Online Annexes[1]

Online Annex 2.1. Data Description

Six sets of data are used in the analysis, covering commodity prices and structural shocks, macro aggregate variables, external sector variables, financial variables, global variables and the US dollar, and policy and structural variables. The table below offers an overview of the variables used and their respective sources.

Online Annex Table 2.1.1. Data Sources

Indicator	Sources
Commodity Prices and Shocks	
Commodity Prices	International Monetary Fund, Primary Commodity Price System (PCPS)
Shock series from Baumeister and Hamilton (2019)*, [1]	Baumeister and Hamilton (2019)
Shock series from Känzig (2021)*, [2]	Känzig (2021)
Shock series from Kilian and Murphy (2014)*, [3]	Kilian and Murphy (2014); Zhou (2020)
Shock series from Baumeister and Hamilton (2023)*, [4]	Baumeister and Hamilton (2023)
Macro Aggregate Variables	
Real Gross Domestic Product (SA)**	International Monetary Fund, Global Data Source (GDS)
Real Consumption (SA)**	International Monetary Fund, Global Data Source (GDS)
Real Investment (SA)**	International Monetary Fund, Global Data Source (GDS); Belgium's and Poland's investments from CEIC; China's annual investment from China National Bureau of Statistics
Consumer Price Index (SA)	International Monetary Fund, Global Data Source (GDS)
Policy Rate[5]	Bank for International Settlements (BIS) Central Bank Policy Rates; Haver Analytics.
Domestic Credit to Nonfinancial Sector	Credit to the Non-Financial Sector, Bank for International Settlements (BIS)

[1] Prepared by Lukas Boer, Jiaqian Chen, Santiago Gomez, Ting Lan, Cyril Rebillard, Xiaohan Shao, and Brian Hyunjo Shin.

Online Annex Table 2.1.1 ***(continued)***

Fiscal Balance	International Monetary Fund, Global Data Source (GDS)
External Sector Variables	
Current Account Balance (SA)	International Monetary Fund, Global Data Source (GDS)
Domestic Saving[6]	International Monetary Fund, Global Data Source (GDS); International Monetary Fund, International Financial Statistics (IFS); Haver Analytics
Domestic Investment	International Monetary Fund, Global Data Source (GDS)
Bilateral Exchange Rates	International Monetary Fund, Global Data Source (GDS)
Real Effective Exchange Rates (REER)	International Monetary Fund, Global Data Source (GDS)
Terms of Trade (SA)[7]	Global Financial Data (GFD); Haver Analytics; Refinitiv Datastream; Eurostat
Nonenergy/Energy Trade Balance (SA)	Trade Data Monitor (TDM)
Imports of Goods and Services (SA)**	International Monetary Fund, Balance of Payments Statistics (BOP)
Exports of Goods and Services (SA)**	International Monetary Fund, Balance of Payments Statistics (BOP)
Financial Variables	
Net Financial Flows	International Monetary Fund, Balance of Payments Statistics (BOP); China's Financial Account Balance from CEIC
Private and Public Inflows[8]	Avdjiev and others (2022)
Net International Investment Position	International Monetary Fund, Balance of Payments Statistics (BOP)
Valuation Changes	Allen and others (2023)
Valuation Changes due to Exchange Rate Movements	Allen and others (2023)
Valuation Changes due to Asset Prices and Other Statistical Changes	Allen and others (2023)
Primary Income	International Monetary Fund, Balance of Payments Statistics (BOP)
Reserve Asset (SA)	International Monetary Fund, Balance of Payments Statistics (BOP)

Online Annex Table 2.1.1 *(continued)*

Global Variables and US Dollar Index	
Global Balances[9]	International Monetary Fund, Global Data Source (GDS)
Global Industrial Production	International Monetary Fund, Global Data Source (GDS); Baumeister and Hamilton (2019)
Global Oil Production	US Energy Information Administration (EIA)
BAA Spread	Federal Reserve Bank of St. Louis, Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity
US Dollar Broad Index*	Federal Reserve Board
Policy and Structural Variables	
Inflation Anchoring	Bems and others (2021)
Exchange Rate Regime[10]	Ilzetzki, Reinhart, and Rogoff (2019)
Investment in energy-exporting countries[11]	International Monetary Fund, coordinated portfolio investment survey (CPIS), coordinated direct investment survey (CDIS)
External Positions[12]	IMF staff assessments
Government-Debt-to-GDP Ratio	International Monetary Fund, Global Data Source (GDS)
Energy Dependence[13]	Energy Trade Balance from Trade Data Monitor (TDM)

Source: IMF staff compilation.

Note: SA = variables from GDS are seasonally adjusted using X-12, other variables are adjusted using X-13.

*Monthly data converted to quarterly by averaging.

**Data are adjusted to account for extreme movements during the COVID period (see Online Annex 2.3).

[1] Shock series are computed based on Baumeister and Hamilton (2019). Four structural drivers of oil prices are identified, including a global activity shock, an oil supply shock, an oil consumption demand shock, and an oil inventory demand shock.

[2] Känzig (2021) identifies an oil supply news shock by exploiting the institutional features of the Organization of the Petroleum-Exporting Countries (OPEC) and information contained in high-frequency data.

[3] Shock series are computed based on Kilian and Murphy (2014). Three structural shocks are identified: an oil supply shock, an aggregate demand shock, and an oil speculative demand shock.

Online Annex Table 2.1.1 *(continued)*

[4] Baumeister and Hamilton (2023) identifies oil demand and supply shocks through granular instrumental variables approach.

[5] To fill missing data for Pakistan, the Call Money Rate is used from Haver Analytics. Japan's policy rate is Basic Loan Rate, formerly the Official Discount Rate from Haver. Indonesia's data before 2005 are filled with the policy rate from IMF International Financial Statistics (IFS). Thailand's data after 1999 are emerging markets' policy rate from Haver. All rates are winsorized above the 95th percentile and below the 5th percentile.

[6] To fill missing data for Malaysia, Peru, and the Philippines, data from Haver Analytics are used. Domestic saving is calculated as the sum of the current account balance and domestic investment.

[7] Terms of trade are calculated by export price index over import price index. Data or Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Mexico, The Netherlands, New Zealand, Norway, Pakistan, Peru, the Philippines, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, South Africa, Spain, Sweden, Switzerland, Thailand, Türkiye, the United Kingdom, and the United States are from Global Financial Data. Data for Colombia and India are from LSEG Eikon. Morocco's price indices are from Eurostat (unit value index from EA19 trade). Romania's price indices are from National Institute of Statistics via LSEG Datastream.

[8] Private inflows are the sum of portfolio debt and other investment debt inflow of banks (except central bank) and corporates; public inflows are the sum of portfolio debt inflow and other investment debt inflow of general government and the central bank.

[9] Global balances are calculated as the absolute sum of current account balance divided by nominal GDP of all sample countries.

[10] Monthly data are aggregated to quarterly data by taking the maximum values of the fine classification of the de facto exchange rate arrangement from Ilzetzki, Reinhart, and Rogoff (2019)

[11] Investment in energy-exporting countries is measured as the share a country's foreign direct investment in Saudi Arabia among its total foreign direct investment.

[12] External position is measured by the External Balance Assessment staff current account gap.

[13] Energy dependence is measured as the absolute value of a country's energy trade balance. A higher value indicates a higher dependence on energy imports.

Online Annex 2.2. Empirical Framework and Data Sample

Instrumental Variables Local Projections and Unit Effect Normalization

This chapter estimates impulse responses of the structural shocks identified from the vector auto regression (VAR) for the global oil market in Baumeister and Hamilton (2019). To facilitate the interpretation of our results and the policy discussion, the shocks are scaled to increase real energy price by 10 percent on impact. This unit effect normalization is implemented through the instrumental variables local projections (LP-IV) approach following Stock and Watson (2018), where the macroeconomic variables are regressed on energy prices, being instrumented by the structural shocks that meet relevance and exogeneity requirements for estimation.[2]

Panel Local Projections

To estimate the effects of oil price shocks on energy exporter and importers, the analysis employs the LP-IV regressions approach (Jordà 2005; Stock and Watson 2018). The estimation equation is specified as follows,

$$y_{i,t+h} - y_{i,t-1} = \mu_{i,h} + \beta_h \Delta p_{i,t} + \sum_{l=1}^{4} \delta_{h,l}\, w_{i,t-l} + \sum_{l=0}^{1} \theta_{h,l} s_{i,t-l} + \epsilon_{i,h,t} \quad (1)$$

where the dependent variable, $y_{i,t+h} - y_{i,t-1}$, is the cumulative change in the real sector or external sector variables of interest over the $t-1$ to $t+h$ horizon. $\mu_{i,h}$ is the country fixed effect. $\Delta p_{i,t}$ is the change in energy price and is instrumented with exogeneous oil supply, global activity, oil consumption demand or oil inventory demand shocks identified following the methodology from Baumeister and Hamilton (2019). $w_{i,t-l}$ contains the lagged values of the left-hand side variable and the instrument (exogeneous shock) up to four lags. $s_{i,t-l}$ is the remaining shock series from the Baumeister and Hamilton (2019) VAR estimation.

The regression is estimated using quarterly data from 1996:Q1 to 2023:Q2 for a group of energy exporters and importers. In total, 44 countries are covered in the analysis, including 11 exporters and 33 importers (see Online Annex Table 2.4.1 for a detailed list of countries included in the analysis). A country is classified as a net energy exporter (importer) if its median net energy export share over the sample period is above (below) zero. The regression is estimated using data for importers or exporters.

Time Series Local Projections

A time series LP-IV is estimated to examine the impact of the four structural shocks identified from Baumeister and Hamilton (2019) on energy price, oil production and global industrial production. The regression is specified as follows:

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h \Delta p_t + \sum_{l=1}^{4} \delta_{h,l}\, w_{t-l} + \sum_{l=0}^{1} \theta_{h,l} s_{t-l} + \epsilon_{h,t} \quad (2)$$

where $y_{t+h} - y_{t-1}$ represents the cumulative change in oil production or global industrial production over the $t-1$ to $t+h$ horizon. The specification follows the same form as equation (1), without country fixed effects.

[2] The same normalized impulse responses can be obtained by taking the ratio of the coefficients from two sets of LP regressions that regress a macro variable and the energy price on structural shocks, but this procedure does not (directly) provide an adequate confidence interval.

Rolling Window Time Series Local Projections

To assess the changing relationships between the US dollars and oil prices over time, the rolling window time series LP-IV is estimated.

$$y_{t+h} - y_{t-1} = \alpha_h^r + \beta_h^r \Delta p_t + \sum_{l=1}^{4} \delta_{h,l}^r w_{t-l} + \sum_{l=0}^{1} \theta_{h,l}^r s_{t-l} + \epsilon_{h,t} \quad (3)$$

where α_h^r, β_h^r, $\delta_{h,l}^r$, and $\theta_{h,l}^r$ are the coefficients estimated in the *r*th window, specifically, the rolling regressions estimate model parameters using a fixed window of subsample rolling through the entire sample period. In this analysis, the model is estimated at monthly frequency with a 36-month window over the sample period from January 1996 to May 2023. Additionally, 42-month and 48-month windows are used as robustness checks.

State-Dependent Panel Local Projections

To examine the impact of negative oil supply shocks, which increase real energy prices, on energy importers under different global financial conditions, country characteristics, and policy settings, we adopt a state-dependent specification following Ramey and Zubairy (2018) and Jordà (2023). Depending on whether the state variable is continuous or binary, we estimate state-dependent responses either by dividing the entire sample into two corresponding subgroups or by interacting energy price changes with the continuous variable of interest.

If the state variable is binary, the estimation equation is specified as follows,

$$\begin{aligned} y_{i,t+h} - y_{i,t-1} = {} & I_{i,t-1}\left(\mu_{i,h} + \beta_h \Delta p_{i,t} + \sum_{l=1}^{4} \delta_{h,l} w_{i,t-l} + \sum_{l=0}^{1} \theta_{h,l} s_{i,t-l}\right) \\ & + \left(1 - I_{i,t-1}\right)\left(\mu'_{i,h} + \beta'_h \Delta p_{i,t} + \sum_{l=1}^{4} \delta'_{h,l} w_{i,t-l} + \sum_{l=0}^{1} \theta'_{h,l} s_{i,t-l}\right) + \epsilon_{i,h,t} \quad (4) \end{aligned}$$

where the state variable $I_{i,t-1}$ is an indicator of the predetermined country characteristics or policies; coefficient β_h captures the impacts of negative oil supply shock that increase real energy prices by 10 percent on impact when state variable $I_{i,t-1} = 1$; and β'_h captures the impacts of the oil supply shocks when state variable $I_{i,t-1} = 0$

If the state variable is continuous, the estimation equation is specified as follows:

$$\begin{aligned} y_{i,t+h} - y_{i,t-1} = {} & \left(\mu_{i,h} + \beta_h \Delta z_{i,t} + \sum_{l=1}^{4} \delta_{h,l} w_{i,t-l} + \sum_{l=0}^{1} \theta_{h,l} s_{i,t-l}\right) \\ & + V_{i,t-1}\left(\mu'_{i,h} + \beta'_h \Delta z_{i,t} + \sum_{l=1}^{4} \delta'_{h,l} w_{i,t-l} + \sum_{l=0}^{1} \theta'_{h,l} s_{i,t-l}\right) + \epsilon_{i,h,t} \quad (5) \end{aligned}$$

where $V_{i,t-1}$ is the state variable, and the term $\beta_h + \beta'_h V_{i,t-1}$ captures the impact of negative oil supply shocks that increases real energy prices. In the analysis, the impacts of negative oil supply shocks are evaluated with the state variable at its 25th and 75th percentiles.

Online Annex 2.3. COVID-19 Adjustment

The unprecedented volatility in macroeconomic variables caused by the COVID-19 pandemic creates a challenge for standard time-series models' estimation. To account for this, this chapter conducts COVID-19 adjustments for various macroeconomic variables, including savings, investments, and imports and exports of goods and services, as well as real GDP. The analysis uses a simplified procedure of Lenza and Primiceri (2022) proposed by Hamilton (2022), whereby one treats the COVID-19 period as a separate regime that features a larger variance. Data in different regimes are then weighted by the inverse of variance; thus, observations during the COVID-19 periods are associated with lower weights in the estimation.

This methodology is robust to alternative approaches, such as the one proposed by Ng (2021), which models the impact of COVID-19 on economic variables as linear functions of direct COVID-19 indicators such as hospitalizations, positive cases, or deaths, aiming to "decovidize" the data.

Online Annex 2.4. Robustness Check on Country Grouping

The baseline LP-IV estimation categorizes countries as energy importers or exporters based on whether their median energy trade balance in the sample period is below or above zero. Online Annex Table 2.4.1 provides a summary of the median value of their net energy trade balances for countries in our sample. Notably, there is a larger variation in the median net energy trade balances among the energy exporters, with an average of 15.8 percent, while the median is 5.8 percent. For instance, Saudi Arabia, the largest energy exporter, boasts a 58 percent net energy export share of merchandise trade, followed by Russia with 38 percent and Norway with 36 percent. The smallest exporter is Denmark, with a mere 0.1 percent net energy export share. There is less variation in net energy trade shares observed among energy importers, with an average share of about −4.7 percent and a median of −3.9 percent.

Online Annex Table 2.4.1. Median Net Energy Trade Share in Total Merchandise Trade of the Country

(Percent)

Energy Exporters		Energy Importers			
Saudi Arabia	58.4	Pakistan	-14.4	South Africa	-3.5
Russia	37.7	India	-13.4	Poland	-3.4
Norway	36.5	Türkiye	-9.4	Brazil	-3.2
Colombia	17.2	Japan	-9.2	Germany	-3.0
Australia	5.9	Greece	-7.6	Austria	-2.9
Canada	5.8	Korea	-7.4	Czech Republic	-2.7
Indonesia	5.3	Chile	-7.0	Peru	-2.6
Mexico	2.7	Philippines	-5.9	Romania	-2.4
Malaysia	2.6	Israel	-5.5	Hungary	-2.4
Argentina	1.1	Thailand	-5.5	Finland	-2.4
Denmark	0.1	United States	-5.2	Sweden	-2.3
		Spain	-4.8	Belgium	-2.2
		New Zealand	-4.5	Ireland	-1.8
		France	-4.4	Switzerland	-1.7
		Portugal	-4.2	The Netherlands	-1.4
		Italy	-4.0	United Kingdom	-1.3
		China	-3.9		
Mean	15.8		-4.7		
Median	5.8		-3.9		

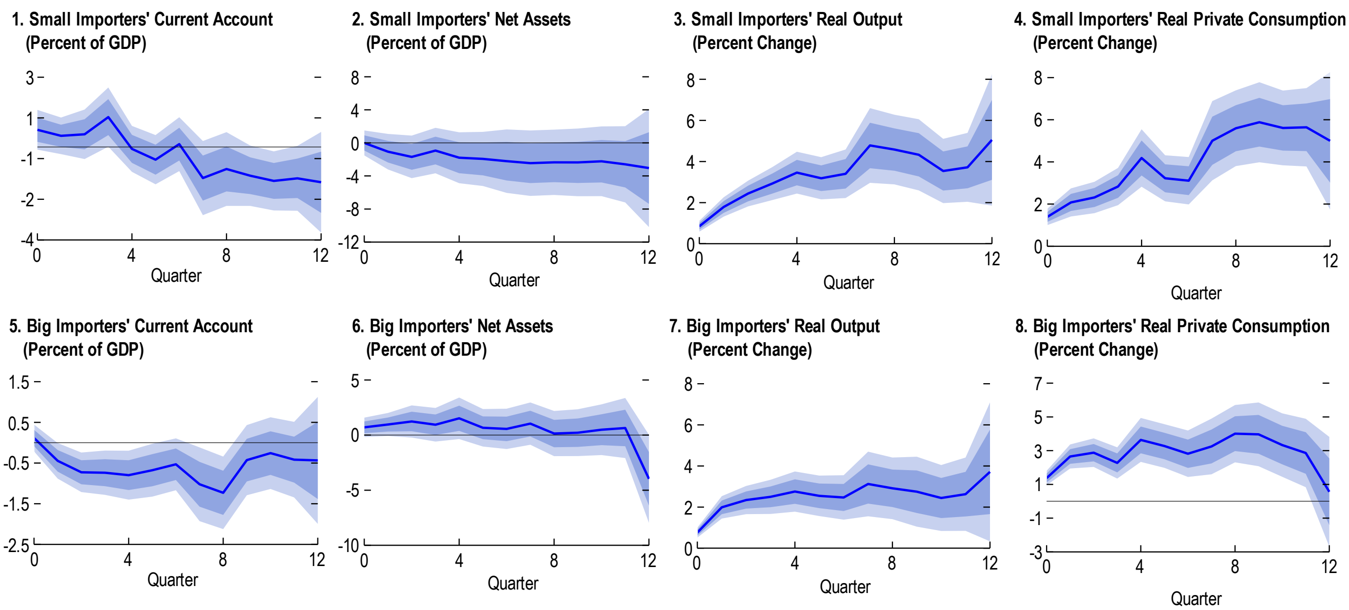
Sources: United Nations Statistics Division, UN Comtrade; IMF staff calculations.

Note: The table computes the median net energy trade share in total merchandise trade for each country in the sample period between 1996:Q1 and 2023:Q2.

One concern with using zero as the threshold for grouping countries into importers and exporters is that the results could be driven by countries with large exposure to energy price swings. To address this, the analysis re-estimates the baseline regression using a sample that consists of large (top 25th percentile) or small (bottom 25th percentile) net energy importers. The findings reveal larger (smaller) responses in terms of current account, consumption, and output when compared with the results estimated using a sample with all importers. Nevertheless, the impulse responses remain statistically significant for the sample of small importers.

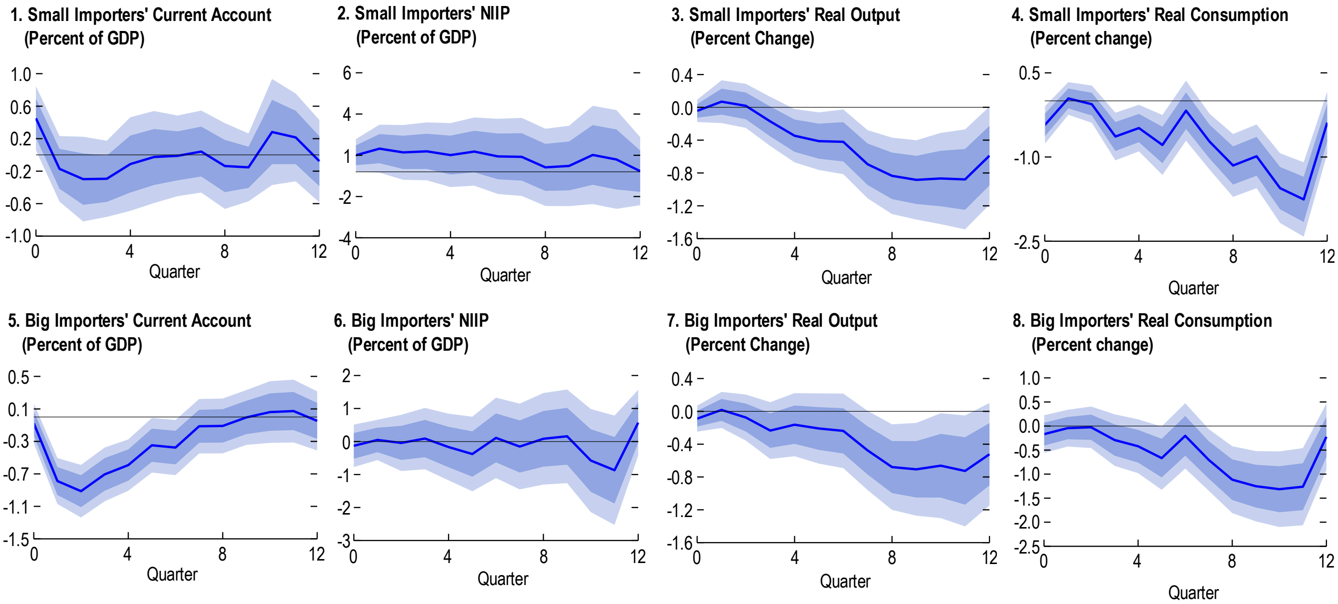
Another concern is that the impact on importers may not be linear with respect to their net energy import share. To address this, the annex compares the impulse responses from the state-dependent local projection regression using countries' net energy import shares as the state variable (Figure 2.6) with the impulse responses estimated using only a sample of small (bottom 25 percentile of the importers) or large energy importers (top 25th percentile of the importers) (Online Annex Figure 2.4.2). The results show that the estimated impact of a negative oil supply shock on consumption, output, and current account is similar between the state-dependent approach and the split sample approach. Thus, the impact of a negative oil supply shock on importers is broadly proportional to importers' net energy imports.

Online Annex Figure 2.4.1. Robustness Check: Effects of Global Activity Shocks on Small and Big Importers



Sources: Baumeister and Hamilton (2019) and IMF staff calculations.
Note: Global activity shocks are identified through the approach outlined by Baumeister and Hamilton (2019). Small importers and big importers refer to the bottom and top 25 percentiles, respectively. Impulse responses show the effects of a global activity shock that increases real energy price by 10 percent on impact with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the small importers, while panels 5–8 illustrate the impulse responses of the big importers.

Online Annex Figure 2.4.2. Robustness Check: Effects of Oil Supply Shocks on Small and Big Importers



Sources: Baumeister and Hamilton (2019) and IMF staff calculations.
Notes: Oil supply shocks are identified through the approach outlined by Baumeister and Hamilton (2019). Small importers and big importers refer to the bottom and top 25 percentiles, respectively. Impulse responses show the effects of an oil supply shock that increases real energy price by 10 percent on impact with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the small importers, while panels 5–8 illustrate the impulse responses of the big importers. NIIP = net international investment position.

Online Annex 2.5. Results on Other Shock Series from Baumeister and Hamilton (2019)

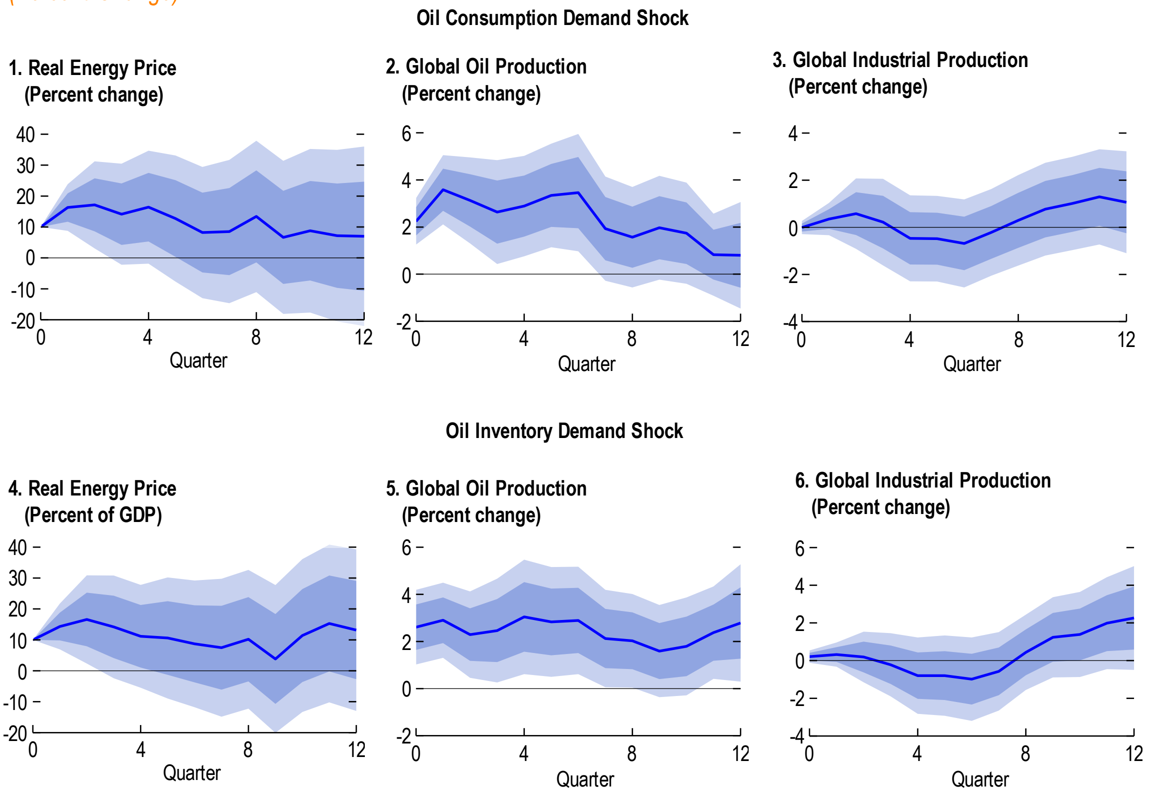
Following Baumeister and Hamilton (2019), four shock series are identified as the drivers of oil price swings: oil supply shocks, global activity shocks, oil consumption demand shocks, and oil inventory demand shocks. The main chapter primarily examines the effects of oil supply and global activity shocks on both importers and exporters. This annex documents the effects of the remaining two shocks from Baumeister and Hamilton (2019): the oil consumption demand and oil inventory demand shocks.

Impact on Oil Production and Global Industrial Production

Online Annex Figure 2.5.1 explores the impact of positive oil consumption demand and oil inventory demand shocks (that increase real energy prices) on oil production and global industrial production.

Online Annex Figure 2.5.1. Additional Results: Impacts on Oil Production and Global Industrial Production

(Percent Change)

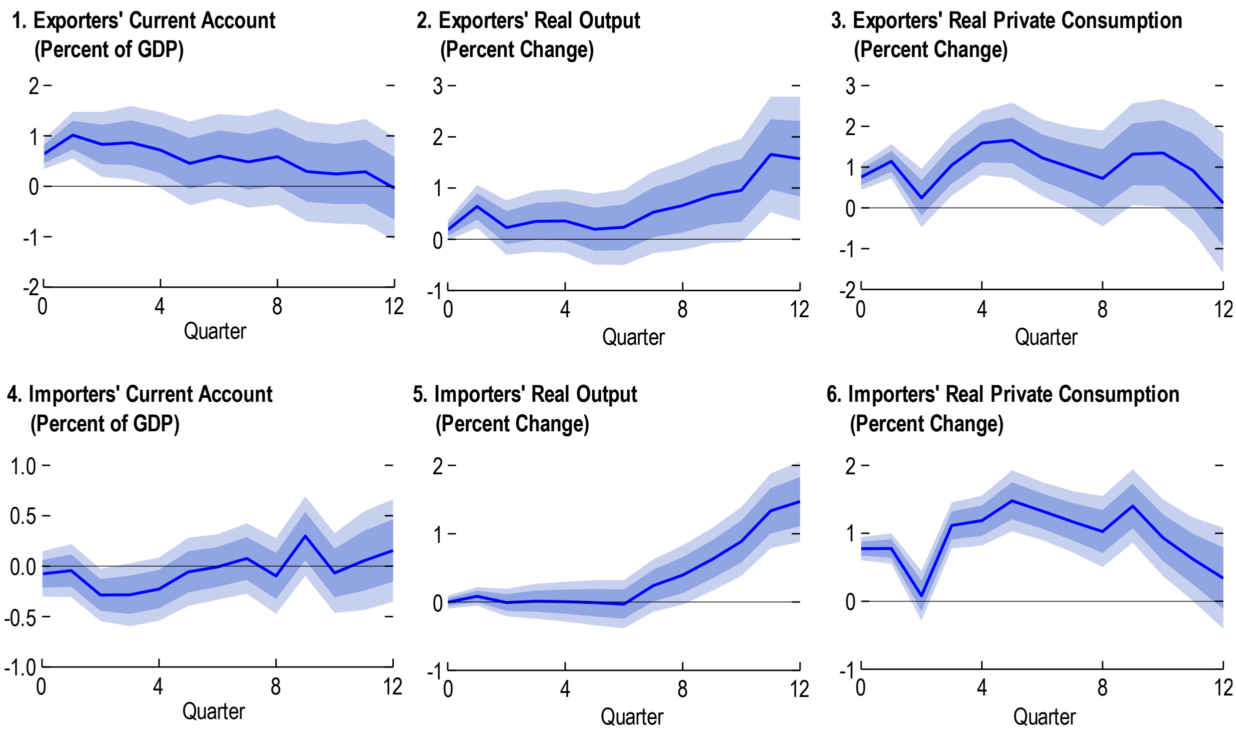


Sources: Baumeister and Hamilton (2019) and IMF staff calculations.
Note: Oil consumption and inventory demand shocks are identified through the approach outlined by Baumeister and Hamilton (2019). Impulse responses show the effects of an oil consumption or inventory demand shock, which increases real energy price by 10 percent on impact, on real energy price, oil production and global industrial production with 68 and 90 percent confidence intervals.

Impact on Energy Importers and Exporters

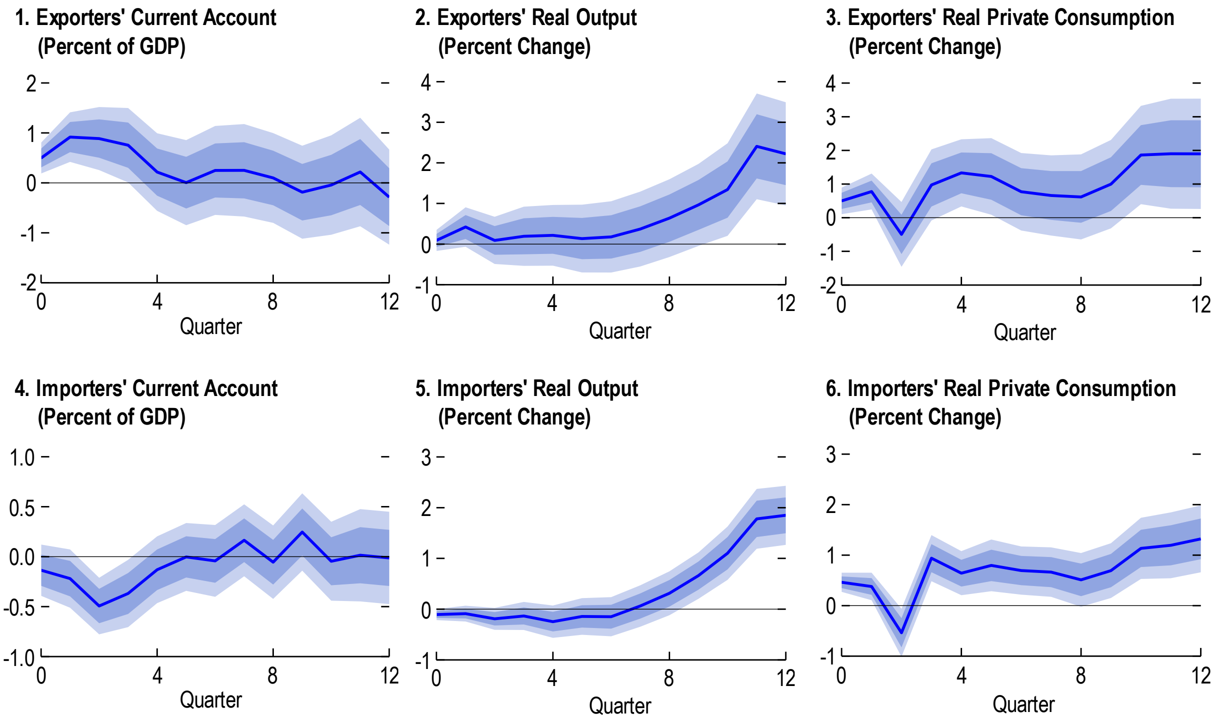
Online Annex Figures 2.5.2 and 2.5.3 analyze the impacts of oil consumption demand and oil inventory demand shocks on exporters and importers, respectively. The impulse responses of current account, real GDP, and real private consumption mirror those observed with global activity shocks, albeit with approximately half the magnitude.

Online Annex Figure 2.5.2. Additional Results: Effects of Oil Consumption Demand Shocks on Energy Exporters and Importers



Sources: Baumeister and Hamilton (2019) and IMF staff calculations.
Note: Oil consumption shocks are identified through the approach outlined by Baumeister and Hamilton (2019). Impulse responses show the effects of an oil consumption demand shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–3 depict the impulse responses of the exporters, while panels 4–6 illustrate the impulse responses of the importers.

Online Annex Figure 2.5.3. Additional Results: Effects of Oil Inventory Demand Shocks on Energy Exporters and Importers



Sources: Baumeister and Hamilton (2019) and IMF staff calculations.
Note: Oil inventory demand shocks are identified through the approach outlined by Baumeister and Hamilton (2019). Impulse responses show the effects of an oil inventory demand shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–3 depict the impulse responses of the exporters, while panels 4–6 illustrate the impulse responses of the importers.

Online Annex 2.6. Robustness Check on Alternative Approaches to Shock Identification

The chapter uses the methodology from Baumeister and Hamilton (2019) to compute the drivers of oil prices in its baseline, given that it's the most recent and comprehensive global oil market model documented in the literature. In addition, the chapter conducts robustness checks using global activity and oil supply shocks derived from other established approaches, including Baumeister and Hamilton (2023), Känzig (2021), and an updated identification method described by Zhou (2020) following Kilian and Murphy (2014). Online Annex Table 2.6.1 summarizes the correlations between these shocks identified from different approaches.

Online Annex Table 2.6.1. Correlations between Quarterly Aggregated Shock Series Identified through Different Approaches

	Oil supply BH'19	Global economic activity BH'19	Oil supply BH'23	Oil supply upd. KM'14	Global economic activity upd. KM'14	Oil supply news Känzig '21
Oil supply BH'19	1					
Global economic activity BH'19	0.21	1				
Oil supply BH'23	0.64	-0.10	1			
Oil supply upd. KM'14	0.54	-0.22	0.51	1		
Global economic activity upd. KM'14	-0.40	0.78	0.19	-0.10	1	
Oil supply news Kaenzig '21	0.71	0.01	0.32	0.37	0.24	1

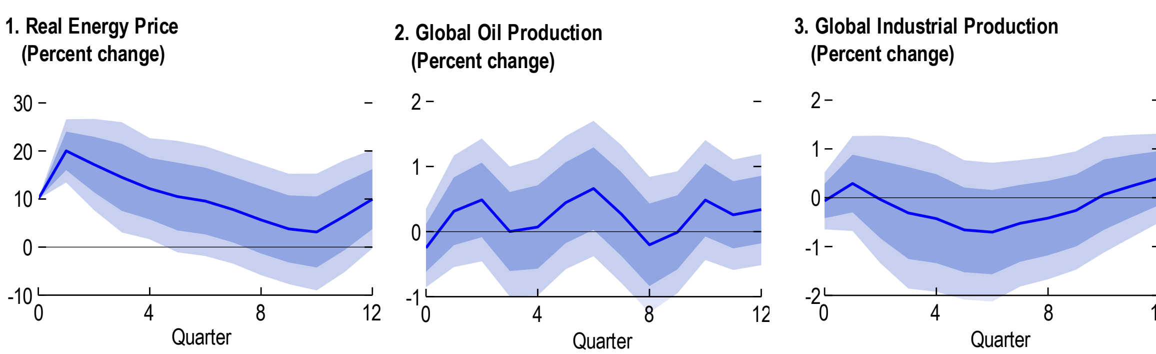
Note: The sample runs from 1961:Q1 to 2023:Q2, except the BH'23 shock runs until 2020:Q1. upd. KM'14 (updated Kilian and Murphy, 2014) follows the methodology in Zhou (2020) and uses the global industrial production index instead of the global real economic activity index. BH'19 and BH'23 are Baumeister and Hamilton (2019, 2023). Känzig '21 is Känzig (2021). All shocks are normalized to be associated with an increase in the real energy price.

Känzig (2021)

By leveraging institutional features of OPEC and information in high-frequency data, Känzig (2021) identifies an oil supply news shock. Robustness checks are performed by employing this novel oil supply news shock as an alternative to the oil supply shock identified in Baumeister and Hamilton (2019). The analysis reveals consistent impulse response dynamics across the external and real variables, such as current account, net international investment position, real GDP, and real consumption (Online Annex Figure 2.6.2).

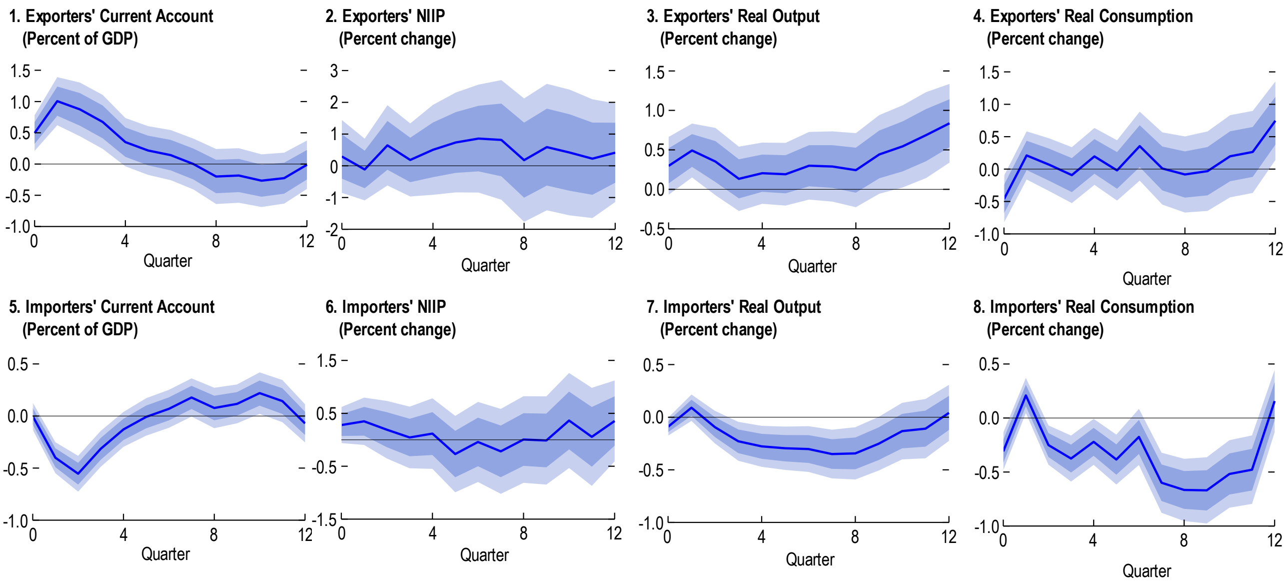
Online Annex Figure 2.6.1. Robustness Check: Effects of Känzig Oil Supply Shocks on Oil Production and Global Industrial Production

(Percent Change)



Sources: Känzig (2021) and IMF staff calculations.
Note: Oil supply shocks are identified by Känzig (2021) approach. Impulse responses show the effects of a Känzig oil supply shock, which increases real energy price by 10 percent on impact, on real energy price, oil production and global industrial production with 68 and 90 percent confidence intervals.

Online Annex Figure 2.6.2. Robustness Check: Effects of Känzig Oil Supply Shocks on Energy Exporters and Importers



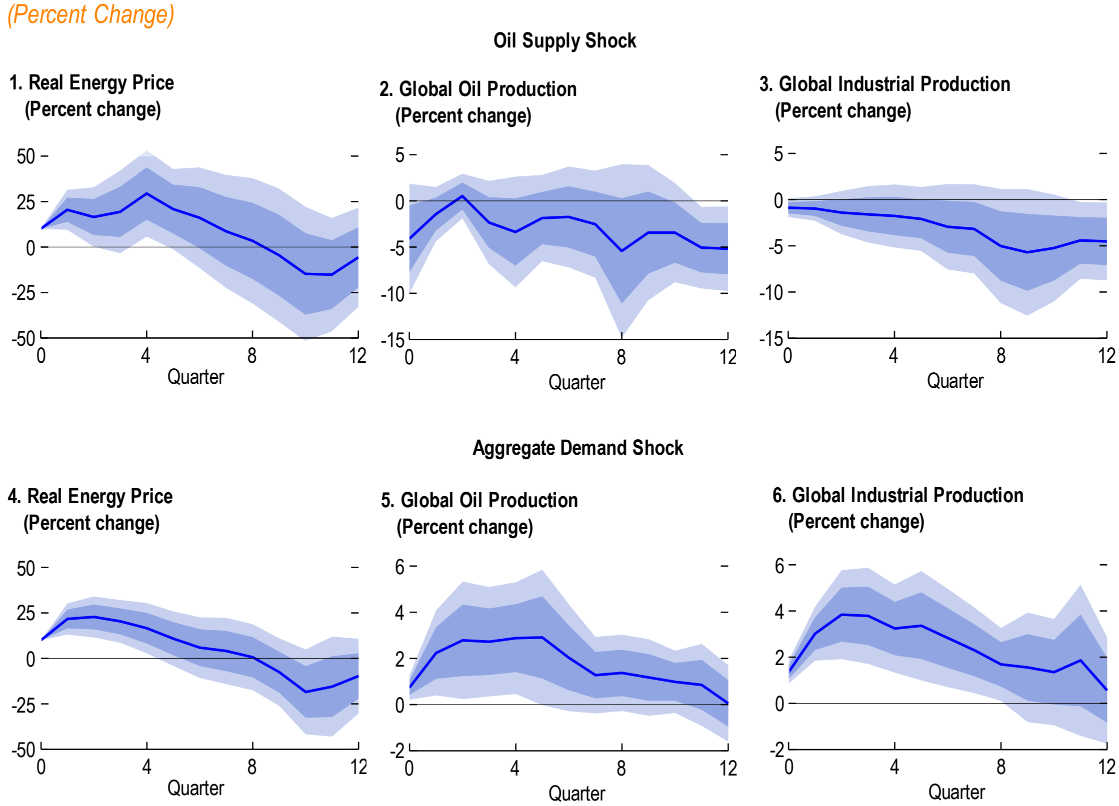
Sources: Känzig (2021) and IMF staff calculations.
Note: Oil supply news shocks are identified by Känzig (2021). Impulse responses show the effects of a Känzig oil supply shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the exporters, while panels 5–8 illustrate the impulse responses of the importers. NIIP = net international investment position.

Kilian and Murphy (2014)

The analysis adopts an updated methodology based on Kilian and Murphy (2014), as outlined in Zhou (2020), to identify the underlying shocks driving the oil price fluctuations. This method uses the global industrial production index, instead of the global real economic activity index. From this approach, three distinct shocks are identified: an oil supply shock, an aggregate demand shock, and an oil speculative demand shock. This subsection presents the results using oil supply and demand shocks from the Kilian and Murphy approach as an alternative for the oil supply and global activities shocks from Baumeister and Hamilton (2019). Online Annex Figures 2.6.3, 2.6.4, and 2.6.5 illustrate the impulse responses to the aggregate demand and oil supply shocks for exporters and importers, respectively. The analysis obtains similar impulse responses as those observed with the oil supply and global activity shocks of Baumeister and Hamilton (2019) in our baseline estimations.

Online Annex Figure 2.6.3. Robustness Check: Effects of Oil Supply Shocks and Aggregate Demand Shocks Identified via the Kilian and Murphy Approach on Oil Production and Global Industrial Production

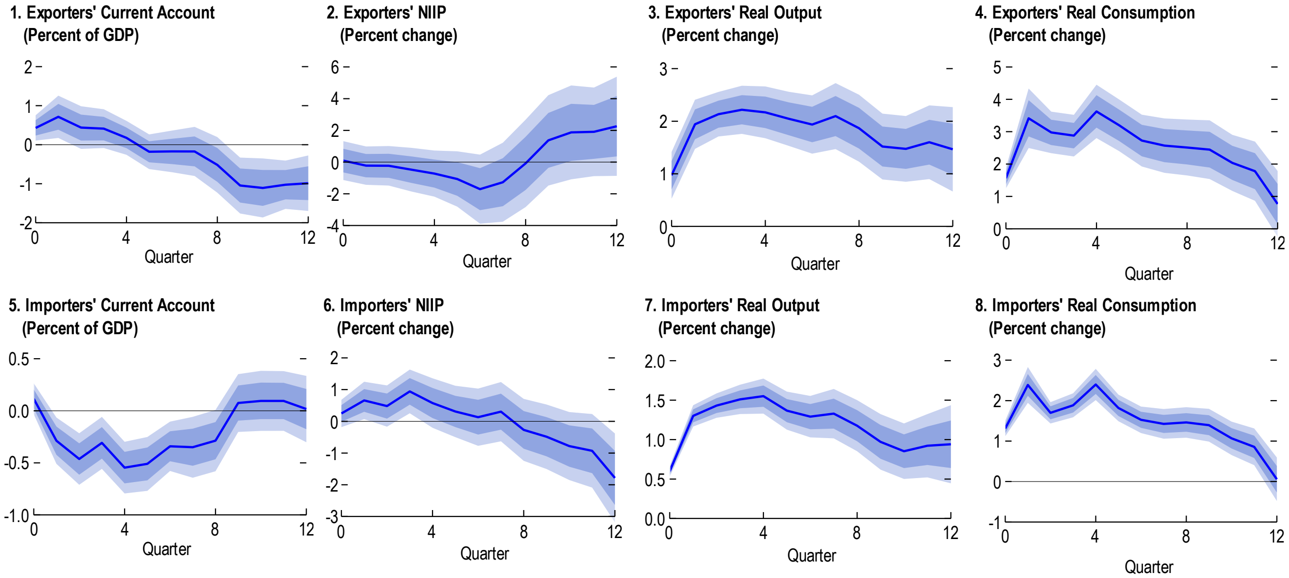
(Percent Change)



Sources: Kilian and Murphy (2014) and IMF staff calculations.

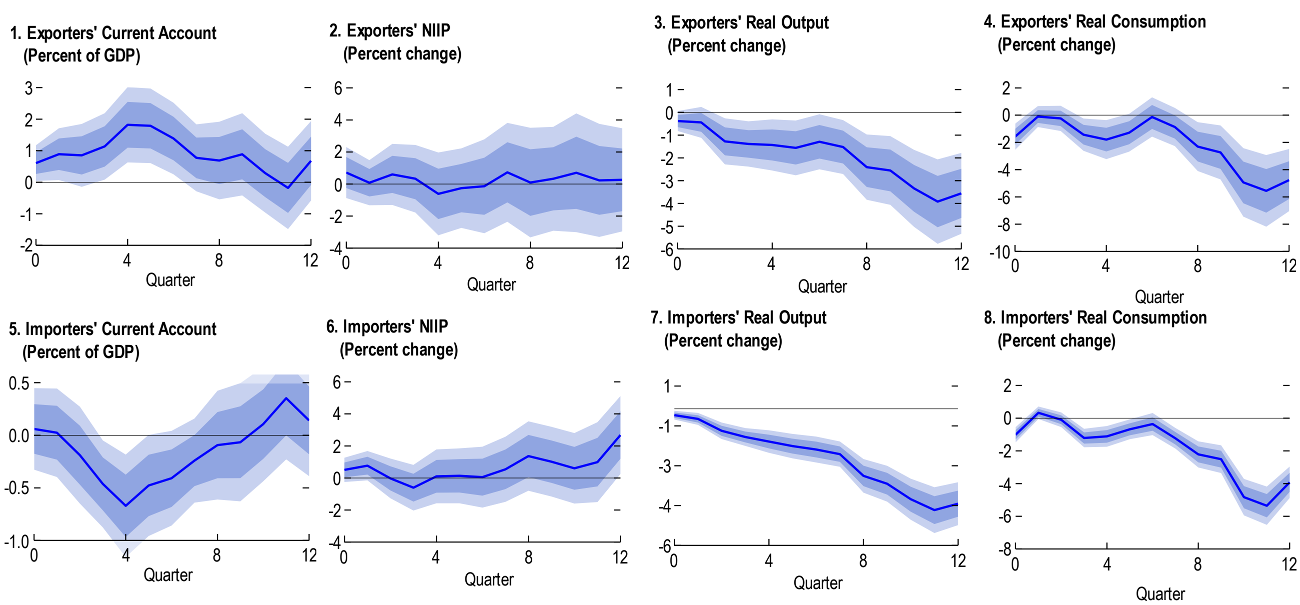
Note: Oil supply and aggregate demand shocks are identified through the approach outlined by Kilian and Murphy (2014). Impulse responses show the effects of an oil supply or an aggregate demand shock identified via the Kilian and Murphy approach, which increases real energy price by 10 percent on impact, on real energy price, oil production, and global industrial production with 68 and 90 percent confidence intervals.

Online Annex Figure 2.6.4. Robustness Check: Effects of Aggregate Demand Shocks Identified via the Kilian and Murphy Approach on Energy Exporters and Importers



Sources: Kilian and Murphy (2014) and IMF staff calculations.
Note: Aggregate demand shocks are identified using the updated Kilian and Murphy (2014) approach outlined by Zhou (2020). Impulse responses show the effects of an aggregate demand shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the exporters, while panels 5–8 illustrate the impulse responses of the importers. NIIP = net international investment position.

Online Annex Figure 2.6.5. Robustness Check: Effects of Oil Supply Shocks Identified via Kilian and Murphy Approach on Energy Exporters and Importers

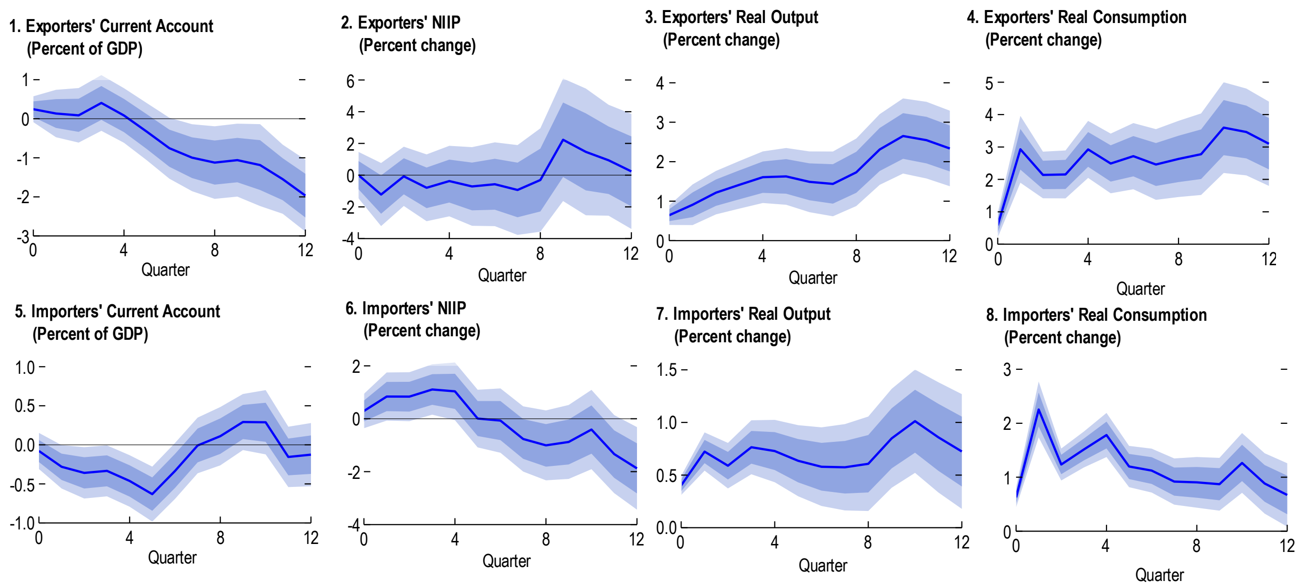


Sources: Kilian and Murphy (2014) and IMF staff calculations.
Note: Oil supply shocks are identified using updated Kilian and Murphy (2014) approach outlined by Zhou (2020). Impulse responses show the effects of an oil supply shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the exporters, while panels 5–8 illustrate the impulse responses of the importers. NIIP = net international investment position.

Baumeister and Hamilton (2023)

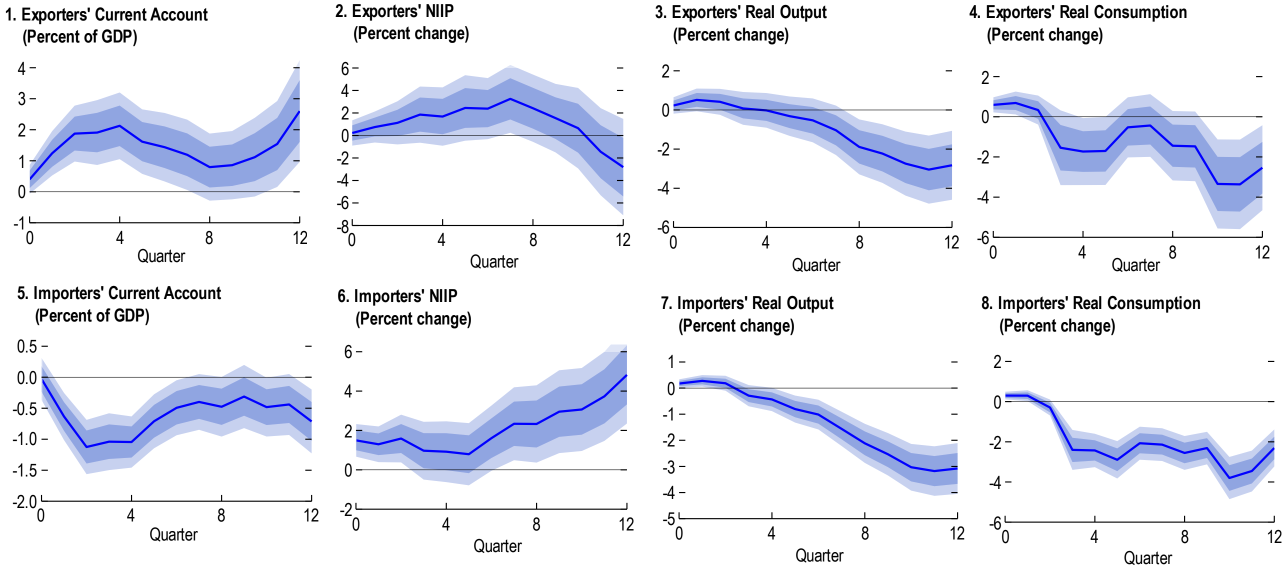
The more recent granular instrumental variables approach presents a novel method for identifying both supply and demand elasticities by leveraging idiosyncratic shocks to either supply or demand. This approach capitalizes on the fact that a few large firms, industries, or countries wield considerable influence over economic activity. Consequently, the idiosyncratic shocks originating from these major players can serve as valid and potent instruments. Gabaix and Koijen (2020) construct a granular instrument based on the disparity between the share-weighted average and arithmetic average of a set of oil-producing countries to estimate supply elasticities. Baumeister and Hamilton (2023) further adopt a broader systemwide approach, which models how the actions of individual units interact to produce aggregate outcomes. In their framework, full-information maximum likelihood estimation of the general system allows for the simultaneous estimation of both local and aggregate structural magnitudes. As a robustness check, the analysis uses the oil demand and supply shocks identified through Baumeister and Hamilton (2023). The impulse responses to the oil supply and demand shocks of Baumeister and Hamilton (2023) are consistent with those of Baumeister and Hamilton (2019).

Online Annex Figure 2.6.6. Robustness Check: Effects of Oil Demand Shocks Identified via Granular IV Approach on Energy Exporters and Importers



Sources: Baumeister and Hamilton (2023) and IMF staff calculations.
Note: Oil demand shocks are identified through granular instrumental variables approach outlined by Baumeister and Hamilton (2023). Impulse responses show the effects of an oil demand shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the exporters, while panels 5–8 illustrate the impulse responses of the importers. IV = instrumental variable.

Online Annex Figure 2.6.7. Robustness Check: Effects of Oil Supply Shocks Identified via Granular IV Approach on Energy Exporters and Importers



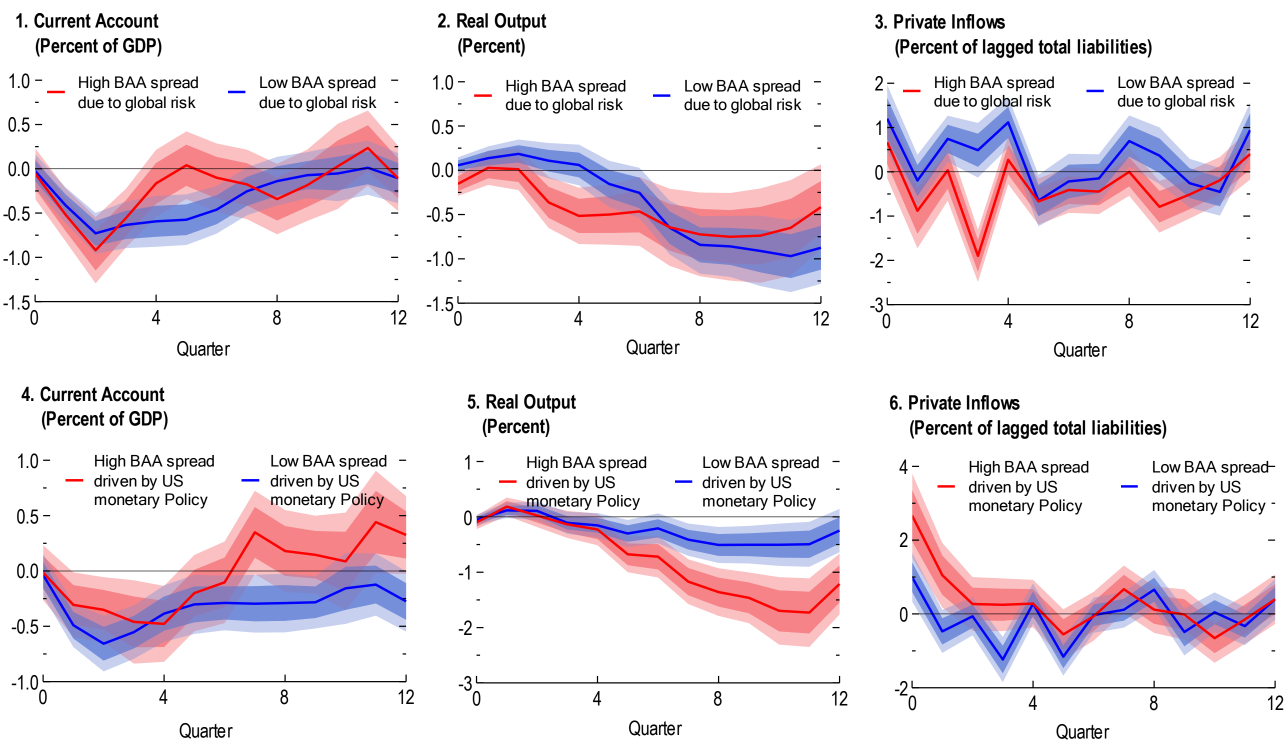
Sources: Baumeister and Hamilton (2023) and IMF staff calculations.
Note: Oil supply shocks are identified through granular instrumental variables approach outlined by Baumeister and Hamilton (2023). Impulse responses show the effects of an oil supply shock, which increases real energy price by 10 percent on impact, on energy exporters and importers with 68 and 90 percent confidence intervals. Panels 1–4 depict the impulse responses of the exporters, while panels 5–8 illustrate the impulse responses of the importers. IV = instrumental variable.

Online Annex 2.7. Global Financial Conditions Decomposition

Following Juvenal and Petrella (2024), this analysis uses BAA spread as an indicator of global financial conditions and it further differentiates between changes in the BAA spread driven by US monetary policy or shifts in global risk appetite. Specially, the BAA spread is decomposed using a regression approach. This involves regressing the BAA spread on US monetary policy shocks obtained from Bu, Rogers and Wu (2021) updated by Ugazio and Xin (2024). The fitted value obtained from the regression represents the portion of the BAA spread that can be attributed to the changes in US monetary policy and the residual from the regression could reflect changes in global risk appetite. Additionally, recognizing that changes in the BAA spread may be influenced by the economic performance of the United States, the analysis excludes the United States from the sample. In both cases, elevated BAA spreads arising from a tighter US monetary policy stance or changes in global risk appetite translate into more stringent financial conditions for importers. This tightening weakens importers' borrowing capacity, evidenced by capital outflows from the private sector. Consequently, it leads to a more substantial decline in real output amid tighter global financial conditions (Online Annex Figure 2.7.1).

However, discernible differences in dynamics emerge. Notably, following a negative oil supply shock that increases real energy price, importers experience an immediate decline in real consumption, investment, and GDP under conditions of low risk appetite. Conversely, when global conditions tighten due to a more stringent US monetary policy, the decline in importers' consumption, investment, and output is more gradual, reflecting a slower transmission of monetary policy.

Online Annex Figure 2.7.1. Additional Results: Effects of Oil Supply Shocks and Global Financial Conditions



Sources: Federal Reserve Bank of St. Louis and IMF staff calculations.
Note: Following Juvenal and Petrella (2024), Moody's seasoned BAA corporate bond yield relative to yield on 10-year treasury constant maturity is used as a measure of global financial conditions. The analysis further differentiates between changes in the BAA spread driven by US monetary policy or shifts in global risk appetite. Impulse responses show the effects of an oil supply shock that increases real energy price by 10 percent on impact with 68 and 90 percent confidence intervals.

Online Annex 2.8. Country Characteristics and Policies

Online Annex Table 2.8.1 presents additional results on the country characteristics and policy variables used in the state-dependent local projections, while Online Annex Table 2.8.2 provides an overview of the correlations among these variables. The correlations between the country characteristics and policy variables are relatively low, suggesting that our state-dependent analysis captures various distinct dimensions of the economy. Additionally, Online Annex Figure 2.8.1 presents the additional results examining the effects of country characteristics and policies in mitigating the negative impacts of oil supply shocks that increase energy prices.

Online Annex Table 2.8.1. Correlations between Country Characteristics and Policy Variables

	Government debt	Energy dependence	Investment in energy-exporting countries	Inflation anchoring	Exchange rate regime	External positions
Government debt	1.00					
Energy dependence	-0.08	1.00				
Investment in energy-exporting countries	-0.13	-0.02	1.00			
Inflation anchoring	-0.02	0.12	-0.10	1.00		
Exchange rate regime	-0.12	0.09	0.22	0.00	1.00	
External positions	0.01	0.14	0.36	0.06	0.01	1.00

Sources: Bems and others (2021); Ilzetzki, Reinhart, and Rogoff (2019); Trade Data Monitor; International Monetary Fund coordinated portfolio investment survey (CPIS), coordinated direct investment survey (CDIS), and Global Data Source (GDS); and IMF staff assessments.

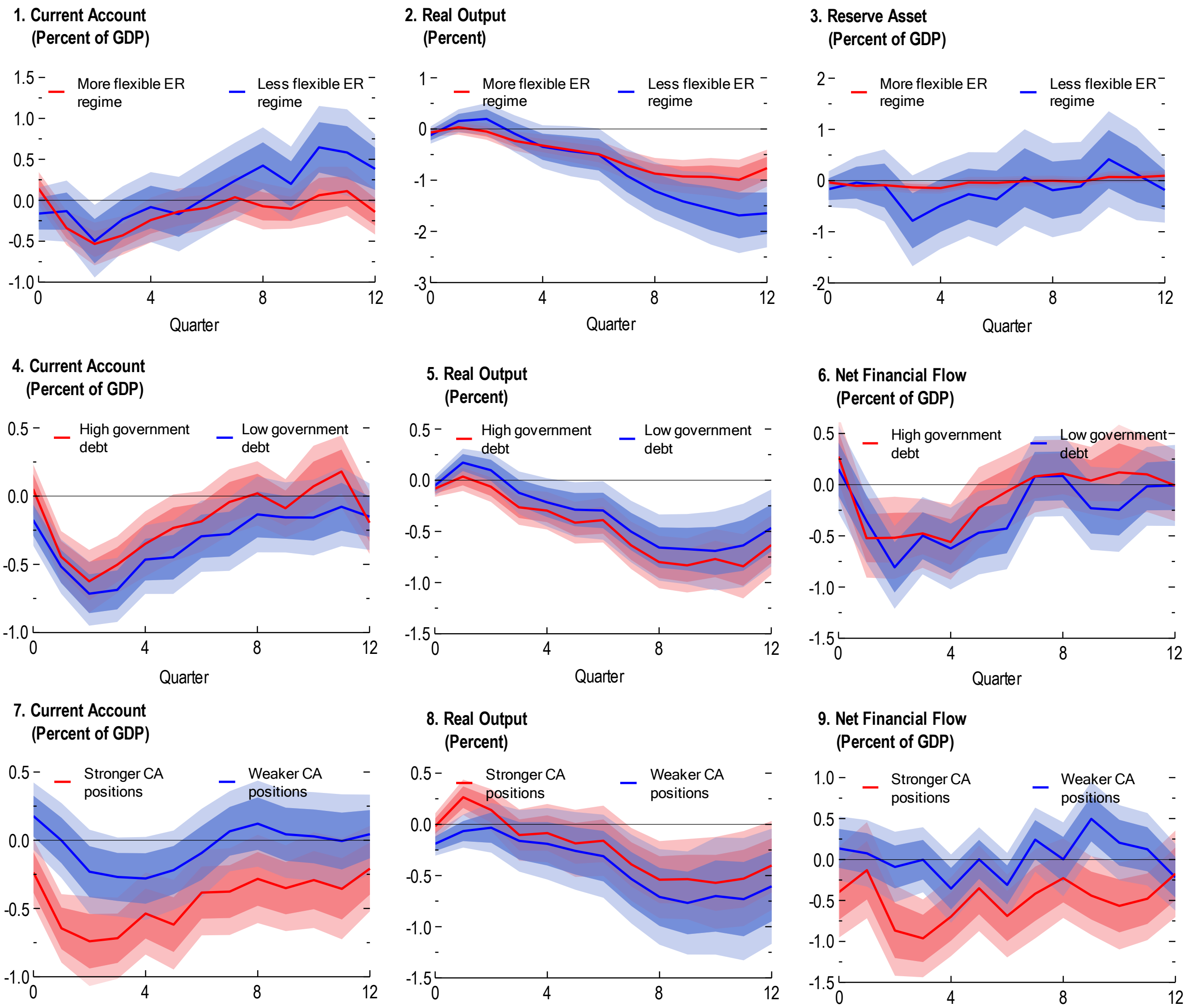
Note: Government debt is calculated as government-debt-to-GDP ratio. Energy dependence is measured as the absolute value of a country's energy trade balance. Investment in energy-exporting countries are measured as the share of a country's foreign direct investment in Saudi Arabia among its total foreign direct investment. External positions are measured by staff current account gap.

Online Annex Table 2.8.2. State Variables and Definition

Measure	Country Characteristics and Policies	Description	Threshold
Binary	Investment in energy-exporting countries	Foreign direct investment in Saudi Arabia	Median
	Exchange rate regime	The fine classification from Ilzetzki, Reinhart, and Rogoff (2019)	Freely floating: 1, 2, 12, 13; other regimes: 3–11
	External positions	IMF staff current accout gap	Strong if current account gap > -1
Continuous	Government debt	Government debt to GDP from IMF Global Data Source (GDS)	Evaluated at 25th and 75th percentiles
	Inflation Anchoring	Monetary policy credibility measures from Bems and others (2021)	Evaluated at 25th and 75th percentiles
	Energy dependence	Country's net energy trade balance as a share of GDP	Evaluated at 25th and 75th percentiles

Sources: Bems and others (2021); Ilzetzki, Reinhart, and Rogoff (2019); Trade Data Monitor; International Monetary Fund coordinated portfolio investment survey (CPIS), coordinated direct investment survey (CDIS), and Global Data Source (GDS); and IMF staff assessments.

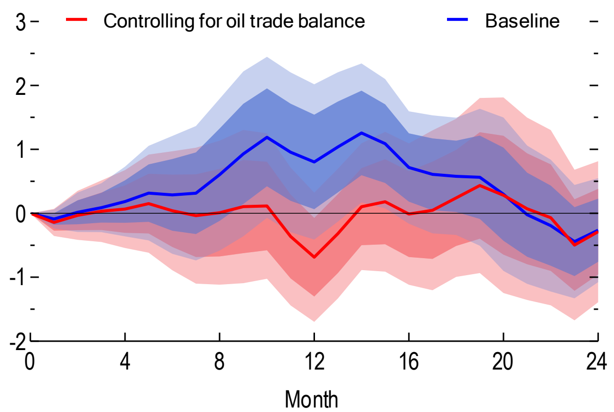
Online Annex Figure 2.8.1. Additional Results: Effects of Oil Supply Shocks and Country Characteristics



Source: IMF staff calculations.
Note: Impulse responses show the effects of an oil supply shock that increases real energy price by 10 percent on impact with 68 and 90 percent confidence intervals. Exchange rate classification follows Ilzetzki, Reinhart, and Rogoff (2019), with countries in refined categories 1, 2, 12, and 13 categorized as having more flexible exchange rate regimes. The impact of an oil supply–driven energy price increase is evaluated based on government-debt-to-GDP ratio at the 75th and 25th percentiles, representing high and low government debt scenarios, respectively. External positions are assessed using the IMF staff current account gap, with a position considered strong if its value is above -1. CA = current account; ER = exchange rate.

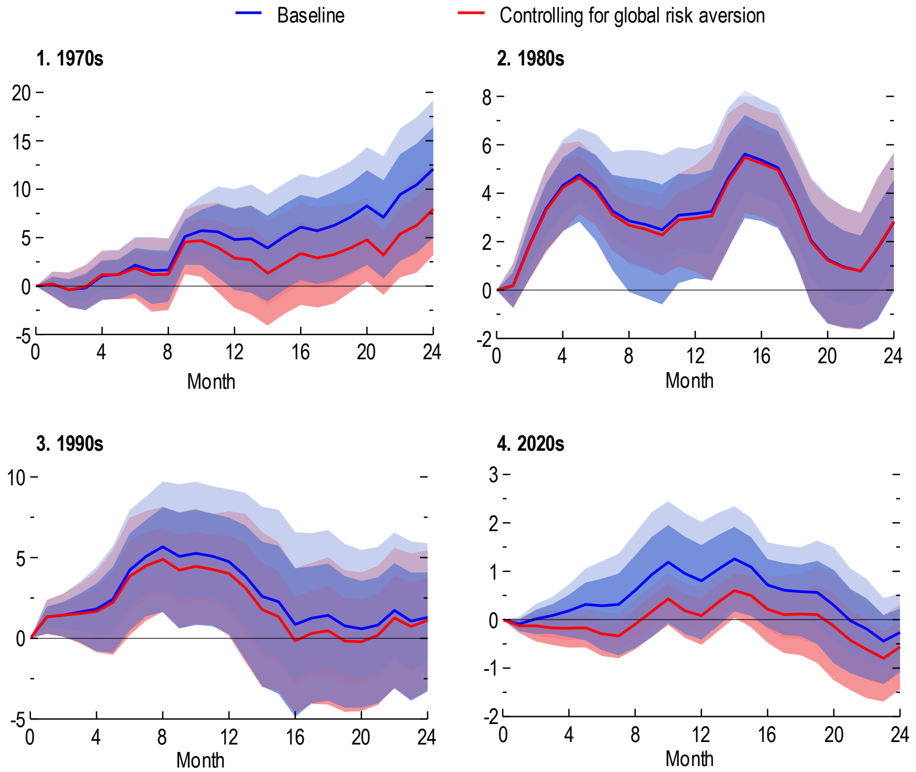
Online Annex 2.9. Oil Price and the US Dollar

Online Annex Figure 2.9.1. The Response of the US Dollar to Oil Supply Shocks When Controlling for the Oil Trade Balance, 2020s
(Percent)



Source: IMF staff calculations.
Note: Impulse responses show the effects of an oil supply shock that increases oil price by 10 percent on impact with 68 and 90 percent confidence intervals. The chart shows the estimated impulse responses using data from 2020:M1 to 2023:M5. Similar impulse responses are observed during the other rolling windows of these positive periods. The blue line shows the impulse responses of the baseline rolling regression and the red line shows the impulse responses when controlling for the oil trade balance.

Online Annex Figure 2.9.2. The Response of the US Dollar to Oil Supply Shocks during Positive Correlation Periods
(Percent)



Sources: Federal Reserve Board; Federal Reserve Bank of St. Louis; Romer and Romer (2004); and Bu, Rogers and Wu (2021).
Note: Impulse responses show a 10 percent increase in oil price driven by an oil supply shock with 68 and 90 percent confidence intervals in the rolling window time series instrumental-variable local projections exercise. The charts show the impulse response during one of the rolling windows in the positive periods of the 1970s, 1980s, 1990s, and 2020s, respectively. Similar impulse responses are observed during the other rolling windows of these positive periods. The blue line shows the impulse responses of the baseline rolling regression, and the red line shows the impulse responses when controlling for global risk aversion measured by the residual obtained by regressing BAA spreads on US monetary policy shocks. In the 1970s and 1980s, BAA spreads are regressed on US monetary policy shocks from Romer and Romer (2004), and in the 1990s and 2020s, BAA spreads are regressed on US monetary policy shocks from Bu, Rogers and Wu (2021) updated by Ugazio and Xin (2024).

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