(0.250)	(0.111)	(0.0417)	(0.277)
Volatility of CTOT growth	-0.290***	-0.358***	-0.0546	-0.0284	-0.0532***	0.0983
	(0.0940)	(0.0850)	(0.202)	(0.0963)	(0.0188)	(0.216)
Initial value of dependent variable	-0.830*	-0.542	-3.727**	-1.595**	-0.605	-3.444***
	(0.481)	(0.501)	(1.664)	(0.711)	(0.667)	(0.975)
Export sophistication	0.934	0.341	1.849	4.965*	-1.591**	8.939**
	(1.630)	(2.127)	(2.990)	(2.793)	(0.628)	(4.344)
Secondary enrolment	1.483***	0.936	1.201	0.304	1.098***	2.067
	(0.499)	(0.664)	(1.275)	(0.779)	(0.277)	(1.712)
Openness	3.924***	4.496***	3.461**	2.743**	0.541**	2.751*
	(0.836)	(1.559)	(1.424)	(1.185)	(0.262)	(1.411)
Government consumption to GDP	-3.591***	-2.952***	-5.183**	-1.488	0.00755	-2.761
	(0.900)	(1.033)	(2.106)	(1.385)	(0.400)	(1.747)
Price instability	-5.948***	-5.243*	-4.250	-7.028*	1.060*	-17.24***
	(2.136)	(2.762)	(4.605)	(3.698)	(0.625)	(3.495)
Constant	19.71	17.65	34.32	0.741	3.743	23.96
	(14.99)	(16.77)	(33.03)	(23.55)	(7.047)	(39.28)
Observations	873	460	448	464	465	413
No. of Countries	118	62	62	62	62	56

Note: GMM estimates are from equation (1). Standard errors are in parentheses. Asterisks indicate statistical significance at 1 percent (***), 5 percent (**), and 10 percent (*).

4. **A CS-ARDL approach is employed as additional evidence and for robustness**. To complement the system GMM results, we estimate the following cross-sectionally augmented panel ARDL model (CS-ARDL), using the Pooled Mean Group (PMG) estimator on annual observations over 1981–2019:

$$\Delta y_{i,t} = a_i + \sum_{l=1}^{p} \varphi_l \Delta y_{i,t-l} + \sum_{l=0}^{p} \boldsymbol{\beta}'_l \Delta \boldsymbol{x}_{i,t-l} + \sum_{l=0}^{p} \boldsymbol{\vartheta}'_l \Delta \bar{\boldsymbol{z}}_{t-l} + \epsilon_{i,t}, \quad (2)$$

Here, y_{it} is the log of Y={real GDP per capita, or TFP, or physical capital, or human capital} of country i in year t; $\boldsymbol{x}_{it}(m) = [g_{CToT}, \sigma_{CToT}]'$, in which $g_{CToT_{it}}$ is the growth rate of the CTOT index, and $\sigma_{CToT_{it}}$

is the volatility of CTOT growth in year t for country i; and $\bar{\boldsymbol{z}}_t = [\overline{\Delta y}, \bar{\boldsymbol{x}}']'$ is a vector of cross-sectional averages of the variables.

5. **Moreover, the long-run effects, $\boldsymbol{\theta_i}$, are calculated from the OLS estimates of the short-run coefficients in equation (2)**. As such, the long-run effects are: $\boldsymbol{\theta} = \Phi^{-1} \sum_{l=0}^{p} \boldsymbol{\beta_l}$, where $\Phi = 1 - \sum_{l=1}^{p} \varphi_l$. Hence, the CS-ARDL allows for heterogeneous error variances, short-term slope coefficients, and intercepts, while restricting the long-run coefficients to be the same across countries.

6. **There are several considerations behind the use of panel ARDL regressions**. These considerations are set out in Pesaran and Smith (1995), Pesaran (1997), and Pesaran and Shin (1999). They show that the traditional panel ARDL approach (i) can be used for long-run analysis; (ii) is valid regardless of whether the underlying variables are I (0) or I (1); and (iii) is robust to omitted variables and bi-directional feedback effects between economic growth and its determinants. The PMG estimator and the inclusion of $\bar{z}_t$ also account for dynamic cross-country heterogeneities and cross-sectional dependencies.[1] Accounting for these factors is particularly important in the analysis in this note, as the effect of CTOT volatility on real per capita growth varies across countries and depends critically on country-specific factors and institutions as well as the feedback effects from determinants of GDP growth. Moreover, neglecting cross-sectional dependencies can lead to biased estimates and spurious regressions, particularly given the rapid increase in world trade, international financial linkages, and exposures to global/regional shocks.

7. **The findings are consistent across the GMM and CS-ARDL approaches**. Considering the system GMM results for commodity exporters (Appendix Table 1), we perform the CS-ARDL regressions focusing on the sample of 62 commodity exporters, for which CTOT growth and CTOT volatility are expected to impact per-capita GDP growth and its determinants. The CS-ARDL results confirm that the main channel of the association is through capital accumulation. In particular, CTOT volatility is associated with lower accumulation of both physical and human capital in the long term and, hence, lower GDP per capita growth (Appendix Table 2).

Appendix I. Table 2. Long-Term Effects of CTOT Growth and Volatility on GDP per Capita Growth and its Determinants in Primary Commodity Exporters, 1981-2019: CS-ARDL Regressions

Dependent variable (growth rate of):	GDP per capita	TFP	Physical Capital	Human Capital
CTOT growth	0.0028***	0.0014*	0.0020***	-0.0005***
	(-0.0006)	(-0.0008)	(-0.0006)	(-0.0002)
Volatility of CTOT growth	-0.0015*	-0.0014	-0.0029***	-0.0042***
	(-0.0009)	(-0.0013)	(-0.0008)	(-0.0005)
No. of Countries (*N*)	62	62	62	62
Average T	35.8	33.7	35.6	35.8
N x T	2219	2090	2207	2219

Note: The PMG estimates are from the CS-ARDL model as shown in equation (2). Standard errors are in parentheses. Asterisks indicate statistical significance at 1 percent (***), 5 percent (**), and 10 percent (*).

[1] See Chudik and others (2013), Chudik and others (2016), and Chudik and others (2017) for details.

B. CTOT Growth Volatility and Headline Inflation Volatility

8. **We also examine the impact of CTOT volatility on headline inflation and its volatility**. We employ a range of Fixed Effects (FE), System GMM, and CS-ARDL regressions. We start by estimating the following regression via FE and system GMM estimators:

$$\sigma_{\pi_{is}} = \gamma_1 \sigma CToT_{is} + \boldsymbol{\beta}' \boldsymbol{z}_{is} + c_{yi} + \eta_s + \varepsilon_{is} \quad (3)$$

Here, $i = 1 \ldots N$ and $s = 1 \ldots S$; $S = T / 5$, where T is the interval between 1972 and 2022; $\sigma_{\pi_{is}}$ is the (log) standard deviation of headline inflation in period s; $\sigma CToT_{is}$ is the (log) volatility of CTOT growth; $\boldsymbol{z}_{is}$ is a set of controls, including openness, initial headline inflation levels in the year prior to the beginning of a given period. c_{yi} is a country-specific fixed effect; η_s is a period-specific time effect; and ε_{is} is an idiosyncratic error term. We also apply the Windermeijer (2005) bias correction approach.

9. **Appendix Table 3 shows the results of the FE and GMM regressions**. The analysis shows that higher headline inflation volatility is positively and significantly associated with greater CTOT volatility, with the size of the effect larger in the GMM than in the FE regressions. This indicates that the latter may be biased downward due to endogeneity, which the GMM can help address. In addition, inflation volatility is significantly and negatively associated with more openness and is positively and significantly associated with higher initial levels of inflation.

Appendix I. Table 3. Long-Term Effects of CTOT Volatility on Headline Inflation Volatility: 1972-2022

	FE	GMM
Dependent variable:	Headline inflation volatility	
CTOT growth volatility	0.0964**	0.188***
	(0.0422)	(0.0479)
Openness	-0.0688	-0.393**
	(0.240)	(0.163)
Initial headline inflation	1.920***	2.267***
	(0.251)	(0.245)
Constant	-3.782***	-1.584*
	(1.033)	(0.807)
Observations	963	963
No. of Countries	118	118

Note: The FE and GMM estimates are from equation (3). Standard errors are in parentheses. Asterisks indicate statistical significance at 1 percent (***), 5 percent (**), and 10 percent (*).

10. We then examine two hypotheses that focus on the long-term relationship between CTOT volatility and inflation:

- Does persistent CTOT volatility lead to structurally higher inflation *levels* in the long term?
- Does persistent CTOT volatility lead to higher inflation *volatility* in the long term?

11. To do so, we estimate the following CS-ARDL regression via the PMG estimator:

$$\Delta y_{i,t} = a_i + \sum_{l=1}^{p} \varphi_l \Delta y_{i,t-l} + \sum_{l=0}^{p} \beta_l \Delta \sigma_{CToT\,i,t-l} + \sum_{l=0}^{p} \boldsymbol{\vartheta}'_l \Delta \bar{\boldsymbol{z}}_{t-l} + \epsilon_{i,t}, \quad (4)$$

Here, y_{it} represents either the standard deviation of monthly CPI inflation growth (yoy) in year t for country i, namely $\sigma_{\pi_{it}}$ or simply the headline inflation, namely π_{it}; $\sigma_{CToT_{it}}$ is the volatility of CTOT growth in year t for country i; and $\bar{\boldsymbol{z}}_t = [\overline{\Delta y}, \overline{\sigma_{CToT}}]'$ is a vector of cross-sectional averages of the variables.

12. The long-run effects, $\boldsymbol{\theta_i}$, are calculated from the OLS estimates of the short-run coefficients in equation (1). As such, the long-run effects are: $\theta = \Phi^{-1} \sum_{l=0}^{p} \beta_l$, where $\Phi = 1 - \sum_{l=1}^{p} \varphi_l$.

13. The long-run results are reported in Appendix Table 4. The results show that:

- CTOT volatility has not led to a structurally higher *level* of inflation over the long term. This could potentially be a result of improved institutions and policy frameworks in many economies, including as evidenced by their record of containing inflationary expectations.
- CTOT volatility is associated with higher inflation *volatility* over the long run across countries.

Appendix I. Table 4. Long-Term Effects of CTOT Growth Volatility on Headline Inflation and Headline Inflation Volatility: 1981-2019

Dependent variable:	Inflation	Inflation volatility
CTOT growth volatility θ	-0.0001	0.1119***
	(-0.0004)	(-0.0216)
No. of Countries (*N*)	180	81
Average T	35.5	31.2
NxT	6386	2529

Note: The PMG estimates are from equation (2). Standard errors are in parentheses. Asterisks indicate statistical significance at 1 percent (***), 5 percent (**), and 10 percent (*).

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