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The macroeconomic effects of oil price and oil shipping costs shocks: Evidence from a GVAR model☆,☆☆

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ABSTRACT

This paper investigates the role of oil shipping cost shocks in global crude oil and refined petroleum markets and their macroeconomic effects. Using a Global VAR (GVAR) model which includes the Baltic Dirty Tanker Index (BDTI) for crude oil shipping costs and the Baltic Clean Tanker Index (BCTI) for refined petroleum shipping costs, the analysis produces several key findings. Shocks to the cost of shipping petroleum commodities have a particularly severe negative impact on real economic activity and on refined petroleum consumption in most regions, while shocks to the price of crude oil and refined petroleum have inflationary effects, especially in net importing countries of those commodities. The Covid-19 pandemic appears to have disrupted the traditional relationship between commodity prices and shipping costs, with a counterfactual analysis showing that these variables have moved in opposite directions since the pandemic. A second counterfactual scenario implies a high likelihood that Russian oil sanctions increased oil shipping costs. The findings highlight the importance of modelling shipping costs when estimating the macroeconomic effects of oil market shocks.

1. Introduction

Crude oil is undoubtedly one of the most important commodities since it is an essential input into refined petroleum products which provide energy for heating, transportation and industrial production. Crude oil and refined petroleum products are traded globally in large quantities which are primarily transported via oceanic shipping (Shi et al., 2013). Yet much of the empirical literature on global oil markets focuses on prices and quantities, without explicitly considering transportation costs, despite the fact that shipping conditions can change frequently and influence the delivered price of the commodity. Existing studies in the global oil-market literature have generated insights using general equilibrium models (Amiri et al., 2021; Backus & Crucini, 2000; Conrad, 2002), structural VARs (Kilian, 2008, 2009), GVARs (Considine et al., 2022; Mohaddes & Pesaran, 2016), arbitrage and options analysis models with transportation costs (Coleman, 2009; Galay, 2018) and Machine Learning applications (Al-Fattah & Aramco, 2021). The present paper addresses two shortcoming of the previous literature: the limited focus on the relationship between crude and refined products and the exclusion of shipping costs. Specifically, we investigate how shipping costs affect the joint dynamics of crude oil and refined petroleum prices in the global oil system, and how these interactions are passed through to the wider economy.

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Accounting for shipping costs is essential since the global oil market operates as an integrated, but geographically dispersed two-tier system comprising the market for crude oil and for refined petroleum products respectively. Crude oil is produced in exporting countries and demanded primarily by refineries, implying seaborne flows from producing to refining countries. Refined petroleum products (such as gasoline, kerosene and fuel oil) instead are shipped from major refining countries to net importers for final consumption. Because shocks are transmitted across tiers in these interlinked markets, crude oil market dynamics are expected to affect refined petroleum markets. Shipping costs matter at two points in this system; the cost of shipping crude oil should mainly affects the refining or importing countries, while the cost of shipping refined petroleum primarily affects end consumers (Poulakidas & Joutz, 2009).

Shipping costs interact with oil prices through various channels. As the cost of transporting the cargo, i.e. oil and petroleum, shipping costs respond to changes in demand and trade volumes of these commodities (Pouliasis and Bentsos, 2023). At the same time tankers require fuel for transportation which makes oil a direct operating cost of seaborne shipping itself. The precise effect is ambiguous: While higher bunker fuel costs increase operating costs, tankers can also be used as storage units, in which case higher oil prices reduce shipping costs. The latter has been found by Michail and Melas (2020a), who report an initially negative response of the BDTI and BCTI to crude oil price increases which turns positive after a few months. Shipping costs also represent direct input costs for refineries, which can be passed through to final refined petroleum prices. The feedback effects suggest that shipping costs are crucial for understanding the interaction and transmission of shocks between the two markets and the delivered price of crude oil and petroleum.

The present paper tests the wider macroeconomic implications of these feedback effects by estimating a Global Vector Autoregressive (GVAR) model which jointly models the crude oil and refined petroleum markets together with their respective shipping costs. The analysis is conducted from January 2000 to May 2024 for a large set of 34 countries, building on earlier oil-market GVAR applications (Considine et al., 2022; Mohaddes & Pesaran, 2016). We also conduct two counterfactual analyses to assess respectively the impact of the Covid-19 pandemic and of Western sanctions imposed on Russian oil on the joint behaviour of prices and shipping costs in the model.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature; Section 3 discusses the modified GVAR model for the oil markets that includes shipping costs; Section 4 presents the empirical results; Section 5 provides some concluding remarks.

2. Literature review

The macroeconomic effects of oil price shocks have been studied extensively in the economics literature. Pioneering work by Kilian (2009), who estimates a structural VAR model of the global crude oil market, shows that oil price shocks have different macroeconomic effects depending on whether they are demand or supply shocks and highlights the importance of endogenising oil prices in subsequent analysis. This is emphasised by Kilian (2014), who notes that a structural model of the global economy and the global oil market is required to identify correctly the relationship between oil prices and individual economies. While Kilian (2009) incorporates dry cargo freight rates as a proxy for global real economic activity, the structural oil market literature has not explicitly modelled petroleum shipping costs as a separate transmission channel linking oil production and consumption geographically. Our contribution is to treat shipping costs not as a summary indicator of demand conditions, but as an endogenous variable in its own right which both responds to and feeds back into oil price dynamics.

While the evidence concerning crude oil shocks is vast, less is known about shocks stemming from refined petroleum commodities, despite these being frequently consumed by households and firms. Petroleum commodities are also demanded indirectly by consumers who purchase goods and services which are reliant on petroleum commodities, such as flights which require jet fuel or shipped goods which require gasoline or diesel for transportation. Therefore, the prices of these petroleum commodities are more representative of those faced by households and firms than the price of crude oil. In this context it is important to distinguish between the different refined product categories, such as gasoline, distillate fuels, fuel oil and kerosene, which are included in the aggregate price of petroleum commodities. Kilian (2008, 2010) shows that gasoline consumption responds strongly to energy price shocks and develops a joint VAR of the global crude oil and US gasoline markets. However, his analysis is limited to the US and a single refined product, whereas the present study models multiple refined petroleum products at the global level. Subsequent work by Melichar (2016) shows that models incorporating alternative energy price shocks stemming from gasoline, diesel, natural gas and heating oil outperform those including crude oil prices. Kilian and Zhou (2022) show that gasoline price shocks account for 42% of variation in US household inflation expectations. Kilian and Zhou (2023) differentiate between energy categories, such as gasoline, diesel and jet fuel, in a structural VAR model of inflation and conclude that focusing only on gasoline price shocks underestimates the inflationary effects of energy price shocks. While these studies confirm the importance of disaggregating energy products they remain focused on the US. At present, there is only a handful of studies analysing the effects of refined petroleum product price shocks on individual countries other than the US or the global economy as a whole (Baumeister & Hamilton, 2023; Liddle & Huntington, 2020; Olanipekun et al., 2019), leaving unexplored how refined petroleum price shocks interact with crude oil markets and shipping costs in a unified framework.

GVAR models have become very popular recently in the global oil market context owing to their ability to model interdependencies between countries in a multi-country setting. Cashin et al. (2014) estimates a Global Oil VAR to show that supply-driven oil price shocks reduce (increase) economic activity in oil importing (exporting) countries, while demand-driven oil price shocks increase inflation and real output in most countries. Mohaddes and Pesaran (2016, 2017) build on this analysis by developing multi-country GVAR approaches to show that the impact of country-specific oil supply shocks differs substantially with the country of origin and that low oil prices positively affect real output globally. While these studies examine crude oil supply shocks, they do not consider refined petroleum products or shipping costs that determine how these products are transported between regions. Considine et al. (2022, 2023) extend these models further by accounting for country-specific oil inventories and critical mineral prices. Their results suggest that pre-existing market conditions determine the global implications of oil price shocks. The present study builds on these GVAR frameworks by explicitly modelling the refined petroleum market alongside the crude oil market and by incorporating their respective costs of shipping.

Focusing on shipping costs is particularly important given that at present there are only a small number of studies which are concerned with the cost of shipping crude oil and petroleum commodities. The Baltic Dirty Tanker Index (BDTI) measures the freight rates for shipping unrefined crude oil, while the Baltic Clean Tanker Index (BCTI) does the same for carrying clean petroleum commodities such as gasoline, kerosene and diesel. Using a structure VAR model, Shi et al. (2013) find that crude oil price shocks moderately increase the BDTI. Michail (2020) then examines the long-run relationship between the BDTI, BCTI, world GDP and the price of oil in a Vector Error Correction Model (VECM); it appears that output growth in middle-income economies has a particularly strong effect the BDTI and BCTI. Michail and Melas (2020b) further show that the BCTI, but not the BDTI, responds strongly to demand-side shocks with significant second-round effects through oil prices. While these studies suggest important linkages between refined petroleum shipping and oil markets, they analyse these relationships in isolation rather than within a comprehensive multi-country modelling framework. Finally Pouliasis and Bentsos (2023) investigate the co-movement in the returns of the price of oil and BDTI in the presence of oil market uncertainty and find a negative impact of oil price uncertainty on the correlation between oil and BDTI returns. The present study builds on this literature by estimating a GVAR model to jointly model crude oil markets, refined petroleum markets, and their respective shipping costs (BDTI and BCTI) across multiple countries. This framework allows us to examine how shocks transmit through the entire oil supply chain, from crude oil exporters through petroleum refiners to final consumers. By combining insights from the oil shock literature, the refined petroleum literature, the GVAR literature, and the shipping cost literature in a single model, this study provides the first comprehensive analysis of how crude and refined petroleum markets are linked through shipping channels. Table 1 summarises the contributions of the studies which form the basis for the analysis in this paper.

3. Empirical framework

3.1. *The general model setup*

Global VAR models are constructed by combining many country-specific models together with common variables into a global model which can account for many transmission channels of shocks. The method is ideally suited to assess the country-specific or regional responses to shocks stemming from global markets, such as the market for oil or shipping. Two attractive features of the model are that it allows to establish the direction of causality in complex systems with endogenous relationships and that it can incorporate counterfactual scenarios. While these features make the GVAR highly suitable for our purpose, it is worthwhile highlighting the limitations of the model. GVARs are linear which means they can miss any nonlinear effects or state-dependencies which might explain important developments the shipping industry in recent years, notably those due to the Covid-19 pandemic and supply chain bottlenecks. We partially address this issue by conducting a Covid-19 counterfactual analysis to estimate the impact of the pandemic on oil and refined petroleum shipping costs. Another drawback is the instability of parameters and shock transmission which can arise due to changing supply chain conditions, differing policy regimes or the imposition of sanctions. We conduct structural stability tests to account for this issue. Lastly, due to the high dimensionality of the model, we are only able to use generalised IRFs and compromise on a structural identification.

We first consider the following aggregate demand functions for crude oil and refined petroleum:

$$Qd_t^O = a_{d^O} + \epsilon_{y^O} a_{y^O}(L) y_t - \epsilon_{b^O} a_{b^O}(L) b_t^O - \epsilon_{p^O} a_{p^O}(L) p_t^O + \varepsilon_{d_t^O} \tag{1}$$

$$Qd_t^P = a_{d^P} + \epsilon_{c^P} a_{c^P}(L) c_t - \epsilon_{b^P} a_{b^P}(L) b_t^P + \epsilon_{I^P} a_{I^P}(L) I_t^P - \epsilon_{p^P} a_{p^P}(L) p_t^P + \varepsilon_{d_t^P} \tag{2}$$

where Qd_t^O is the world demand for crude oil and Qd_t^P the world demand for refined petroleum, y_t stands for world real activity, c_t for refined petroleum consumption, I_t^P for refined petroleum inventories, b_t^O and b_t^P denote the Baltic Dirty and Clean Tanker Indices respectively, and p_t^O and p_t^P stand for the real world prices of crude oil and refined petroleum respectively.[1]; a_{d^O} and a_{d^P} are constants, and $a_{y^O}(L)$, $a_{y^P}(L)$, $a_{b^O}(L)$, $a_{b^P}(L)$, $a_{p^O}(L)$ and $a_{p^P}(L)$ are polynomials in the lag operator whose coefficients add up to unity. It follows that ϵ_{y^O} and ϵ_{p^O} are the long-run income and price elasticities of the demand for crude oil.[2] ϵ_{c^P} and ϵ_{p^P} the long-run income and price elasticities of the demand for refined petroleum, ϵ_{b^O} the long-run cross-elasticity of the demand for crude oil and the cost of shipping crude oil, and ϵ_{p^P} the long-run cross-elasticity of the demand for refined petroleum and the cost of shipping refined petroleum. We assume that the demand for crude oil is determined by its price, the general level of real activity and by its cost of transportation, since

[1] It is important to note that there is no single global price for petroleum, which includes several products such as gasoline, diesel and other fuel oils, all of which are priced differently. For our purposes we create a global production-share weighted price index which is computed using the prices of the individual petroleum categories. We believe this measure to be a reasonable approximation for the aggregate global petroleum price.

[2] The exact calculations of the income and price elasticities can be found in Mohaddes and Pesaran (2016).

Table 1
Summary of key studies.

	Assumptions	Methodology	Contributions
Cashin et al. (2014)	Oil shocks have asymmetric effects on importers vs. exporters	Global Oil VAR with demand- and supply-driven shocks	Supply shocks reduce (increase) activity for importers (exporters) while demand shocks increase inflation and output
Mohaddes and Pesaran (2016)	Country of origin matters for oil supply shocks	Multi-country GVAR for country-specific oil supply shocks	Global effects of oil supply shocks differ by country of origin
Liddle and Huntington (2020)	Refined petroleum impacts vary across countries	Cross-country analysis of refined petroleum shocks	Provided comparative evidence on refined petroleum effects globally
Michail (2020)	Long-run equilibrium exists between shipping costs, GDP, and oil prices	VECM analyzing crude oil, refined petroleum, and dry cargo shipping costs	Oil prices significantly affect BCTI only
Michail and Melas (2020b)	COVID-19 represents demand-side shock with asymmetric freight effects	GARCH and VAR specifications for COVID-19 pandemic shock	BCTI is more strongly affected by demand than BDTI with strong second-round effects via oil prices
Considine et al. (2022)	Pre-shock market conditions determine shock transmission	GVAR with explicit country-specific oil inventories	Global implications of oil price shocks is determined by pre-existing market conditions
Baumeister and Hamilton (2023)	Global refined petroleum dynamics differ from crude oil	Analysed refined petroleum at global level	Extended understanding of refined petroleum shocks to global economy
Kilian and Zhou (2023)	Different energy categories have different inflationary effects	Structural VAR differentiating between gasoline, diesel, and jet fuel	Focusing only on gasoline underestimates total inflationary effects of energy price shocks

the latter is born by those demanding the commodity, i.e. the refining countries. In the case of refined petroleum we assume that demand depends on its price, the total level of petroleum consumption, the cost of shipping refined petroleum and petroleum inventories.

The supply functions for crude oil and refined petroleum take the following general form:

$$Qs_t^O = a_{s^O} + \epsilon_{s^O} a_{s^O}(L) p_t^O + \varepsilon_{s_t^O} \tag{3}$$

$$Qs_t^P = a_{s^P} + \epsilon_{p^P} a_{p^P}(L) p_t^O + \epsilon_{s^P} a_{s^P}(L) p_t^P + \epsilon_{b^P} a_{b^P}(L) b_t^O + \varepsilon_{s_t^P} \tag{4}$$

where Qs_t^O is the world supply of crude oil and Qs_t^P is the world supply of refined petroleum. One can assume that the supply of crude oil depends solely on its price, whilst the supply of refined petroleum depends on the price of refined petroleum as well as the price of crude oil and the cost of shipping crude oil, since the latter two are direct costs of refined petroleum production. For the refiner, the final input cost into production is the price of crude oil plus the cost of shipping crude oil, since the shipping cost is usually borne by the importer of the commodity (assuming free on board which is common in the case of major oil producers including OPEC). It is noteworthy that in our GVAR model crude oil production, but not refined petroleum production, is observed. In addition, the crude oil and refined petroleum shipping cost markets can be described by the following equations:

$$b_t^O = b_{b^O} + b_{y^O}(L) y_t + b_{\pi^O}(L) \pi_t + b_{p^O}(L) p_t^O + \varepsilon_{b_t^O} \tag{5}$$

$$b_t^P = b_{b^P} + b_{y^P}(L) c_t + b_{\pi^P}(L) \pi_t + b_{p^P}(L) p_t^P + \varepsilon_{d_t^P} \tag{6}$$

where π_t is world inflation and $b_{y^O}(L)$, $b_{y^P}(L)$, $b_{\pi^O}(L)$, $b_{\pi^P}(L)$, $b_{p^O}(L)$ and $b_{p^P}(L)$ are polynomials in the lag operator whose coefficients add up to unity. In the case of crude oil economic activity is considered to be the most important determinant of the demand for shipping, and higher economic activity should shift the demand schedule for shipping crude oil to the right (Kilian, 2009). However, the demand for shipping is also determined by the demand and supply of the commodity that is being transported and hence its price (Kilian et al., 2023). In the presence of crude oil price shocks, shipping costs can increase since bunker fuel, which is derived from crude oil, is a direct and necessary input in seaborne transportation (Kilian, 2009). Therefore the cost of shipping crude oil is determined by economic activity, the price of crude oil and overall inflation to capture general trends in prices, while the cost of shipping refined petroleum is determined by petroleum consumption, overall inflation and the price of refined petroleum.

We then assume that crude oil and refined petroleum prices adjust to remove any imbalances between the demand and the supply of crude oil and refined petroleum in their respective markets:

$$\Delta p_t^O = a_{s^O} + \lambda_O \left(Qd_t^O - Qs_t^O \right) + \varepsilon_{p_t^O} \tag{7}$$

$$\Delta p_t^P = a_{s^P} + \lambda_P \left(Qd_t^P - Qs_t^P \right) + \varepsilon_{p_t^P} \tag{8}$$

where λ_O is the speed of adjustment between crude oil supply and demand, and λ_P is the speed of adjustment between refined petroleum supply and demand; a_{s^O} and a_{s^P} are constants which reflect scarcity of crude oil and refined petroleum, respectively, and $\varepsilon_{p_t^O}$

and $\varepsilon_{p_t^P}$ represent speculative changes in the price of crude oil and refined petroleum which are not related to fundamental factors.

Substitution of (1) and (2) into (5) and (6) gives:

$$\Delta p_t^O = a_{p^O} + \lambda_O \left(a_{d^O} + \epsilon_{y^O} a_{y^O}(L) y_t - \epsilon_{b^O} a_{b^O}(L) b_t^O - \epsilon_{p^O} a_{p^O}(L) p_t^O + + \varepsilon_{d_t^O} - Qs_t^O \right) + \varepsilon_{p_t^O} \tag{9}$$

$$\begin{aligned} \Delta p_t^P = {} & a_{p^P} + \lambda_P \big(a_{d^P} + \epsilon_{y^P} a_{y^P}(L) c_t - \epsilon_{b^P} a_{b^P}(L) b_t^P + \epsilon_{I^P} a_{I^P}(L) I_t^P - \\ & - \epsilon_{p^P} a_{p^P}(L) p_t^P + \varepsilon_{d_t^P} - Qs_t^P \big) + \varepsilon_{p_t^P} \end{aligned} \tag{10}$$

or

$$\Delta p_t^O = a_{f^O} + \lambda_O \left(\epsilon_{y^O} a_{y^O}(L) y_t - \epsilon_{b^O} a_{b^O}(L) b_t^O - \epsilon_{p^O} a_{p^O}(L) p_t^O - - Qs_t^O \right) + \varepsilon_{f_t^O} \tag{11}$$

$$\Delta p_t^P = a_{f^P} + \lambda_P \left(\epsilon_{y^P} a_{y^P}(L) c_t - \epsilon_{b^P} a_{b^P}(L) b_t^P + \epsilon_{I^P} a_{I^P}(L) I_t^P - - \epsilon_{p^P} a_{p^P}(L) p_t^P - Qs_t^P \right) + \varepsilon_{f_t^P} \tag{12}$$

where $a_{f^O} = a_{s^O} + \lambda_O a_{d^O}$, $a_{f^P} = a_{s^P} + \lambda_P a_{d^P}$, $\varepsilon_{f_t^O} = \varepsilon_{s_t^O} + \lambda_O \varepsilon_{d_t^O}$ and $\varepsilon_{f_t^P} = \varepsilon_{s_t^P} + \lambda_P \varepsilon_{d_t^P}$. One can then solve for p_t^O and p_t^P to obtain the following autoregressive distributed lag (ARDL) models:

$$p_t^O = c_O + \sum_{l=1}^{m_{p^O}} \alpha_l^O p_{t-l}^O + \sum_{l=1}^{m_{y^O}} \beta_l^O y_{t-l} + \sum_{l=1}^{m_{b^O}} \gamma_l^O b_{t-l}^O + \sum_{l=1}^{m_{q^O}} \delta_l^O Qs_{t-l}^O + v_t^O \tag{13}$$

$$p_t^P = c_O + \sum_{l=1}^{m_{p^P}} \alpha_l^P p_{t-l}^P + \sum_{l=1}^{m_{y^P}} \beta_l^P c_{t-l} + \sum_{l=1}^{m_{b^P}} \gamma_l^P b_{t-l}^P + \sum_{l=1}^{m_{b^P}} \theta_l^P I_{t-l}^P + \sum_{l=1}^{m_{q^P}} \delta_l^P Qs_{t-l}^P + v_t^P \tag{14}$$

where the maximum lag lengths m_{p^O}, m_{y^O}, m_{b^O}, m_{q^O}, m_{p^P}, m_{y^P}, m_{b^P} and m_{q^P} are selected using the Schwartz-Bayesian information criterion (BIC) and are allowed to vary for the different variables.[3] Equations (13) and (14) are used later to allow for feedback from the country-level variables to the global ones.

3.2. The country-specific VARX* models

The GVAR model is estimated in two steps. First, Vector Autoregressive Models with foreign variables (VARX*) are estimated for each country individually; these include both domestic and foreign variables as well as a set of dominant unit variables which are common across all countries, namely the world crude oil and refined petroleum prices in addition to the corresponding shipping costs. In the second step, all individual models are combined into a GVAR one for the whole world. The country-specific equations take the following form:

$$X_{it} = \mu_{i0} + \mu_{i1} t + \Phi_i(L) X_{it} + \Theta_i(L) X_{it}^* + \Gamma_i(L) Z_t + u_{it} \tag{15}$$

where X_{it} is a $(k_i \times 1)$ vector of country-specific endogenous variables for $i = 1, 2, \ldots, N$, X_{it}^* is a $(k_i \times 1)$ vector of country-specific *star* foreign variables which are weakly exogenous, and Z_t is a (4×1) vector of global variables, more specifically $Z_t = \left(p_t^o, p_t^P, b_t^O, b_t^P\right)$. The country-specific domestic variables are given by the vector $X_{it} = \left(Qs_{it}^O, y_{it}, c_{it}^P, \pi_{it}, I_{it}, ep_{it}, eq_{it}, r_{it}^S, r_{it}^L\right)$, where Qs_{it}^O stands for the production of crude oil at time t for country i, y_{it} for real GDP, c_{it}^P for the consumption of refined petroleum goods, π_{it} for the inflation rate, ep_{it} for the real exchange rate, eq_{it} for the equity price index, and r_{it}^S and r_{it}^L for the short- and long-term interest rates respectively. The foreign variables are given by $X_{it}^* = \left(y_{it}^*, c_{it}^{P^*}, I_{it}^*, eq_{it}^*, r_{it}^{L^*}\right)$ and are trade-weighted using country-specific trade shares:

$$X_{it}^* = \sum_{j=1}^{N} w_{ij} X_{jt} \tag{16}$$

where w_{ij} are bilateral trade weights with $i, j = 1, 2, \ldots, N$, with $w_{ii} = 0$ and $\sum_{j=1}^{N} w_{ij} = 1$. The trade weights are computed as a three-year moving average. All variables are tested for unit roots and cointegration. A VECM is estimated when cointegrating relations exist; otherwise, a VAR with stationary-transformed variables is used. The lag order for each country VAR/VECM is selected from a maximum lag length of 12 lags using the BIC criterion. The local and global variables for each country model are selected following the existing convention in the GVAR-oil literature (Considine et al., 2022; Mohaddes & Pesaran, 2016).

[3] We use the BIC since it remains consistent even in large sample sizes and avoids overfitting which is particularly important in complex GVAR models.

3.3. Solving the GVAR model

In the second stage, we solve the GVAR where all variables are endogenous. For this purpose the country-specific equations are combined with the crude oil and refined petroleum price ones and the corresponding shipping cost ones. The combined model allows for bidirectional linkages between the global economy and the prices and shipping costs of both crude oil and refined petroleum. While the estimation is done country-by-country, the GVAR model is solved for the global variables and all country variables simultaneously.[4] which are collected in the vector $Y_t = (Z_t, X_{it}')'$, where $X_{it}^* = W_i X_t$ and W_i is a $k_i^* \times (k+1)$ matrix of the trade weights w_{ij} with $k = \sum_{i=1}^N k_i$. One then obtains $A_i W_i X_t = \mu_{i0} + \mu_{i1} t + B_i W_i X_{t-1} + e_{it}$ such that the country-specific models can be stacked as follows:

$$GX_t = \mu_0 + \mu_1 t + \Phi(L) X_t + \Gamma(L) Z_t + u_t \tag{17}$$

where $\mu_0 = \begin{pmatrix} \mu_{10} \\ \mu_{20} \\ \vdots \\ \mu_{N0} \end{pmatrix}$, $\mu_1 = \begin{pmatrix} \mu_{11} \\ \mu_{21} \\ \vdots \\ \mu_{N1} \end{pmatrix}$, $G = \begin{pmatrix} \mathrm{A}_{10}\mathrm{W}_1 \\ \mathrm{A}_{20}\mathrm{W}_2 \\ \vdots \\ \mathrm{A}_{N0}\mathrm{W}_{N} \end{pmatrix}$, $\Phi_{\mathrm{j}} = \begin{pmatrix} \mathrm{B}_{1j} W_1 \\ \mathrm{B}_{2j} W_2 \\ \vdots \\ \mathrm{B}_{Nj} W_N \end{pmatrix}$, $\Gamma_{\mathrm{j}} = \begin{pmatrix} \Gamma_{1\mathrm{j}} \\ \Gamma_{2\mathrm{j}} \\ \vdots \\ \Gamma_{N\mathrm{j}} \end{pmatrix}$, $u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \\ \vdots \\ u_{Nt} \end{pmatrix}$, $j = 1, 2, \ldots, p$ with maximum lag length p and $A_i W_i$ and $B_i W_i$ are both k-dimensional matrices of coefficients that differ across countries, and Γ is a matrix of coefficients on the global variables. The GVAR can then be expressed in terms of the endogenous variables Y_t as:

$$GY_t = \mu_0 + \mu_1 t + HY_{t-1} + \vartheta_t \tag{18}$$

which has the following reduced-form solution:

$$Y_t = d_0 + d_1 t + FY_{t-1} + \xi_t \tag{19}$$

where $d_i = G^{-1}\mu_i$, $i = 0,1$, $F = G^{-1}\mathrm{H}$ and $\xi_t = G^{-1}\vartheta_t$. The above model combines the country-specific models with the global crude oil and refined petroleum price equations as well as the crude oil and refined petroleum shipping cost equations.

One can allow for feedback from the domestic variables to the dominant unit variables through the price equations for crude oil (15) and refined petroleum (16), and through the shipping cost equations for crude oil (5) and refined petroleum (6), by attaching the following weights to the global macroeconomic variables:

$$y_t^* = \sum_{j=1}^N \omega_j^y y_{jt}; \quad Qs_t^{O*} = \sum_{j=1}^N \omega_j^{Q^O} Qs_{jt}^O$$

$$I_t^* = \sum_{j=1}^N \omega_j^I I_{jt}; \quad c_t^{P*} = \sum_{j=1}^N \omega_j^{Q^P} c_{jt}^P$$

where ω_j^y is the three-year average of the PPP-GDP weights of country j with $\sum_{j=1}^N \omega_j^y = 1$, and $\omega_j^{Q^O}$ and $\omega_j^{Q^P}$ are the three-year average of the weighted contribution of country j to global crude oil and refined petroleum production respectively with $\sum_{j=1}^N \omega_j^{Q^O} = 1$ and $\sum_{j=1}^N \omega_j^{Q^P} = 1$.

Next impulse response functions can be obtained. Specifically, generalised impulse response functions as in Pesaran and Shin (1998) are estimated here since they are invariant to the ordering of the variables - restrictions would otherwise have to be imposed to achieve identification, which would not feasible in a model with 34 countries and a large set of endogenous variables, since too many would be required. For the estimation the toolbox provided by Smith and Galesi (2014) is used. The lags lengths for the unit root tests, the VARX models and the weak exogeneity tests are determined using the Schwartz-Bayesian information criterion. The weak exogeneity test is an F-test of the null that the coefficients on the error correction term are zero in the marginal model for the foreign variables and dominant unit variables.

3.4. Counterfactual analysis

The Covid-19 pandemic had large effects on supply chains and oceanic shipping markets, which increased the cost of seaborn transportation. In order to assess them in the context of our GVAR model we estimate it for a subsample ending in December 2019, i.e. shortly before the Covid-19 pandemic outbreak, as well as for the full sample ending in May 2024, with January 2000 as the start date in both cases. A counterfactual analysis is then conducted to investigate the impact of the Covid-19 shock by using growth forecast revisions as in Chudik et al. (2021). Specifically, we compare the IMF GDP forecasts made in December 2019 (before the start of the pandemic) with those in April 2020 (shortly after the start of the pandemic). The difference between the two, i.e. the forecast revisions, can be attributed to the Covid-19 shock.

As a second counterfactual scenario we consider developments specific to the oil shipping market, namely the effects of Western

[4] As domestic variables we only include those that are at most $I(1)$ and as foreign variables only those that pass the weak exogeneity tests. The crude oil and refined petroleum price and shipping cost variables enter all country models as dominant unit variables.

sanctions on Russian oil, specifically the ban of seaborne imports of Russian oil imposed since December 2022. The procedure is the following. We first compute the model using the trade weights for 2022 throughout the years 2023 and 2024. This provides us with the unrestricted model corresponding to the case of no sanctions on Russian oil. We then set the trade weights for the years 2023 and 2024 between Russia and all Western economies that imposed sanctions on Russian oil (the G7, all EU countries, Australia, New Zealand and Switzerland) equal to zero. Since these are used to compute the trade relations between countries in terms of shipping oil only, this is a reasonable assumption. For countries that did not impose sanctions on Russian oil, in particular China and India, we revise the bilateral weights with Russia upwards, so that all bilateral weights for Russia add up to unity. We then ask the question whether shipping costs are higher under the sanctions scenario given a reduction in Russian oil supply compared to the unrestricted case without sanctions. Specifically, we report the conditional probability distribution for the differences in future realisations of shipping costs rather than comparing point forecasts, since the latter can be highly uncertain. In addition to a reduction in Russian oil supply, we also consider an increase in real activity in China and India and an increase in real activity in several Western European countries, for which we compare the sanctions case with the unrestricted one.

3.5. Data description

We use monthly data from January 2000 to May 2024. The Baltic Dirty Tanker Index (BDTI) and the Baltic Clean Tanker Index (BCTI) are obtained from Bloomberg. The BDTI is a benchmark index constructed from spot freight rates for tankers that carry crude oil. The BCTI is the equivalent index for tankers carrying refined petroleum products. Both are calculated from a basket of representative tanker routes and the underlying components are assessed using Worldscale, a system for calculating freight rates. They are released every working day at the same time. They are suitable for our analysis since they represent the cost of moving oil products from exporting to importing countries and therefore create a wedge between the oil price and the delivered price faced by refiners or consumers of the commodity. They further capture bottlenecks such as canal blockages or rerouting, which have become increasingly frequent in recent years with large implications for global supply chains. Worldscale is updated annually on 1st January to reflect changes in tanker operating costs, port fees and bunker prices. One potential issue that may arise is that this can cause temporary disruptions in the BDTI and BCTI as traders adjust their shipping cost expectations before the indices return to move according to supply and demand forces. These disruptions usually only last one or two weeks before normalisation occurs, which means they can influence the average value of the indices for each January, but should not affect the overall interpretation of the results significantly. Fig. 1 plots the BDTI and BCTI over the sample period considered. Brent spot prices are used for the global crude oil prices, but the analysis is also repeated using WTI (West Texas Intermediate) prices as a robustness check. Both are obtained from the US EIA (Energy Information Administration). The refined petroleum price is constructed as a global production-share weighted price index computed using the prices of the individual refined petroleum categories, namely gasoline, kerosene, diesel fuel, heating oil and propane. The index is calculated ed by weighting the prices of these five individual petroleum commodities by their share of world total production, which is then converted to Dollars per barrel.[5] Crude oil production, petroleum inventories and petroleum consumption data were obtained from the EIA, while industrial production and consumer prices indices were taken from the OECD Key Economic Indicators database for most countries. Short- and long-term interest rates were also obtained from the same database for OECD countries and for the remaining countries from Bloomberg. Further details on variables, data sources and transformations can be found in Appendix A. We include real GDP, inflation, the nominal short and long rates, real equity indices, real exchange rates and crude oil production for all countries with the exception of real GDP for Iran and Saudi Arabia. Petroleum consumption is included for all countries except Brazil, China, India, Indonesia, Iran, Malaysia, Peru, Philippines, Russia, South Africa, Saudi Arabia, Singapore and Thailand, for which the series are unavailable. The oil and petroleum price variables and their respective shipping costs enter all country models unless they fail the weak exogeneity test. Further details on variables, data sources and transformations can be found in Appendix A. Due to data availability limitations, information on crude oil and refined petroleum exports and imports is excluded from the model. The only way to classify countries into exporters and importers is by assigning them to regions using import and export value data. The sample includes a total of 34 countries which together account for over 90% of world GDP. These are the same as in Mohaddes and Pesaran (2016), but for our purpose we classify them into different regions. Specifically, we separate them into net exporters of crude oil, net importers of crude oil, net exporters of refined petroleum and net importers of refined petroleum. The breakdown is shown in Table 2. The classifications are somewhat arbitrary, since net exporters of crude oil or refined petroleum can also be large importers of certain refined petroleum products. For instance, Canada and Mexico are net exporters of crude oil but import refined products, such as gasoline. Therefore, we would expect that in some instances net exporters of crude oil or refined petroleum are similarly affected by global shocks as net importers of refined petroleum.[6] Detailed data sources for all country-specific variables are provided in Appendix A. The results of the unit root, weak exogeneity and structural stability tests for all variables are reported in Appendix B and confirm that all those entering the model are either I(0) or I(1) and weakly exogenous. All individual VAR models and the GVAR system as a whole are stable.

[5] While this approach suffers from limitations due to the aggregation of different product types with different dynamics, it offers the closest approximation to a global refined petroleum price one can obtain.

[6] We experimented with including and excluding countries from the list of net importers of crude oil and net exporters of refined petroleum if they fall into both categories. These countries are India and the US in our case. The results (not reported) appear robust to these changes. All results reported in the paper follow the country classification outlined in Table 2.

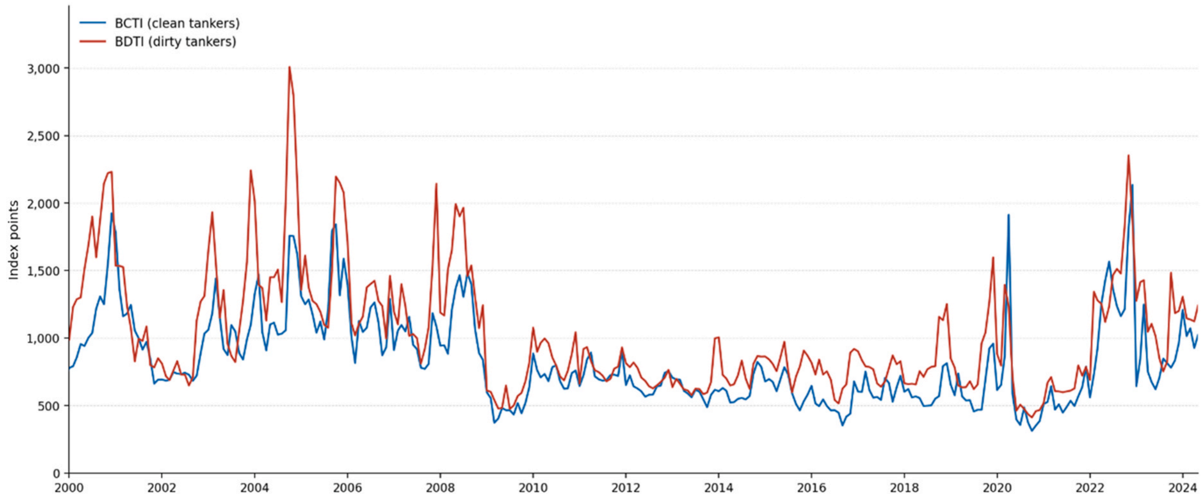

Fig. 1. BDTI and BDTI over time
Notes: BDTI and BCTI indices over time.

Table 2
Countries and regions in the GVAR model.

Net exporters of crude oil	Net importers of crude oil	Net exporters of refined petroleum	Net importers of refined petroleum
Canada	Brazil	US	Austria
Indonesia	China	Belgium	Chile
Iran	India	Malaysia	Finland
Mexico	Japan	Netherlands	France
Norway	South Korea	New Zealand	Germany
Russia	UK	Singapore	Italy
Saudi Arabia		Turkey	Peru
			Philippines
			South Africa
			Spain
			Sweden
			Switzerland
			Australia
			Thailand

Notes: Countries and regions in the GVAR model.

4. Empirical results

4.1. Responses of the global variables

In this section we present the responses of the global variables to the global shocks. On the basis of the model structure outlined in Section 3 we expect that crude oil shipping cost shocks act as a negative supply shock for crude-importing economies, while refined petroleum shipping cost shocks should act as a negative supply shock for net importers of refined products. We also expect crude oil price shocks to increase the cost of shipping crude oil and refined petroleum. We assume that oil and refined petroleum price shocks act as cost-push shocks in countries with high import-dependence. Fig. 2 shows the responses to a positive one standard deviation shock to the crude oil and refined petroleum prices as well as to BDTI and BCTI. This corresponds to an increase by 8.67% and 8.4% in the price of crude oil and refined petroleum respectively, and by 15.90% and 28.89% in the case of BDTI and BCTI in turn. There appear to be strong linkages between crude oil and refined petroleum, but not between their prices and shipping costs. The results are robust to whether the Brent spot prices or the WTI ones are used (the latter results are not reported to save space). Despite the lack of a significant relationship between oil prices and shipping costs, the latter might still affect regional or country-level macroeconomic variables, which we investigate next.

4.2. Regional and country-level responses to global shocks

Evidence on the responses of regional and country-level variables to the global shocks is presented in the following figures, which in the country-level case only includes results that are significant at least at some horizons. First of all, Fig. 3 shows that crude oil price shocks have a positive effect on inflation in countries which are net exporters of refined petroleum (0.09%) and on those which are net

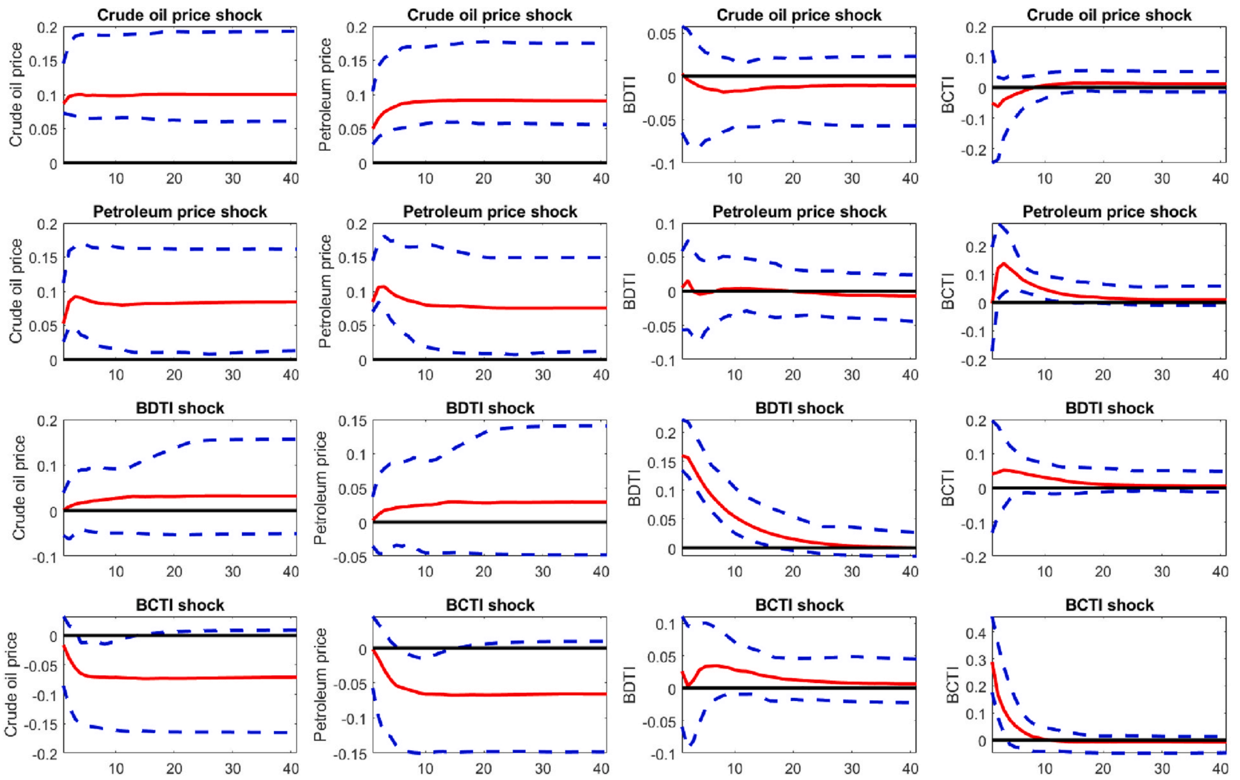

Fig. 2. Global variable responses to global shocks
Notes: Impulse responses to a one-standard deviation positive reduced-form shock to the global variables. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

importers of refined petroleum products (0.08%), which suggests that refining countries pass on higher crude oil prices to end consumers. Notably, the magnitude of inflationary effects is similar across both exporters and importers, reflecting the uniform pass-through of input costs regardless of the trade position. We also find that petroleum consumption responds to higher crude oil prices, as shown in Fig. 3. Interestingly, petroleum consumption increases in all countries, which could be due to a short-term inelasticity to price changes. Alternatively, if crude oil prices increase due to higher global demand, this general increase in economic activity can lead to higher petroleum consumption. Given the size of the global oil industry and the complexity of supply chains which span many countries, most economies could benefit from an increase in the price of crude oil, since they are involved either directly (as producers of crude oil or refined petroleum) or indirectly (for instance as suppliers of equipment used in the refining process). A shock to the price of refined petroleum (Fig. 5) instead increases inflation not only for net importers of refined petroleum (0.08%) and exporters of refined petroleum (0.1%), but also for importers of crude oil (0.09%), which is likely due to the wide use of petroleum products for economic activity in all countries. Net exporters of refined petroleum are also large consumers of refined petroleum themselves, and therefore should also be affected by changes in petroleum prices (see Fig. 4).

Figs. 6 and 7 report the responses of regional petroleum product consumption and real economic activity to a BCTI shock. A positive shock to the cost of shipping refined petroleum lowers the consumption of petroleum commodities by 0.6% in net exporting and net importing countries of refined petroleum. Real economic activity decreases by 1% in net crude oil importing countries, net refined petroleum exporting and net refined petroleum importing countries in response to the same shock. In contrast to price shocks, which primarily affect inflation, shipping cost shocks reduce both consumption and real economic activity; this pattern holds uniformly across nearly all country groups.

Next we report country-specific responses to the global shocks. Fig. 8 displays the responses of inflation to a positive BCTI shock for selected countries. In India, the Philippines, South Africa, Saudi Arabia and Thailand the response is negative, while in Brazil, Norway and Sweden it is positive. The size of the responses is largest in India (−0.16%), Thailand (−0.15%) and Sweden (0.10%). This divergence in inflation responses, with some countries experiencing deflation and others inflation, likely reflects differences in exchange rate dynamics, domestic refining capacity, and the structure of consumption baskets. Fig. 9 shows the responses of petroleum commodity consumption to a positive BCTI shock. As expected, petroleum commodity consumption falls in all countries and especially in Italy (−1.40), France (−0.90%), the UK (−0.80%) and the US (−0.76%). The particularly large consumption declines in these developed economies suggest higher demand elasticity and greater capacity for substitution compared to other countries. Finally, Fig. 10 displays the effects of a positive BCTI shock on real economic activity in individual countries. The latter falls in all countries with the exception of Finland, Indonesia, Japan, Norway, Russia and Singapore. The strongest responses are recorded for Indonesia

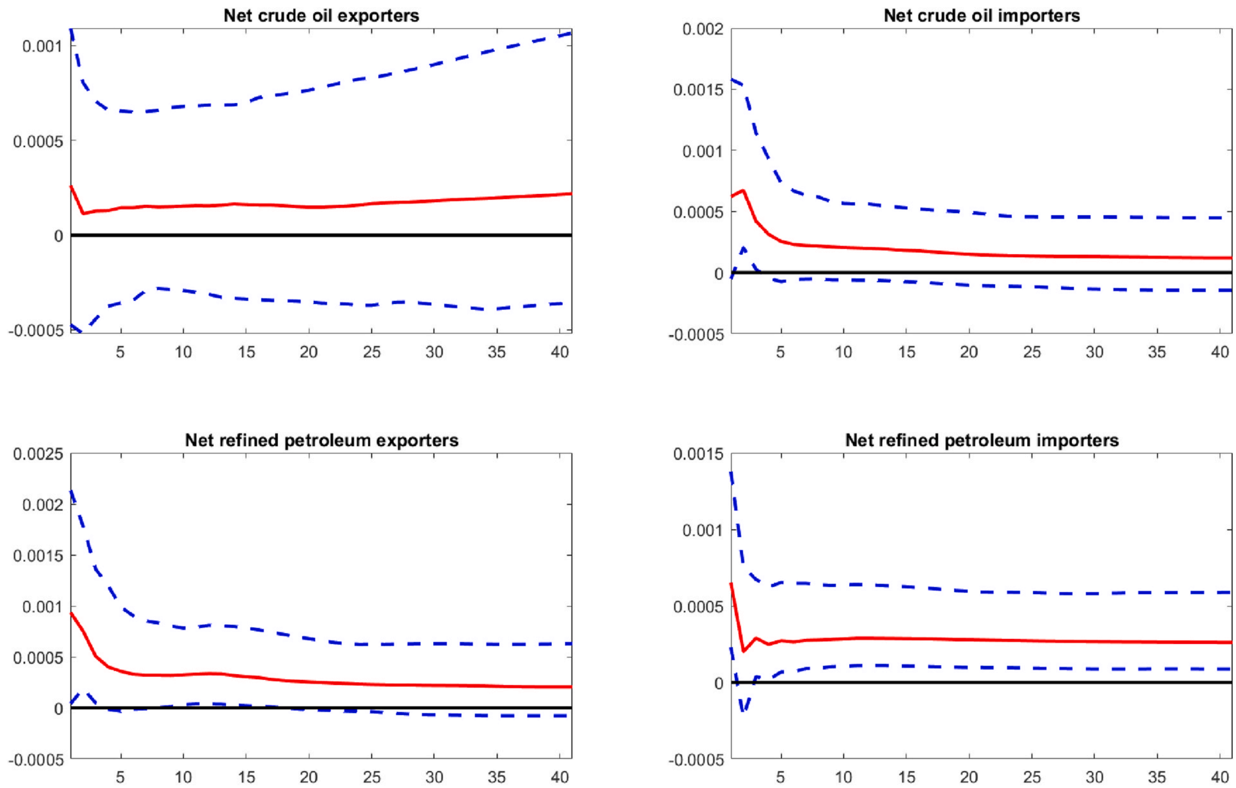

Fig. 3. Regional inflation responses to a crude oil price shock
Notes: Impulse responses to a one-standard deviation positive reduced-form crude oil price shock. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

(9.13%), Singapore (8.05%), India (−3.89%), South Africa (−2.14%) and Russia (1.78%). The effect is also relatively large for Italy, Mexico, Turkey, Austria, Peru, China and Brazil, with values ranging between 1.10% and 1.39%. The key pattern here is that crude oil exporters either maintain or increase economic activity, while import-dependent economies, particularly India and South Africa, experience the largest contractions, reflecting their vulnerability to higher shipping costs, probably due to limited possibilities for domestic substitution.

In summary, it seems that shocks to the price of crude oil and refined petroleum primarily increase overall inflation, while those to the cost of shipping refined petroleum reduce petroleum consumption and real economic activity. The latter seems to be the case in all countries except crude oil exporters, which relates to the fact that most countries are heavily reliant on refined petroleum for general economic activity. By contrast, the cost of shipping crude oil does not appear to have an impact on either inflation or real economic activity, which suggests that demand for energy is primarily that for refined petroleum, rather than crude oil. This asymmetry, where crude oil shipping costs have no effects whilst refined petroleum shipping costs cause major economic fluctuations, suggests that the refined petroleum supply chain either passes through more critical chokepoints or, since a much larger number of countries are at the receiving end of this supply chain as final consumers, disruptions have more widespread economic consequences. These findings confirm those by Michail and Melas (2020b), who show that the demand side of the economy is closely linked with the BCTI, but not the BDTI. These results support our approach recognising that the crude oil and refined petroleum markets are a two-tier system since it appears that shocks to the cost of shipping refined petroleum products (unlike shocks to the cost of shipping crude oil) have important economic effects. Hence it is important to consider the market for refined petroleum products and their cost of shipping alongside the crude oil market.

4.3. The effect of the Covid-19 pandemic

Next we investigate the effect of the Covid-19 pandemic on the dynamic linkages between the variables in the model. For this purpose, first we estimate the GVAR model for a subsample ending in December 2019, which yields different results for the global variables compared to the full sample ones (see Fig. 11). Estimating a model on a subsample which excludes the Covid-19 pandemic period is a common approach in the literature to examine whether the pandemic has changed the relationships between the variables in the model (Kilian & Zhou, 2024). More precisely, we now find a significant response of BDTI and BCTI to crude oil and refined petroleum price shocks and vice versa, which suggests a stronger link between commodity prices and shipping costs before the pandemic. This suggests that since its beginning shipping costs might have been more strongly influenced by general supply chain

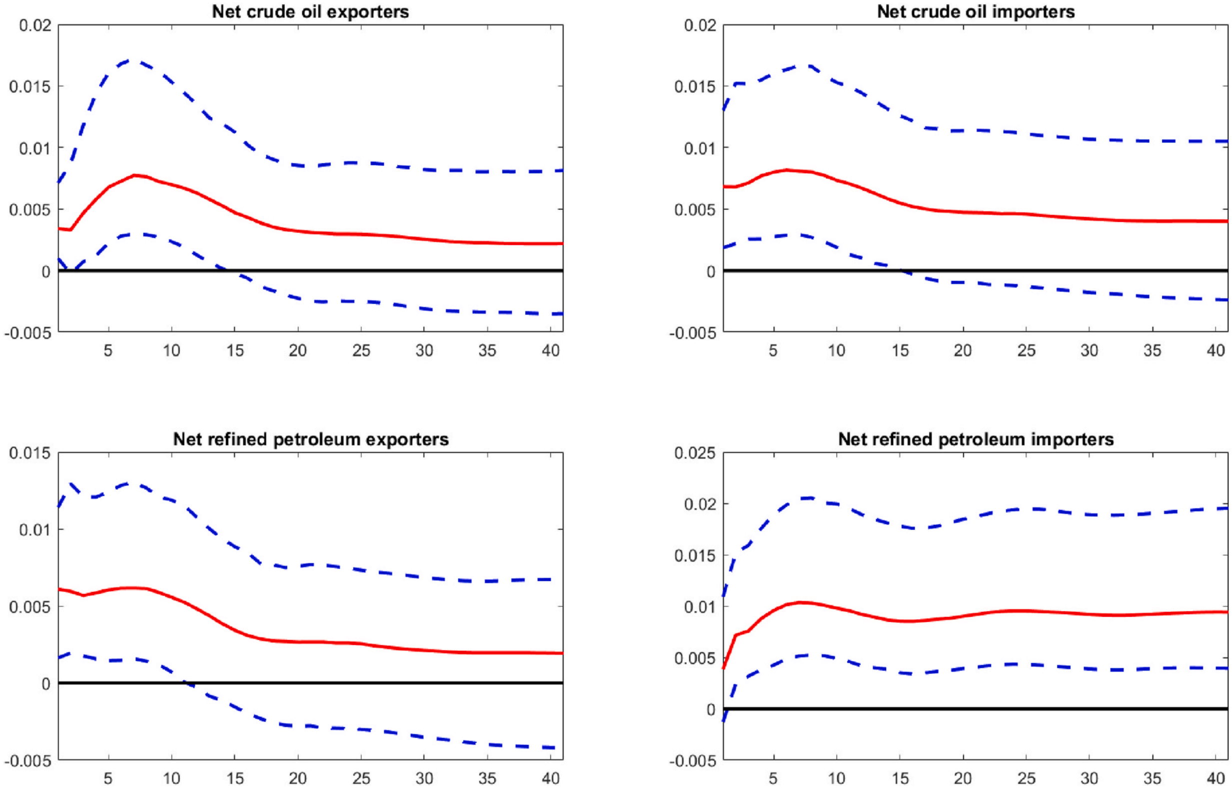

Fig. 4. Regional petroleum consumption responses to a crude oil price shock
Notes: Impulse responses to a one-standard deviation positive reduced-form crude oil price shock. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

pressures and bottlenecks rather than the price of the commodity that is being shipped. To analyse more rigorously the impact of the pandemic on the global variables in the model, we conduct a counterfactual analysis using the IMF growth projection revisions between December 2019 and April 2020. These results are reported in Fig. 12 and indicate that the Covid-19 shock caused a large increase of around 10% in BDTI and BCTI, although there is a significant amount of uncertainty around the counterfactual paths. Crude oil and refined petroleum prices decreased by around 5% in response to the Covid-19 shock.

To verify the structural break at the onset of the Covid-19 pandemic, we employ a Chow test in the VAR model of the dominant unit variables at the known break date of March 2020. We further compare bivariate Granger causality tests on pre-Covid (until February 2020) and post-Covid (from March 2020) subsamples. Both the Chow and Granger causality test results reported in Tables C1 and C2 in Appendix C indicate structural changes following the Covid-19 pandemic. Prior to March 2020 we observe a bidirectional causality between oil and petroleum prices and significant feedback from shipping costs to petroleum prices. Post-Covid, several causal relationships disappear, including the oil-petroleum price relation and all feedback channels from shipping costs to petroleum prices, while a new relationship emerges where the BDTI Granger-causes oil prices. The latter may also reflect the emergence of the Russian shadow fleet following the 2022 sanctions, which further disrupted the availability of crude oil tankers and their shipping costs. Notably, the petroleum price to petroleum shipping cost channel is the only causal direction that remains robust between both subsamples ($p = 0.000$ in both the pre- and post-Covid periods), suggesting that petroleum prices exert a stable, regime-invariant cost-push pressure on tanker freight rates. This is consistent with the fuel and cargo value both representing structurally fixed components of petroleum shipping economics which are independent of more general demand disruptions. The Chow test for the BDTI equation yields a p-value of 0.2697, failing to reject the null of parameter stability at the March 2020 break date, in contrast to the other three equations. A plausible economic explanation lies in the distinctive demand dynamics facing crude tanker markets at the start of the pandemic. While oil demand collapsed, the concurrent Saudi-Russia price war increased cheap crude oil flows in the global market, prompting a surge in floating storage. This absorbed significant tanker capacity, partially offsetting the demand shock and keeping freight rates from falling sharply. These opposing forces effectively cancelled out, explaining why a structural break in March 2020 is not detected in the case of the BDTI equation.

Several mechanisms can explain our findings. At the onset of the pandemic, demand for oil fell owing to lockdown restrictions and reduced economic activity, with global oil demand declining by approximately 9 million barrels per day in April 2020 (IEA, 2020). With excess supply of oil and limited storage capacity on land, tankers were increasingly used as floating storage, leading to an increase in freight rates despite falling oil prices (Michail & Melas, 2020b). This floating storage phenomenon has become more pronounced in recent years, effectively removing a substantial portion of the tanker fleet from shipping services. At the same time, supply-side

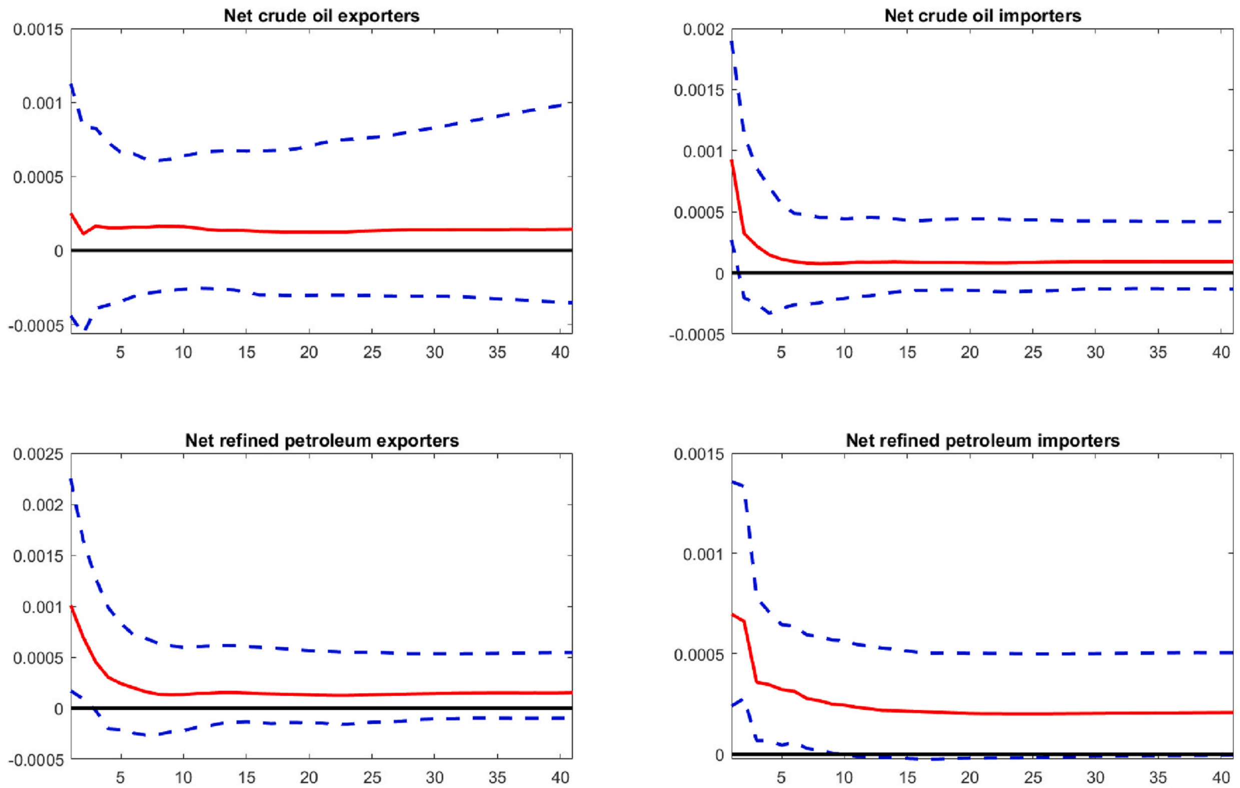

Fig. 5. Regional inflation responses to a refined petroleum price shock
Notes: Impulse responses to a one-standard deviation positive reduced-form refined petroleum oil price shock. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

disruptions in the shipping sector led to further decoupling of oil prices and shipping costs. Congestion in ports and delays due to health protocols reduced vessel availability and increased turnaround times (UNCTAD, 2021). The pandemic also caused vessel routing changes as traditional trade patterns were disrupted. Refineries in some regions experienced temporary closures or reduced operations, necessitating longer shipping routes to alternative destinations which increased ton-mile demand even though overall cargo volumes declined (Notteboom et al., 2021). Furthermore, the post-pandemic period has seen the emergence of shadow fleets, particularly for Russian oil following Western sanctions, which has fundamentally altered traditional shipping market dynamics and price relationships. While these shadow fleets represent a significant share of crude oil shipping capacity, they operate under shipping costs which are different from the market (Notteboom et al., 2021).

4.4. A Russian oil sanctions scenario

In this section we examine how shipping costs are affected by sanctions on Russian oil. We assess the conditional probability distribution that the global variables are higher in the scenario with sanctions, given a certain path of another variable, by considering the conditional forecast period between May 2023 and April 2024. We investigate separately the cases of reduced Russian oil supply, higher demand from China and India and higher demand from European countries. Fig. 13 reports the results. We find a high probability that the BDTI is higher following a reduction in Russian oil supply when sanctions are imposed. Likewise, crude oil and refined petroleum prices have a higher probability of being larger under the sanctions scenario. These results reflect key supply disruptions, which show that removing Russian crude oil from Western markets tightens global supply, raising both commodity prices and the cost of shipping existing supplies over longer distances. A high probability of a higher BDTI under the sanctions scenario can also be found following an increase in European demand. This is expected since, due to the sanctions, European nations had to source crude oil from countries other than Russia, which resulted in increased demand for seaborne shipping along greater distances. This finding reflects recent real-world developments, with European countries shifting to Middle Eastern and Atlantic Basin suppliers, which substantially increased transport distances and consequently ton-mile demand for tankers. In the case of higher demand in China and India, there is a higher probability that the BCTI is higher when sanctions are imposed, but less so for the BDTI. These findings are consistent with the fact that, due to the sanctions imposed on Russian oil by Western economies, most crude oil exports from Russia were shipped to China and India, which meant longer shipping routes, but also the emergence of the shadow fleet, which explains the low probability that the BDTI is higher when demand in China and India increases under the sanctions scenario. The different impacts on BCTI versus BDTI reflect the shadow fleet created by Russia to transport oil to Asia, which added shipping capacity

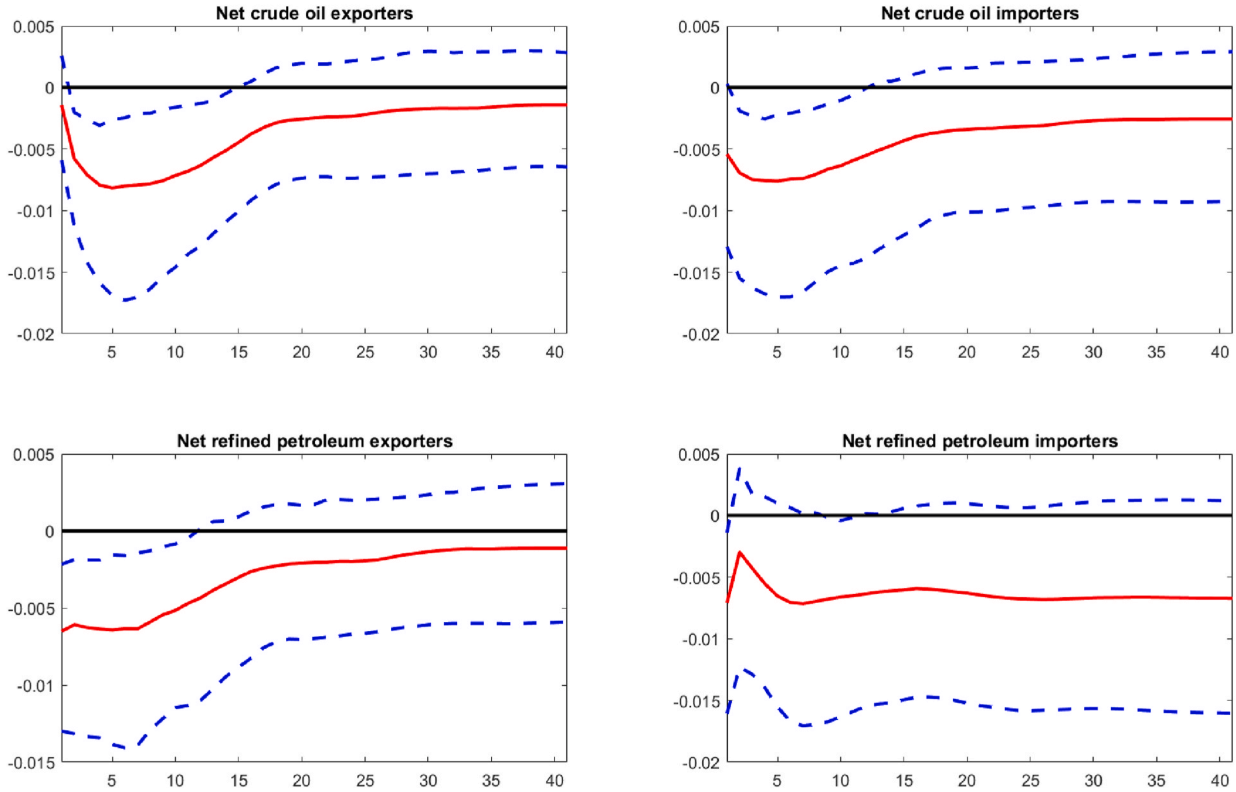

Fig. 6. Regional refined petroleum consumption responses to BCTI shock
Notes: Impulse responses to a one-standard deviation positive reduced-form BCTI shock. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

outside of conventional markets and kept the BDTI lower even though shipping distances increased.

5. Conclusions

This paper examines the role of shipping costs for crude oil and refined petroleum commodities in the global oil markets and their impact on the world economy. For this purpose a GVAR model is estimated for 34 countries using monthly data from January 2000 until May 2024, with the Baltic Dirty and Clean Tanker Indices being included as measures of shipping costs in the crude oil and refined petroleum markets. A counterfactual analysis is then conducted to assess the effects of the Covid-19 shock on the global variables.

Our findings can be summarised as follows. First, there appears to be linkages between the price of crude oil or refined petroleum and their respective shipping costs only in the period before the start of the Covid-19 pandemic, during which crude oil price shocks had large positive effects on shipping costs and vice versa. When the full sample is used, this relationship breaks down, which suggests that shipping costs and oil prices have been driven by other factors since the pandemic. Second, shocks to the price of crude oil and refined petroleum primarily affect inflation, while shocks to the cost of shipping petroleum commodities mainly influence refined petroleum consumption and real economic activity. Third, the Covid-19 counterfactual analysis shows that the shipping costs for crude oil and refined petroleum increased by around 10% as a result of the pandemic shock, while crude oil and refined petroleum prices fell by approximately 5%, namely they moved in the opposite direction. Fourth, it appears that there is a high probability that shipping costs are higher following reduced Russian crude oil supply and increased European demand as a result of Western sanctions imposed on Russian oil.

These findings have important implications for policymakers. In particular, given the inflationary effects of oil price shocks and the recessionary effects of refined petroleum shipping cost shocks, a simultaneous shock to both can increase the risk of stagflation. This poses a difficult challenge to central banks with dual mandates and rules-based policies, since interest rate changes cannot solve both inflation and recession. In such cases policies to reduce dependency on oil and supply-side policies aimed at increasing productivity might be the only effective measures. The results are also important for those operating in the oil shipping markets to better understand their dynamics and how changes in shipping costs can influence the supply chain from crude oil to refined petroleum. Finally, given the evidence on the impact of the Covid-19 pandemic, future work should investigate in greater depth the time-varying nature of the relationship between crude oil and refined petroleum prices and shipping costs and the transmission to the domestic and global economy of shocks to these variables.

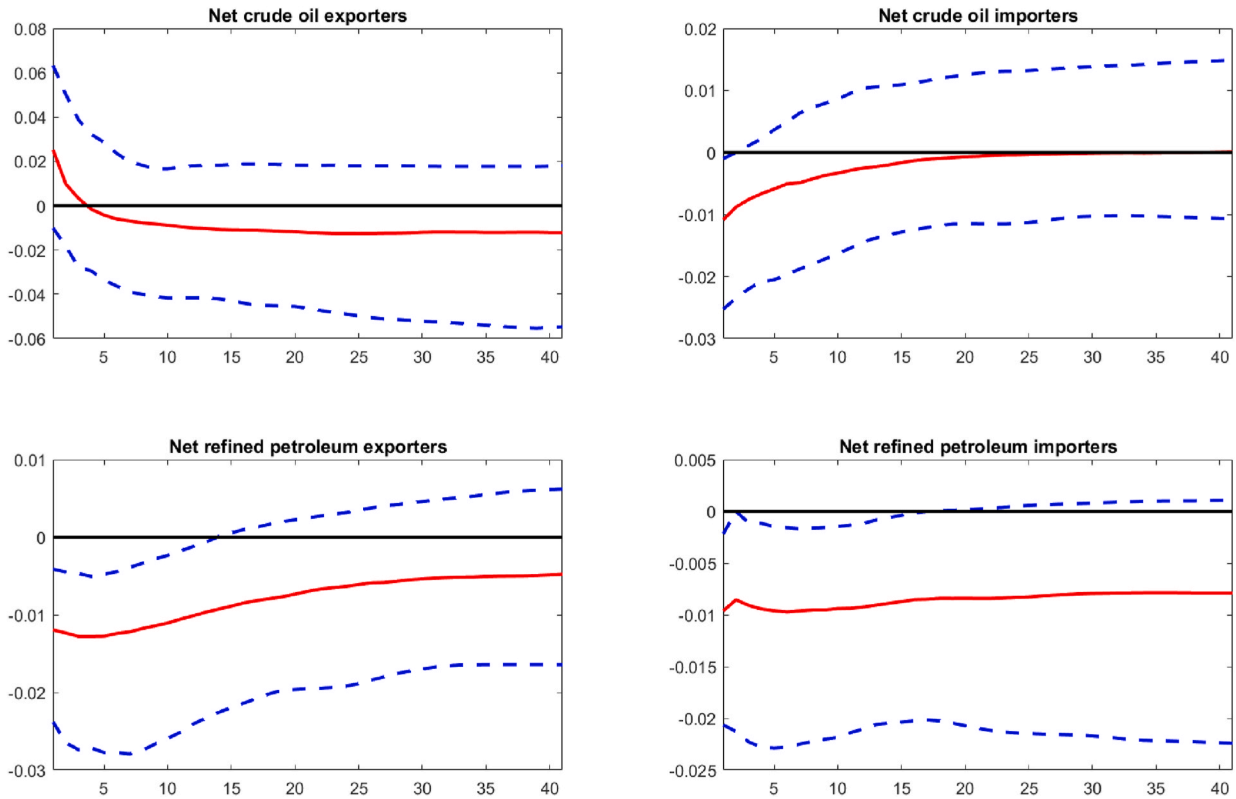

Fig. 7. Regional real activity responses to BCTI shock
Notes: Impulse responses to a one-standard deviation positive reduced-form BCTI shock. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

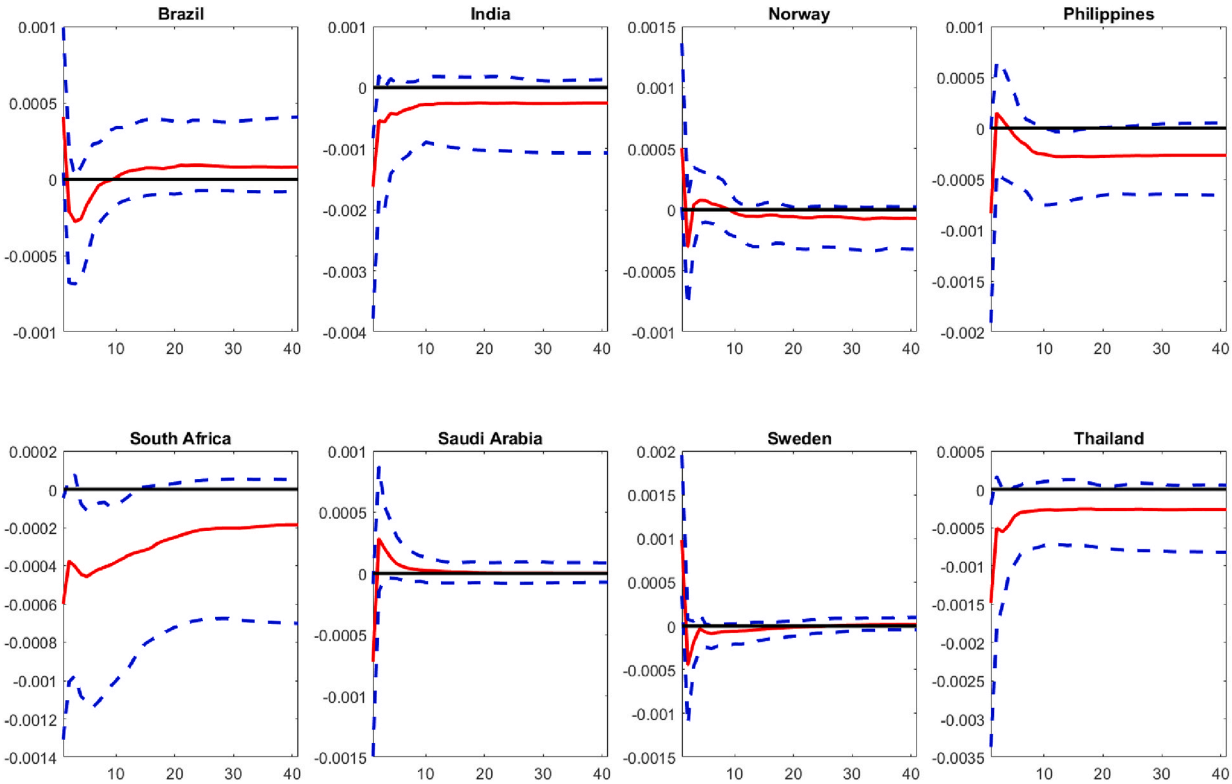

Fig. 8. Country-level inflation responses to BCTI shocks
Notes: Impulse responses to a one-standard deviation positive reduced-form BCTI shock for selected countries. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

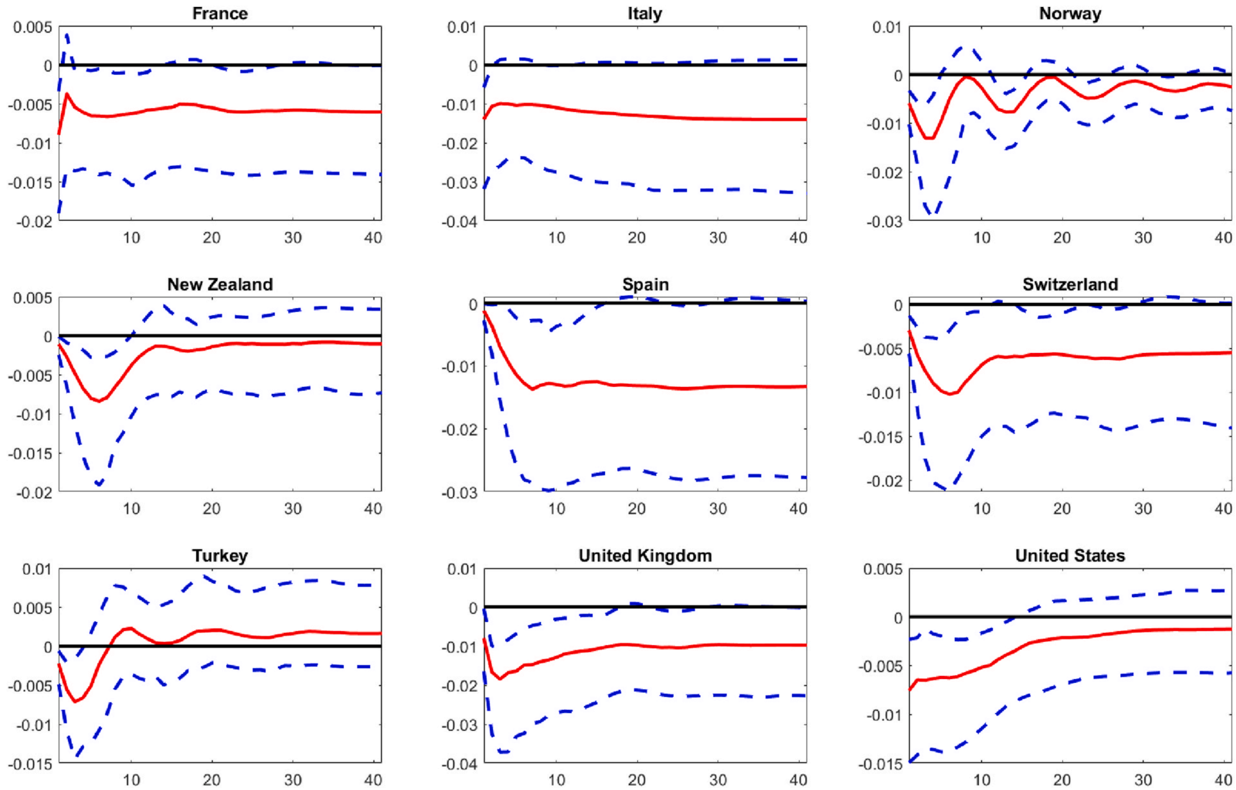

Fig. 9. Country-level refined petroleum consumption responses to BCTI shocks
Notes: Impulse responses to a one-standard deviation positive reduced-form BCTI shock for selected countries. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

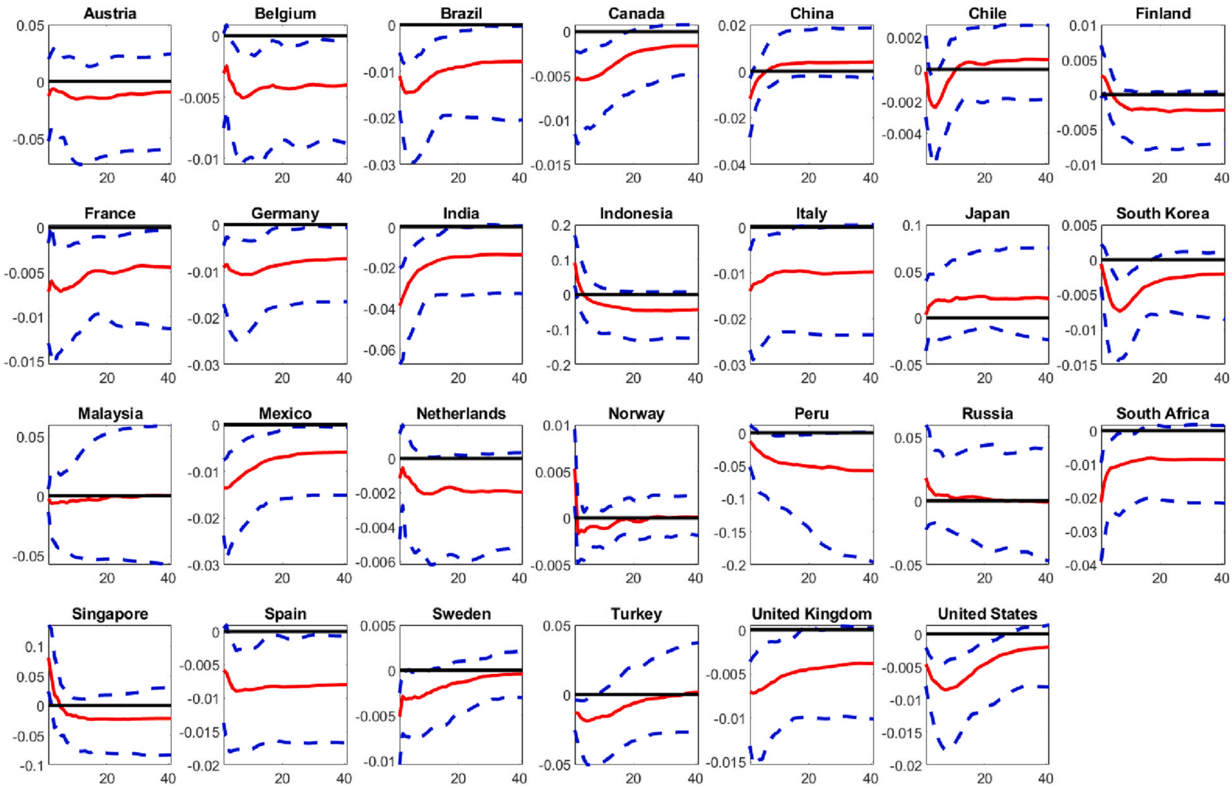

Fig. 10. Country-level real activity responses to BCTI shock
Notes: Impulse responses to a one-standard deviation positive reduced-form BCTI shock. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

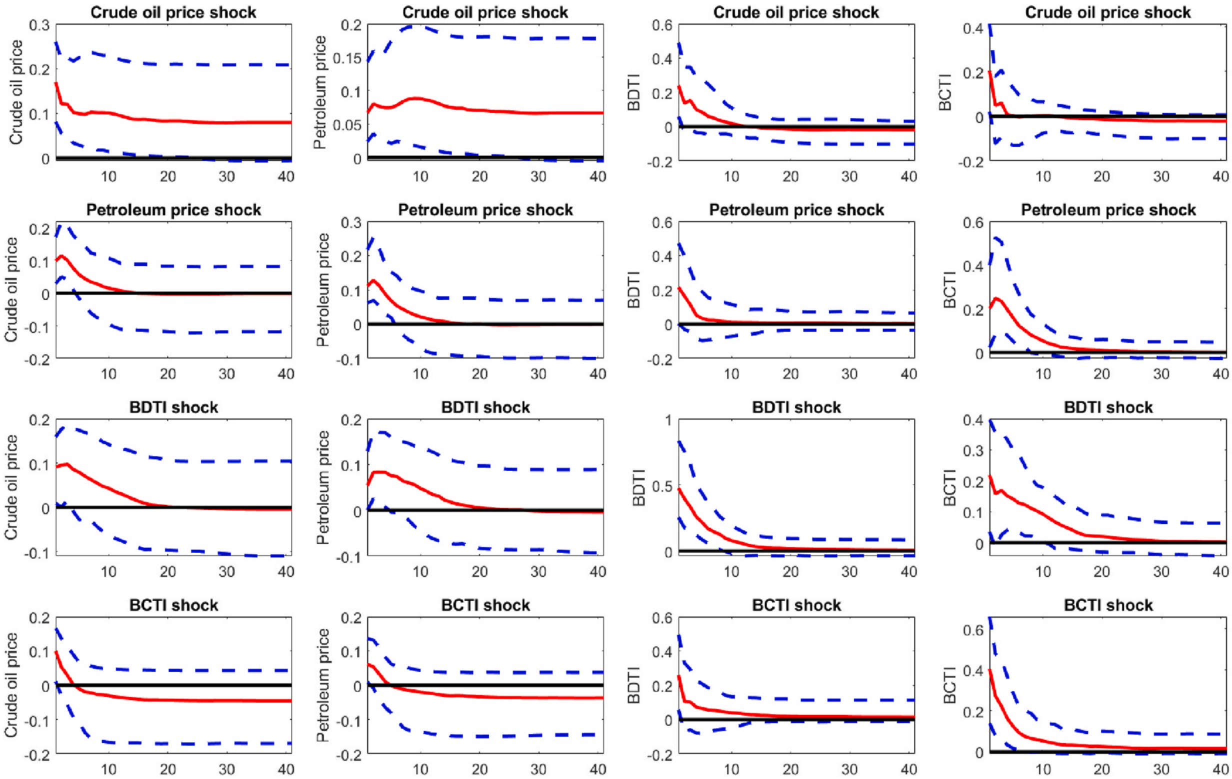

Fig. 11. Global variable responses to global shocks before the Covid-19 pandemic
Notes: Impulse responses to a one-standard deviation positive reduced-form shock to the global variables for the subsample ending in December 2019. Bootstrap median estimates with 90% bootstrap error bounds. All responses are in percentage.

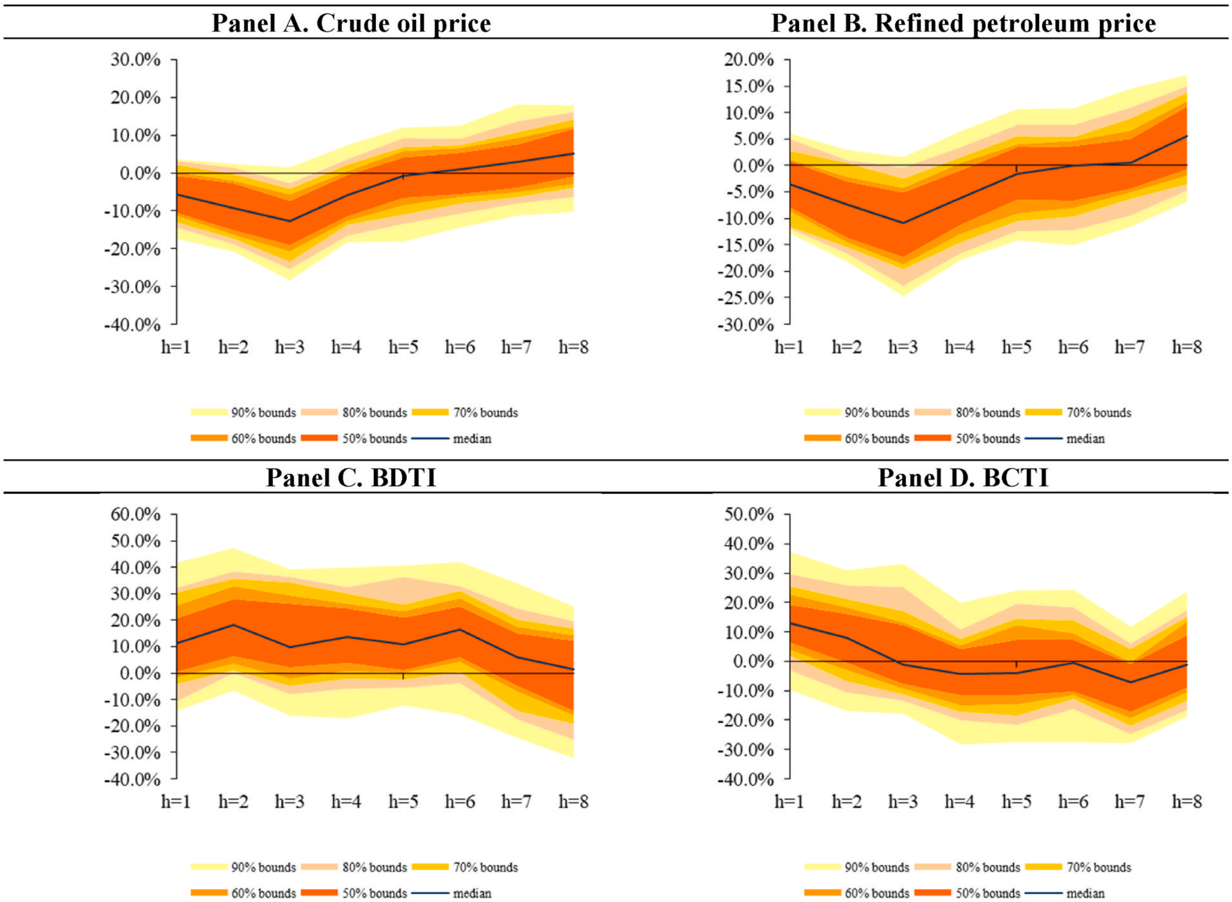

Fig. 12. The impact of the Covid-19 pandemic on the global variables
Notes: Impact of the Covid-19 shock in percentage deviation from the baseline.

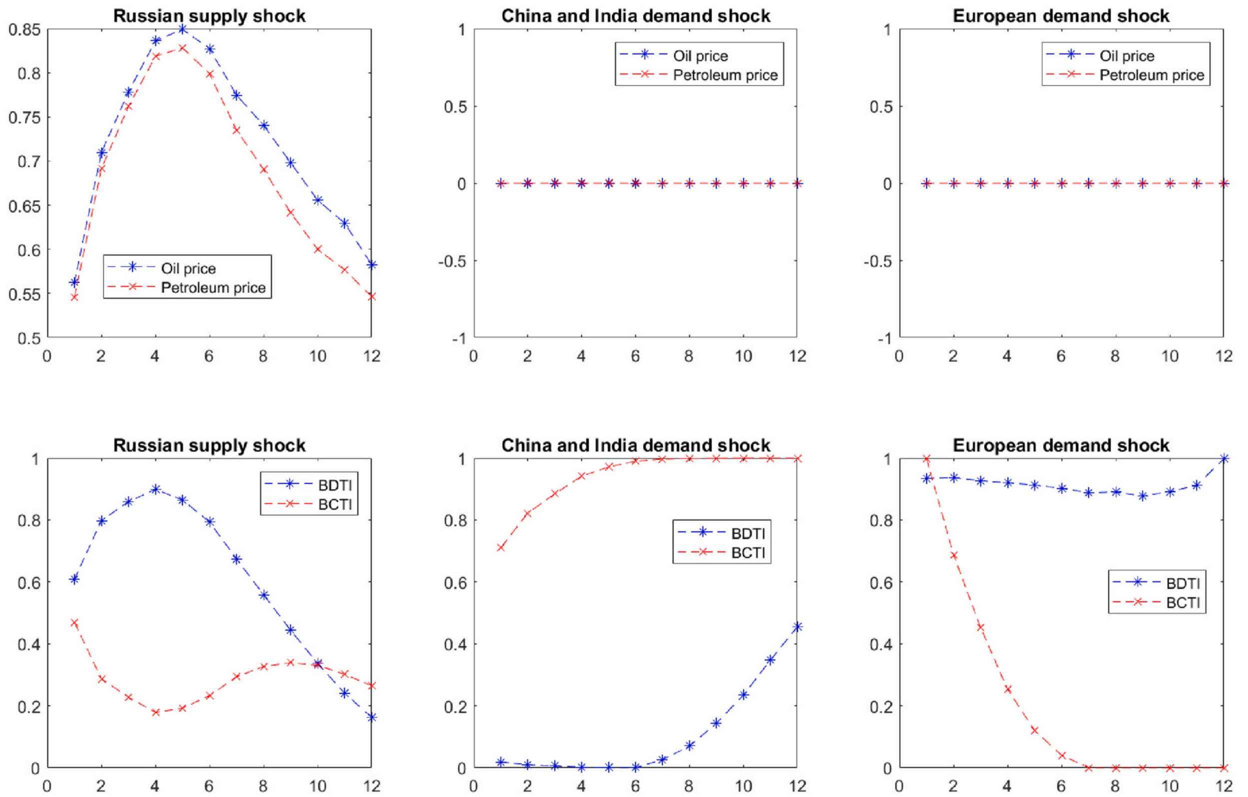

Fig. 13. The global variables and Russian oil sanctions
Notes: Probabilities of the responses being larger under the sanctions scenario.

Appendix A. Data Sources

A.1. Global variables

The price of crude oil is the Brent spot price in dollar per barrel, which is obtained from the EIA (Energy Information Administration). The petroleum price is computed by weighting the prices of individual petroleum commodities listed in Table A1 by their share of world total production. The resulting price is then multiplied by 42 to convert it from Dollars per gallon to Dollars per barrel. The Baltic Clean and Dirty Tanker indices are obtained from Bloomberg.

Table A.1
Petroleum product prices included in construction of the petroleum price

Variable	Description	Source
Gasoline	New York Harbor Conventional Gasoline Regular Spot Price FOB (Dollars per Gallon)	EIA
Diesel fuel	Los Angeles, CA Ultra-Low Sulfur CARB Diesel Spot Price (Dollars per Gallon)	EIA
Heating oil	New York Harbor No. 2 Heating Oil Spot Price FOB (Dollars per Gallon)	EIA
Kerosene	U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB (Dollars per Gallon)	EIA
Propane	Mont Belvieu, TX Propane Spot Price FOB (Dollars per Gallon)	EIA

Notes: Individual fuel prices to compute the aggregate petroleum price.

A.2. Country-specific oil market variables

All country-specific oil market variables are obtained from the EIA. The crude oil production data is total crude oil production including lease condensate; petroleum inventories are the country-level inventories from the monthly OECD petroleum and other liquids stocks dataset; and petroleum consumption data are obtained from the monthly OECD refined petroleum products consumption dataset.

A.3. Real activity

The real activity measure is the total industry production volume obtained from the OECD Key Economic Indicators database for all countries except Australia, China, Chile, Finland, Indonesia, Iran, Malaysia, Mexico, New Zealand, Peru, Philippines, South Africa, Singapore, Switzerland and Thailand for which the series are obtained from Bloomberg. For Australia and New Zealand we interpolated the quarterly real activity series using the multiplicative cubic spline method. We construct the real activity series by deflating the nominal industrial production series by the CPI index.

A.4. Consumer price index

The headline consumer price indices are obtained from the OECD national Consumer Price Indices for Energy (COICOP 1999) dataset for most countries except Australia, Iran, Malaysia, New Zealand, Peru, Philippines, Singapore and Thailand for which they are obtained from Bloomberg. For Australia and New Zealand we interpolated the quarterly inflation series using the multiplicative cubic spline method (Considine et al., 2023).

A.5. Short-term interest rates

Short-term interest rates are rates on 3-month government securities obtained from the OECD Key Economic Indicators database for most countries, except for Brazil, China, Chile, India, Iran, Malaysia, Peru, Philippines, Russia, Saudi Arabia, Singapore, Thailand and Turkey for which they are obtained from Bloomberg.

A.6. Long-term interest rates

Long-term interest rates are rates on 10-year government bonds obtained from the OECD Key Economic Indicators database for all countries except China, Chile, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Singapore, Thailand and Turkey for which they are obtained from Bloomberg. We could not obtain long-term interest rates for Iran and Saudi Arabia.

A.7. Real equity price index

All nominal equity price indices are obtained from Bloomberg with the exception of Iran, for which we could not obtain any equity price index. We construct the real equity price series by deflating the nominal series by the CPI index.

A.8. Exchange rates

The nominal exchange rates for all country currencies against the US dollar are obtained from the Pacific exchange rate service (PERS) except for the case of Iran for which the series is obtained from Bloomberg. The real exchange rate of all currencies vis-à-vis the US dollar is constructed by deflating the nominal exchange rate by the CPI index.

A.9. Weighting data

The bilateral trade weights are taken from the IMF direction of trade statistics database and are in monthly frequency. Exports (free on board) and imports (cost, insurance and freight) were averaged to construct the bilateral trade weights. We also obtain annual PPP-GDP weights from the World Bank for the regional analysis to aggregate groups of countries to represent regions and subregions as outlined in Table 2.

A.10. Transformations and seasonality

All variables are entered in logs except for the inflation series which is a month-on-month growth rate and the short- and long-term interest rate series which are included without any transformation. Following the method in Considine et al. (2023) seasonality tests were performed on all series and seasonal adjustment was performed when required using Census X-12, which decomposes the series into trend-cycle, seasonal, and irregular components and remove the seasonal factor to produce the seasonally adjusted series.

Appendix B. Unit Root, Weak Exogeneity and Structural Stability Test Results for Variables Included in the Model

Table B1
Unit root test results for the domestic variables for the first set of countries

Domestic variables	Statistic	Critical value	Australia	Austria	Belgium	Brazil	Canada	China	Chile	Finland	France	Germany	India
y (with trend)	ADF	−3.45		−0.38302	−3.18905	−2.62103	−2.4932	−1.50392	−1.10907	−1.93927	−3.68584	−1.57746	−2.65199
y (with trend)	WS	−3.24		−0.68265	−2.9142	−2.54038	−2.54556	0.682218	−0.87797	−1.93047	−3.83731	−1.64934	−2.33839
y (no trend)	ADF	−2.89		−0.03702	−3.27838	−0.00964	−1.14751	−3.52287	1.155893	−0.44204	−0.85675	−0.36731	−1.6548
y (no trend)	WS	−2.55		−0.2439	−2.59324	0.877154	0.123386	1.123714	0.889288	−0.66709	−0.22902	−0.627	−1.92793
Dy	ADF	−2.89		−12.0387	−16.1509	−12.3489	−13.4648	−18.4233	−15.5054	−17.1636	−16.096	−14.3045	−14.0393
Dy	WS	−2.55		−12.1409	−16.1537	−12.4272	−13.5705	−18.5083	−15.5754	−17.2633	−16.2087	−14.3901	−14.172
DDy	ADF	−2.89		−13.0284	−14.201	−12.7149	−13.9318	−15.9226	−14.9166	−15.2414	−13.63	−13.765	−15.5217
DDy	WS	−2.55		−13.1769	−14.3329	−12.7888	−14.0572	−16.196	−15.1061	−15.3675	−13.7793	−13.6934	−15.6931
inf (with trend)	ADF	−3.45	−7.70054	−6.20013	−6.95706	−7.63432	−11.1757	−10.3661	−8.51604	−9.9686	−11.4156	−10.2702	−9.17271
inf (with trend)	WS	−3.24	−7.65373	−6.3174	−7.05498	−7.56857	−11.2588	−10.4247	−8.61549	−9.99782	−11.5158	−10.3715	−9.30655
inf (no trend)	ADF	−2.89	−7.70509	−5.85628	−6.86858	−7.53236	−11.1356	−10.3842	−8.37308	−9.86879	−11.3877	−10.0602	−9.18949
inf (no trend)	WS	−2.55	−7.67745	−5.99667	−6.98346	−7.51886	−11.2257	−10.4422	−8.47559	−9.9252	−11.4834	−10.1528	−9.32293
Dinf	ADF	−2.89	−12.5356	−17.8103	−21.1727	−15.9202	−15.4568	−13.932	−12.6991	−16.3427	−14.0634	−15.2334	−13.4094
Dinf	WS	−2.55	−12.5154	−18.9398	−21.2621	−16.02	−15.5781	−14.0181	−12.8113	−16.5703	−14.2198	−15.3934	−13.5693
DDinf	ADF	−2.89	−12.6016	−18.8935	−18.4244	−13.9876	−15.8704	−16.6107	−18.203	−18.1817	−17.5958	−16.7295	−17.8338
DDinf	WS	−2.55	−12.5436	−20.0029	−18.5964	−13.9825	−16.0625	−15.3187	−18.3844	−19.0342	−17.6571	−16.846	−18.2491
st (with trend)	ADF	−3.45	−2.76157	−1.6031	−1.6031	−3.41765	−1.84537	−2.72821	−2.83943	−1.6031	−1.6031	−1.6031	−3.33396
st (with trend)	WS	−3.24	−2.95383	−1.89075	−1.89075	−3.5858	−1.72892	−2.91208	−2.99049	−1.89075	−1.89075	−1.89075	−1.60078
st (no trend)	ADF	−2.89	−2.30269	−1.99759	−1.99759	−2.61833	−2.28719	−2.85353	−2.65883	−1.99759	−1.99759	−1.99759	−3.47517
st (no trend)	WS	−2.55	−2.27473	−1.98093	−1.98093	−2.52362	−1.70949	−2.9904	−2.57268	−1.98093	−1.98093	−1.98093	−1.38658
Dst	ADF	−2.89	−5.97215	−5.52743	−5.52743	−5.55935	−6.63768	−12.8901	−6.70331	−5.52743	−5.52743	−5.52743	−11.182
Dst	WS	−2.55	−5.97018	−5.11503	−5.11503	−5.65673	−6.64056	−12.9954	−6.81176	−5.11503	−5.11503	−5.11503	−11.2843
DDst	ADF	−2.89	−19.0285	−10.3883	−10.3883	−17.4748	−11.5812	−15.4573	−18.4319	−10.3883	−10.3883	−10.3883	−14.6347
DDst	WS	−2.55	−19.154	−10.5207	−10.5207	−17.5945	−11.7219	−15.6095	−18.5554	−10.5207	−10.5207	−10.5207	−14.7991
lt (with trend)	ADF	−3.45	−1.87115	−0.7577	−0.51344	−2.29248	−1.32263	−1.65851	−2.16015	−0.16617	−0.40715	−0.72244	−1.98859
lt (with trend)	WS	−3.24	−2.00993	−0.99479	−0.84356	−2.09271	−1.07484	−1.68527	−2.00132	−0.50171	−0.71954	−0.95636	−2.12311
lt (no trend)	ADF	−2.89	−1.9536	−1.78798	−1.61637	−2.09463	−2.22283	−2.03315	−2.20048	−1.64405	−1.65127	−1.78784	−1.21361
lt (no trend)	WS	−2.55	−1.18258	−0.81404	−0.74648	−0.99879	−0.55301	−1.30065	−1.47083	−0.57513	−0.66765	−0.72249	−1.20544
Dlt	ADF	−2.89	−10.5825	−11.3809	−11.8934	−5.34235	−11.9901	−10.9348	−12.0662	−12.1889	−11.9056	−11.3229	−12.2704
Dlt	WS	−2.55	−10.4731	−11.4646	−11.9793	−4.80106	−11.927	−11.037	−12.1699	−12.2518	−11.9719	−11.3941	−12.3745
DDlt	ADF	−2.89	−13.3541	−16.3995	−14.2478	−37.8429	−12.721	−12.8865	−12.7562	−17.2876	−13.5837	−16.1269	−14.5425
DDlt	WS	−2.55	−13.505	−16.5181	−14.4016	−37.2442	−12.7276	−13.0393	−12.9077	−17.4162	−13.7371	−16.2321	−14.7051
equ (with trend)	ADF	−3.45	−0.40612	−2.23214	−2.37049	−2.27208	−3.21136	−2.61516	−1.59939	−3.516	−2.54841	−3.55799	−2.54589
equ (with trend)	WS	−3.24	−0.80196	−2.08277	−2.5395	−2.47377	−3.18717	−2.8049	−1.75492	−1.40021	−1.7031	−2.02365	−2.55388
equ (no trend)	ADF	−2.89	−0.86643	−2.32778	−2.37012	−1.82761	−1.73792	−2.57955	−1.71211	−3.59765	−2.39796	−1.02494	−0.85754
equ (no trend)	WS	−2.55	−0.75543	−1.91227	−2.48826	−1.9611	−1.91037	−2.70283	−0.84132	−1.28635	−1.7175	−1.35526	−0.89991
Dequ	ADF	−2.89	−13.1458	−10.3342	−11.5749	−12.2105	−11.2072	−10.3913	−11.6205	−12.9321	−12.4463	−12.5533	−12.1567
Dequ	WS	−2.55	−2.70921	−10.4352	−11.6751	−12.2824	−11.1575	−10.3416	−11.7041	−12.9761	−12.4394	−12.573	−12.2555
DDequ	ADF	−2.89	−13.284	−16.1373	−15.1902	−13.5139	−13.7497	−14.7897	−13.3044	−13.2067	−12.9254	−13.2255	−13.7981
DDequ	WS	−2.55	−3.82081	−16.2757	−15.317	−13.6872	−13.9059	−14.9155	−13.2766	−13.3267	−12.9065	−12.923	−13.9495

(*continued on next page*)

Table B1 (*continued*)

Domestic variables	Statistic	Critical value	Australia	Austria	Belgium	Brazil	Canada	China	Chile	Finland	France	Germany	India
rer (with trend)	ADF	−3.45		−2.16212	−2.07617	−1.66756	−1.7676	−0.45744	−4.27312	−2.1143	−2.0315	−2.11337	−1.70127
rer (with trend)	WS	−3.24		−2.09564	−1.98974	−1.94512	−1.68058	−0.88034	−4.42722	−2.00315	−1.90021	−2.05859	−1.94229
rer (no trend)	ADF	−2.89		−1.86313	−1.95091	−1.66963	−1.83826	−1.44266	−3.0399	−2.09519	−2.1454	−2.03665	−1.33529
rer (no trend)	WS	−2.55		−0.60399	−0.64103	−1.64214	−0.42271	0.054051	−3.11296	−0.9738	−1.06962	−1.01048	0.245493
Drer	ADF	−2.89		−11.1212	−11.1022	−10.1242	−10.5735	−10.1713	−10.8891	−10.9043	−10.8885	−11.0603	−11.5526
Drer	WS	−2.55		−11.1294	−11.0984	−10.2044	−10.6754	−10.2667	−11.0013	−10.9291	−10.8834	−11.0323	−11.6558
DDrer	ADF	−2.89		−13.0717	−12.8629	−13.748	−14.198	−13.1488	−8.42708	−12.7336	−12.8336	−12.6929	−14.1348
DDrer	WS	−2.55		−12.9292	−12.6862	−13.8998	−14.3497	−13.1892	−8.55159	−12.6065	−12.6247	−12.5272	−14.345
oilpro (with trend)	ADF	−3.45	−0.92647	0.530172	−2.10027	−0.16883	−0.1697	−0.20325	−3.76476	−2.05003	0.022131	−0.18649	−0.12213
oilpro (with trend)	WS	−3.24	−1.34178	0.113045	−2.22544	−0.67849	−0.69524	−0.72407	−3.94846	−2.09169	−0.34584	−0.61861	−0.63988
oilpro (no trend)	ADF	−2.89	0.004963	0.731137	−1.92925	−1.05172	−0.75652	−0.44885	−3.56237	−1.80296	−0.9449	−0.78005	−0.01759
oilpro (no trend)	WS	−2.55	−0.06281	0.524792	−2.04622	−1.14085	−0.93329	−0.65377	−3.68983	−1.96949	−1.09894	−0.87356	−0.24304
Doilpro	ADF	−2.89	−12.6309	−12.4793	−11.9791	−11.8997	−11.9634	−12.0296	−14.8012	−11.9791	−12.2039	−12.0058	−12.0727
Doilpro	WS	−2.55	−12.7357	−12.5837	−12.083	−12.0021	−12.0668	−12.1332	−14.9116	−12.083	−12.308	−12.1045	−12.176
DDoilpro	ADF	−2.89	−12.9889	−17.4271	−12.9297	−22.4299	−22.4612	−22.6934	−13.1627	−12.9186	−12.944	−15.5944	−22.8142
DDoilpro	WS	−2.55	−13.1693	−17.5705	−13.0754	−22.4238	−22.4546	−22.6824	−13.3061	−13.0633	−13.1139	−15.8666	−22.8034
petcon (with trend)	ADF	−3.45	−2.83857	−4.0499	−4.23549		−2.99271		−2.46416	−2.60262	−4.82111	−5.35741	
petcon (with trend)	WS	−3.24	−3.014	−3.25696	−4.10063		−1.69369		−2.68292	−2.54778	−4.92524	−5.38576	
petcon (no trend)	ADF	−2.89	−2.0623	−2.48499	−3.86113		−3.11832		−1.31628	−0.86423	−2.03055	−1.70362	
petcon (no trend)	WS	−2.55	−1.65888	−2.55971	−3.92871		−0.63237		−0.77369	−1.07063	−1.82888	−1.68547	
Dpetcon	ADF	−2.89	−7.56666	−8.20363	−15.6143		−20.4324		−10.8028	−10.7888	−21.2539	−12.636	
Dpetcon	WS	−2.55	−7.82838	−8.28418	−15.725		−20.4037		−10.8016	−10.8289	−21.3535	−12.768	
DDpetcon	ADF	−2.89	−19.7958	−11.9641	−13.4531		−15.2519		−14.6301	−13.7143	−16.5121	−16.9597	
DDpetcon	WS	−2.55	−19.8195	−12.0569	−13.5887		−15.8126		−14.761	−13.8576	−16.624	−17.1495	
petinv (with trend)	ADF	−3.45					−5.07766				−2.83954	−2.59342	
petinv (with trend)	WS	−3.24					−4.80724				−2.46835	−2.31773	
petinv (no trend)	ADF	−2.89					−2.15729				−1.56799	−2.60064	
petinv (no trend)	WS	−2.55					−0.93504				−1.82565	−2.35318	
Dpetinv	ADF	−2.89					−12.8835				−17.7342	−13.8814	
Dpetinv	WS	−2.55					−12.9889				−17.8411	−13.7956	
DDpetinv	ADF	−2.89					−14.0828				−16.0754	−13.7105	
DDpetinv	WS	−2.55					−14.2366				−16.2496	−13.7455	

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B2
Unit root test results for the domestic variables for the second set of countries

Domestic variables	Statistic	Critical value	Indonesia	Iran	Italy	Japan	South Korea	Malaysia	Mexico	Netherlands	Peru	Philippines
y (with trend)	ADF	−3.45	−1.87096		−3.30713	−1.31591	−2.24808	−0.03079	−3.79152	−2.98756	−3.5732	
y (with trend)	WS	−3.24	−1.73443		−3.45729	−1.4526	−2.21371	−0.82793	−3.50316	−3.04843	−3.69234	
y (no trend)	ADF	−2.89	−2.11413		−1.25348	−0.30533	−2.15114	−1.23377	−1.28275	−1.74718	−0.85479	
y (no trend)	WS	−2.55	−0.97267		−0.37271	−0.60738	−1.01478	−1.44186	0.662796	−1.18485	0.196497	
Dy	ADF	−2.89	−12.085		−15.9284	−11.9697	−13.2688	−3.10134	−15.7716	−14.3328	−14.1049	
Dy	WS	−2.55	−12.1886		−16.0392	−12.0725	−13.3747	−3.49562	−15.8712	−14.4413	−14.2176	
DDy	ADF	−2.89	−12.9266		−14.2401	−12.9484	−14.1254	−9.24412	−14.4264	−14.8848	−15.5742	
DDy	WS	−2.55	−13.0794		−14.3986	−13.1015	−14.33	−9.87589	−14.6347	−15.0145	−15.8392	
inf (with trend)	ADF	−3.45	−11.9974	−7.13316	−8.11034	−12.492	−13.9834	−11.34	−9.4894	−13.5302	−12.5667	−8.872
inf (with trend)	WS	−3.24	−11.9596	−7.24025	−8.21311	−12.5724	−14.0837	−11.4348	−9.58845	−13.6083	−12.6667	−8.93504
inf (no trend)	ADF	−2.89	−10.8721	−5.19085	−8.12326	−12.4639	−13.8792	−11.3588	−9.50582	−13.4605	−12.3465	−8.85254
inf (no trend)	WS	−2.55	−10.9316	−5.27255	−8.22624	−12.5324	−13.9851	−11.454	−9.605	−13.5531	−12.4508	−8.92652
Dinf	ADF	−2.89	−13.505	−18.0452	−16.7501	−15.8809	−16.4981	−12.9695	−15.9746	−16.3552	−15.8177	−13.0459
Dinf	WS	−2.55	−13.614	−18.1087	−16.895	−16.0381	−16.7445	−13.1173	−16.0039	−16.4741	−15.9876	−13.2327
DDinf	ADF	−2.89	−15.9343	−14.0443	−19.721	−21.277	−18.6146	−14.6378	−17.1851	−18.7885	−19.7366	−16.0831
DDinf	WS	−2.55	−15.994	−14.3179	−19.9121	−21.4572	−18.7178	−14.7779	−17.2855	−18.945	−19.9186	−16.285
st (with trend)	ADF	−3.45	−2.97005	−1.69243	−1.6031	−1.74997	−1.93882	−1.83906	−1.70169	−1.6031	−1.93933	−2.25245
st (with trend)	WS	−3.24	−3.13957	−1.27212	−1.89075	−1.48884	−1.48364	−1.6171	−0.22922	−1.89075	−2.12204	−2.41601
st (no trend)	ADF	−2.89	−2.34412	−1.36827	−1.99759	−1.4844	−2.44415	−2.06541	−2.26714	−1.99759	−2.27854	−2.25145
st (no trend)	WS	−2.55	−2.08591	−1.30799	−1.98093	−1.63564	−0.70173	−0.95237	0.056904	−1.98093	−1.88065	−1.8566
Dst	ADF	−2.89	−6.95751	−11.9398	−5.52743	−6.65381	−9.33716	−10.7828	−5.976	−5.52743	−6.12254	−8.15401
Dst	WS	−2.55	−7.03208	−12.0435	−5.11503	−6.77543	−9.39116	−10.8846	−5.96885	−5.11503	−6.19679	−8.01031
DDst	ADF	−2.89	−12.9082	−14.0042	−10.3883	−16.529	−12.0804	−12.5468	−9.51083	−10.3883	−12.6368	−14.4671
DDst	WS	−2.55	−13.0283	−14.1641	−10.5207	−16.6732	−12.2076	−12.6977	−10.4243	−10.5207	−12.7449	−14.6246
lt (with trend)	ADF	−3.45	−0.56533		−2.04484	−1.5168	−4.84512	−4.4503	−3.62569	−0.60756	−1.11729	−1.33899
lt (with trend)	WS	−3.24	−0.68832		−2.23723	−1.75737	−2.24651	−3.59355	−2.35371	−0.8537	−1.2638	−1.42084
lt (no trend)	ADF	−2.89	−1.35353		−2.06503	−1.84032	−3.16297	−4.04502	−3.67904	−1.77238	−1.89897	−1.92344
lt (no trend)	WS	−2.55	−1.35956		−1.75904	−1.45036	−2.40922	−2.48876	−2.18877	−0.73326	−0.8569	−0.67062
Dlt	ADF	−2.89	−8.67871		−11.2633	−12.8878	−13.0502	−12.3664	−12.8505	−11.2442	−10.6637	−11.8259
Dlt	WS	−2.55	−8.78075		−11.3548	−12.9407	−13.1562	−12.471	−12.9559	−11.3214	−10.7318	−11.8175
DDlt	ADF	−2.89	−13.081		−12.4679	−14.3667	−14.7818	−13.2413	−13.3096	−16.6484	−12.8134	−13.3359
DDlt	WS	−2.55	−13.1188		−12.5731	−14.4586	−14.9465	−13.397	−13.4642	−16.775	−12.8389	−13.3678
equ (with trend)	ADF	−3.45	−1.99891	−0.70296	−1.81694	−1.40035	−2.98837	0.796826	−1.0676	−2.49878	−2.83897	−1.4089
equ (with trend)	WS	−3.24	−2.0328	−1.00536	−1.54164	−1.66377	−3.09504	0.293216	−1.34971	−1.28609	−2.90181	−1.30084
equ (no trend)	ADF	−2.89	−1.24836	−1.46006	−2.49992	−0.78053	−2.01963	−0.2772	−1.49855	−2.35671	−0.89013	−1.27205
equ (no trend)	WS	−2.55	−1.23097	−1.47602	−1.01964	−0.98872	−2.04481	−0.47301	−0.64804	−1.31084	−0.66489	−1.5529
Dequ	ADF	−2.89	−8.25419	−11.9182	−12.771	−12.0012	−8.81013	−4.80296	−7.55529	−11.2889	−10.9213	−11.1552
Dequ	WS	−2.55	−8.09693	−12.0205	−12.8121	−12.1034	−8.45157	−5.07031	−7.54458	−11.3492	−11.0234	−10.9801
DDequ	ADF	−2.89	−13.1399	−12.5724	−14.6869	−12.923	−14.0056	−12.9584	−13.915	−12.8759	−15.6871	−13.811
DDequ	WS	−2.55	−13.1203	−13.0723	−14.7832	−13.0737	−13.8202	−13.2976	−14.0636	−12.9923	−15.8268	−13.4027
rer (with trend)	ADF	−3.45	−1.41182	−2.2977	−2.00203	−2.35316	−2.05966		−1.73523	−2.18	−2.14169	−1.36967
rer (with trend)	WS	−3.24	−1.6395	−2.21905	−1.81236	−2.46783	−2.20988		−1.86875	−1.9617	−1.89093	−1.27392
rer (no trend)	ADF	−2.89	−1.68164	−1.10307	−2.1388	−2.10968	−1.81201		−1.37057	−2.07501	−2.38839	−0.69445
rer (no trend)	WS	−2.55	−0.63851	−1.35226	−0.83535	−2.35611	−1.00755		−1.20635	−0.62571	−1.64559	−0.58115
Drer	ADF	−2.89	−12.9041	−11.9971	−10.9262	−9.62557	−11.8359		−12.3417	−11.0341	−11.4963	−10.0679
Drer	WS	−2.55	−12.9715	−12.1009	−10.9206	−9.72164	−11.9251		−12.4112	−11.0619	−11.5384	−10.1448
DDrer	ADF	−2.89	−13.6424	−12.9331	−13.0308	−11.9906	−14.3892		−14.2651	−12.9979	−13.4875	−13.4834
DDrer	WS	−2.55	−13.7116	−13.0799	−12.8784	−11.617	−14.5506		−14.3405	−12.842	−13.4755	−13.7262
oilpro (with trend)	ADF	−3.45	−0.4512	−0.6189	−1.70961	0.471725	−0.92843	−0.05557	−0.42492	−0.63828	−0.70865	−1.73752

(*continued on next page*)

Table B2 (*continued*)

Domestic variables	Statistic	Critical value	Indonesia	Iran	Italy	Japan	South Korea	Malaysia	Mexico	Netherlands	Peru	Philippines
oilpro (with trend)	WS	−3.24	−0.95258	−1.08985	−2.00099	0.221564	−1.26293	−0.57109	−0.90713	−1.0611	−1.18523	0.278926
oilpro (no trend)	ADF	−2.89	0.266464	−0.35627	−1.88374	1.810833	−1.78038	0.434237	0.547828	−0.99965	0.170489	−1.93565
oilpro (no trend)	WS	−2.55	0.098085	−0.57102	−1.9703	1.55395	−1.83078	0.196264	0.329959	−1.16972	−0.00939	0.272396
Doilpro	ADF	−2.89	−12.0239	−12.0324	−8.46721	−12.2879	−14.0727	−12.0011	−12.034	−12.1919	−12.058	−10.817
Doilpro	WS	−2.55	−12.1273	−12.1326	−8.60747	−12.375	−14.1789	−12.1043	−12.1377	−12.2961	−12.1614	−10.9192
DDoilpro	ADF	−2.89	−22.5032	−22.5093	−15.0021	−23.5563	−14.8575	−22.4904	−22.7243	−16.865	−22.5992	−14.9
DDoilpro	WS	−2.55	−22.4966	−22.5058	−15.1222	−23.5956	−14.953	−22.4885	−22.712	−17.0114	−22.5988	−15.0333
petcon (with trend)	ADF	−3.45			−4.6798	−3.51034	−4.59855		−3.03168	−3.02145	−5.4243	
petcon (with trend)	WS	−3.24			−4.78271	−3.30107	−4.62733		−3.12583	−1.66658	−5.56306	
petcon (no trend)	ADF	−2.89			−1.48703	−0.72802	−2.08819		−2.23357	−0.95918	−5.40192	
petcon (no trend)	WS	−2.55			−1.17353	−0.4592	−2.09177		−2.42091	−1.14805	−5.50432	
Dpetcon	ADF	−2.89			−11.9433	−17.8179	−14.6156		−7.22628	−9.40585	−21.6139	
Dpetcon	WS	−2.55			−12.0872	−16.8508	−14.6544		−7.36967	−9.5105	−21.5809	
DDpetcon	ADF	−2.89			−14.6162	−15.6883	−14.7387		−10.6157	−12.7622	−12.491	
DDpetcon	WS	−2.55			−14.7176	−15.4803	−14.5419		−10.7389	−12.8391	−12.5936	
petinv (with trend)	ADF	−3.45			−2.83956	−3.29923	−1.66736					
petinv (with trend)	WS	−3.24			−2.76639	−2.48704	−1.87678					
petinv (no trend)	ADF	−2.89			−1.34194	0.780367	−1.74378					
petinv (no trend)	WS	−2.55			−1.40986	0.578719	−0.96191					
Dpetinv	ADF	−2.89			−16.4705	−11.7517	−14.1291					
Dpetinv	WS	−2.55			−16.5665	−11.8929	−14.2307					
DDpetinv	ADF	−2.89			−17.3272	−16.3968	−13.4431					
DDpetinv	WS	−2.55			−17.3473	−16.3039	−13.9323					

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B3
Unit root test results for the domestic variables for the third set of countries

Domestic variables	Statistic	Critical value	South Africa	Saudi Arabia	Singapore	Spain	Sweden	Switzerland	Thailand	Turkey	United Kingdom	United States
y (with trend)	ADF	−3.45	−3.44539	−3.8442		−0.47811	−2.25196	−2.75447			0.379886	−2.31567
y (with trend)	WS	−3.24	−0.84243	−3.8444		−0.47992	−2.44232	−2.76152			1.067709	−2.28114
y (no trend)	ADF	−2.89	−2.12072	−0.09885		−1.79678	−1.18597	−1.13831			1.152054	−0.10145
y (no trend)	WS	−2.55	−0.93813	0.588233		−0.87621	0.050689	−1.27733			4.453548	0.103843
Dy	ADF	−2.89	−12.0299	−13.748		−8.7234	−14.3465	−14.8566			−11.3117	−13.6697
Dy	WS	−2.55	−12.1339	−13.8582		−8.82588	−14.4533	−14.8262			−11.4007	−13.777
DDy	ADF	−2.89	−12.999	−14.2032		−10.2463	−14.129	−13.6515			−15.2655	−13.9529
DDy	WS	−2.55	−13.1525	−14.3606		−10.1476	−14.296	−14.1233			−15.528	−14.1141
inf (with trend)	ADF	−3.45	−8.60896	−7.4781	−10.7983	−6.65143	−16.2729	−11.652	−15.4668	−10.2326	−3.55675	−10.4729
inf (with trend)	WS	−3.24	−8.55066	−7.58673	−10.7951	−6.77257	−16.4159	−11.7347	−15.6053	−10.3341	−3.66916	−10.5739
inf (no trend)	ADF	−2.89	−8.35296	−7.49057	−10.8122	−6.6147	−16.2769	−11.3173	−15.4916	−10.18	−3.42528	−10.1163
inf (no trend)	WS	−2.55	−8.36393	−7.59991	−10.7962	−6.72864	−16.4208	−11.4169	−15.63	−10.2789	−3.5614	−10.2129
Dinf	ADF	−2.89	−11.597	−13.3336	−13.7598	−14.1301	−22.234	−18.2969	−19.5772	−13.3243	−13.4572	−19.7507
Dinf	WS	−2.55	−11.7426	−13.3819	−13.7948	−14.3982	−22.4653	−18.4561	−20.2252	−13.4779	−13.228	−19.9557
DDinf	ADF	−2.89	−14.7002	−15.9703	−17.4899	−17.6115	−25.9852	−18.0835	−22.9096	−15.0931	−18.6713	−21.4054
DDinf	WS	−2.55	−14.8641	−16.0118	−17.4902	−17.4737	−26.2709	−18.384	−24.4528	−15.2747	−18.645	−22.0825
st (with trend)	ADF	−3.45	−3.8101	−1.77751	−1.86403	−1.11804	−1.6031	−1.50319	−1.29545	−1.8921	−1.8921	−0.59091
st (with trend)	WS	−3.24	−2.60972	−2.01052	−1.5685	−1.36014	−1.89075	−1.81525	−1.61968	−2.00523	−2.00523	−0.80138
st (no trend)	ADF	−2.89	−3.54716	−1.89045	−2.25322	−1.18435	−1.99759	−2.08588	−2.03975	−1.09444	−1.09444	−1.64094
st (no trend)	WS	−2.55	−1.78849	−1.74079	−1.55866	−1.38733	−1.98093	−1.92701	−1.80792	−0.99579	−0.99579	−1.0201
Dst	ADF	−2.89	−10.4173	−8.07415	−5.72186	−13.4771	−5.52743	−6.4811	−7.67819	−12.0416	−12.0416	−6.04573
Dst	WS	−2.55	−8.92725	−8.14795	−5.68008	−13.5267	−5.11503	−6.33566	−6.93811	−12.1451	−12.1451	−6.14832
DDst	ADF	−2.89	−13.5059	−15.3226	−12.318	−13.6567	−10.3883	−15.3579	−12.6378	−12.9846	−12.9846	−11.9791
DDst	WS	−2.55	−12.1617	−15.2404	−12.387	−13.7541	−10.5207	−15.1322	−12.6004	−13.1381	−13.1381	−12.0912
lt (with trend)	ADF	−3.45		−2.46672		−3.25786	−1.52223	−1.16642	−1.25378	−4.22707	−3.31523	−0.37615
lt (with trend)	WS	−3.24		−0.66352		−3.07141	−1.77909	−1.38675	−1.47188	−3.51619	−3.26863	−0.7241
lt (no trend)	ADF	−2.89		−2.65681		−3.13207	−1.72751	−1.7029	−1.76302	−2.92747	−0.61104	−1.48089
lt (no trend)	WS	−2.55		−0.62526		−2.36692	−1.33335	−0.64326	−0.65365	−1.26424	−0.60979	−0.8762
Dlt	ADF	−2.89		−13.4103		−12.2473	−11.8969	−11.1931	−12.3916	−12.1345	−10.7476	−11.9262
Dlt	WS	−2.55		−13.4703		−12.3104	−11.9796	−11.1549	−12.3021	−12.174	−10.8491	−11.8948
DDlt	ADF	−2.89		−12.9292		−13.5401	−12.824	−12.5467	−12.5426	−16.4716	−15.6007	−15.7046
DDlt	WS	−2.55		−12.9174		−13.5508	−12.8884	−12.167	−12.5616	−16.6129	−15.7419	−15.7852
equ (with trend)	ADF	−3.45	−1.48071	−1.91098	−2.19635	0.15314	−2.95026	−4.15342	−2.42023	1.032312	−3.40219	−3.00245
equ (with trend)	WS	−3.24	−0.60046	−2.07536	−1.48674	−0.13989	−2.76083	−2.25288	−2.18239	0.472079	−1.81685	−2.41395
equ (no trend)	ADF	−2.89	−2.30783	−1.73165	−2.38268	−0.4731	−2.83019	−0.14915	−1.29973	−1.07915	−2.49684	−3.06728
equ (no trend)	WS	−2.55	−0.76026	−0.7283	−1.08425	−0.58675	−1.92085	−0.66489	−1.61767	−1.047	−1.91911	−2.22387
Dequ	ADF	−2.89	−7.10856	−11.7383	−10.4903	−3.35137	−13.1057	−8.20793	−11.0398	−6.31654	−12.6887	−12.7134
Dequ	WS	−2.55	−7.21501	−11.7889	−10.5922	−3.54135	−13.1296	−8.1657	−11.0489	−6.36417	−12.7489	−12.7868
DDequ	ADF	−2.89	−14.4002	−13.0376	−12.7826	−6.30228	−13.6464	−14.655	−14.3674	−18.1586	−14.2205	−15.2977
DDequ	WS	−2.55	−14.473	−13.1273	−12.9068	−6.33162	−13.2022	−14.4829	−14.5237	−18.0918	−14.3396	−15.4565
rer (with trend)	ADF	−3.45	−1.43175	−2.45907	−1.23169		−1.97599	−2.10163	−2.10073		−1.57805	−2.32346
rer (with trend)	WS	−3.24	0.408214	−2.66145	−0.65738		−1.70698	−2.15004	−2.01803		−1.41499	−2.42322
rer (no trend)	ADF	−2.89	−2.64505	−2.42041	0.005986		−2.15852	−2.20471	−1.84308		−1.59561	−2.06972
rer (no trend)	WS	−2.55	0.047453	−2.50488	1.0892		−0.63162	−1.91601	−0.17626		−1.41055	−1.71994
Drer	ADF	−2.89	−6.60552	−11.2149	−10.8837		−10.9838	−10.893	−11.9575		−12.9441	−10.0584
Drer	WS	−2.55	−6.71695	−11.2772	−10.7772		−10.9769	−10.9862	−11.9469		−13.0499	−10.0898
DDrer	ADF	−2.89	−12.5241	−13.3541	−13.5438		−13.4219	−13.8646	−13.2446		−13.5371	−15.8783
DDrer	WS	−2.55	−12.5947	−13.4718	−13.6032		−13.2541	−13.9332	−13.2117		−13.6951	−15.9958
oilpro (with trend)	ADF	−3.45	−0.01788	−0.51693	−0.00383	−1.95801	−0.81048	1.017077	−1.52799	0.717843	−0.89492	−0.34737

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Table B3 (*continued*)

Domestic variables	Statistic	Critical value	South Africa	Saudi Arabia	Singapore	Spain	Sweden	Switzerland	Thailand	Turkey	United Kingdom	United States
oilpro (with trend)	WS	−3.24	−0.52812	−0.94134	−0.53203	−2.21419	−1.09884	0.61276	−1.31802	0.209635	−0.81469	−0.82864
oilpro (no trend)	ADF	−2.89	−0.21537	0.957915	−0.05234	−1.98008	−1.67773	−1.42756	−2.03562	−0.22762	−1.99953	0.888806
oilpro (no trend)	WS	−2.55	−0.40551	0.782812	−0.27247	−2.21031	−1.58773	−0.7493	−1.35124	−0.26975	−1.03933	0.845167
Doilpro	ADF	−2.89	−12.0274	−11.98	−12.0861	−11.9791	−11.8173	−11.9313	−11.9791	−12.0631	−12.0623	−12.1677
Doilpro	WS	−2.55	−12.1307	−12.0832	−12.1896	−12.083	−11.9208	−12.035	−12.083	−12.1645	−12.1663	−12.2715
DDoilpro	ADF	−2.89	−22.6739	−22.2203	−22.8884	−12.9846	−12.6868	−15.58	−12.9011	−22.6528	−12.2037	−22.572
DDoilpro	WS	−2.55	−22.6635	−22.2281	−22.8767	−13.1381	−12.8137	−15.8386	−13.0444	−22.6478	−12.3341	−22.5881
petcon (with trend)	ADF	−3.45					−2.66762	−6.39448	−4.31875		−2.85555	−4.95211
petcon (with trend)	WS	−3.24					−2.42572	−6.37574	−4.27479		−2.76869	−5.02879
petcon (no trend)	ADF	−2.89					−1.75098	−2.51249	−1.40565		−0.40785	−2.98599
petcon (no trend)	WS	−2.55					−2.02182	−1.94206	−1.42323		−0.38398	−3.02103
Dpetcon	ADF	−2.89					−8.59001	−7.92277	−7.62581		−8.78909	−11.9625
Dpetcon	WS	−2.55					−8.71425	−7.85936	−7.76709		−8.91502	−12.1077
DDpetcon	ADF	−2.89					−14.1119	−19.3128	−17.9996		−19.0671	−14.1374
DDpetcon	WS	−2.55					−14.2683	−18.8717	−18.0887		−19.225	−14.2501
petinv (with trend)	ADF	−3.45										−3.65975
petinv (with trend)	WS	−3.24										−3.71652
petinv (no trend)	ADF	−2.89										−1.1638
petinv (no trend)	WS	−2.55										−0.99869
Dpetinv	ADF	−2.89										−16.2607
Dpetinv	WS	−2.55										−16.3649
DDpetinv	ADF	−2.89										−14.7855
DDpetinv	WS	−2.55										−14.6893

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B4
Unit root test results for the foreign variables for the first set of countries

Domestic variables	Statistic	Critical value	Australia	Austria	Belgium	Brazil	Canada	China	Chile	Finland	France	Germany	India
ys (with trend)	ADF	−3.45	0.325655	−1.52008	−0.77715	0.183472	−0.43251	−0.1042	−0.40258	−2.52773	−0.24152	0.69852	0.409686
ys (with trend)	WS	−3.24	0.571955	−0.62956	−0.18378	1.139028	−0.40903	−0.04379	0.057889	−0.0264	0.535462	1.690733	0.721485
ys (no trend)	ADF	−2.89	−0.01612	0.447123	1.275557	0.018114	1.31127	1.062154	−0.06367	−0.62351	1.612822	2.578559	−0.7536
ys (no trend)	WS	−2.55	0.479077	0.120446	0.847817	1.128603	0.902859	0.673633	0.165954	−0.01702	1.26386	2.318963	0.322866
Dys	ADF	−2.89	−11.445	−12.7005	−12.6391	−12.9879	−12.4142	−11.2366	−13.3224	−11.8218	−11.8545	−11.6114	−9.85546
Dys	WS	−2.55	−11.5488	−12.7958	−12.7402	−13.0908	−12.5171	−11.3371	−13.4258	−11.9233	−11.9467	−11.7125	−9.96037
DDys	ADF	−2.89	−12.6424	−13.7264	−14.1348	−14.1078	−13.625	−13.6175	−13.4766	−13.5055	−14.0719	−14.3467	−12.0433
DDys	WS	−2.55	−12.8165	−13.8075	−14.2609	−14.3689	−13.8366	−13.7658	−13.6907	−13.6688	−14.2274	−14.5374	−12.2058
infs (with trend)	ADF	−3.45	−11.3681	−7.94843	−9.12192	−10.6318	−11.0828	−9.03038	−11.5325	−8.09468	−7.62831	−8.88012	−8.57545
infs (with trend)	WS	−3.24	−11.4595	−8.05198	−9.2231	−10.7199	−11.1717	−9.12447	−11.6156	−8.18652	−7.73222	−8.97884	−8.67572
infs (no trend)	ADF	−2.89	−11.3825	−7.8618	−9.04059	−10.5957	−11.0258	−8.99675	−11.5254	−8.09966	−7.55898	−8.83214	−8.45235
infs (no trend)	WS	−2.55	−11.4759	−7.96089	−9.14112	−10.6907	−11.1222	−9.08141	−11.614	−8.18607	−7.66236	−8.93384	−8.55428
Dinfs	ADF	−2.89	−13.5245	−14.0017	−13.4799	−13.6893	−15.0387	−13.2934	−13.6146	−14.0568	−14.2665	−13.7904	−12.4468
Dinfs	WS	−2.55	−13.4996	−14.1583	−13.6242	−13.7424	−15.1744	−13.438	−13.6492	−14.2134	−14.4231	−13.8582	−12.6347
DDinfs	ADF	−2.89	−16.719	−15.6075	−16.7409	−16.6367	−14.4849	−15.539	−16.6152	−14.9893	−15.6503	−16.6703	−15.897
DDinfs	WS	−2.55	−16.3819	−15.7318	−16.9778	−16.7449	−14.7123	−15.6886	−16.4021	−15.178	−15.8064	−17.1277	−16.0024
sts (with trend)	ADF	−3.45	−1.8921	−1.8921	−1.8921	−1.8921	−1.89211	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921
sts (with trend)	WS	−3.24	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523
sts (no trend)	ADF	−2.89	−1.09444	−1.09443	−1.09443	−1.09443	−1.09443	−1.09443	−1.09443	−1.09443	−1.09443	−1.09443	−1.09444
sts (no trend)	WS	−2.55	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579
Dsts	ADF	−2.89	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416
Dsts	WS	−2.55	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451
DDsts	ADF	−2.89	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846
DDsts	WS	−2.55	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.138	−13.1381	−13.1381	−13.1381	−13.1381
lts (with trend)	ADF	−3.45	−2.84042	−0.48021	−0.54041	−2.33408	−1.94868	−1.2596	−2.38765	−0.7236	−0.61068	−0.73972	−2.73942
lts (with trend)	WS	−3.24	−2.99553	−0.76053	−0.78854	−2.54254	−1.90262	−1.54349	−2.59249	−0.99079	−0.88078	−1.00146	−2.85831
lts (no trend)	ADF	−2.89	−2.76503	−1.69178	−1.69958	−2.33368	−2.33926	−1.69663	−2.34906	−1.68148	−1.6714	−1.66766	−2.64566
lts (no trend)	WS	−2.55	−2.959	−0.73399	−0.78376	−2.45248	−1.50769	−1.46407	−2.45173	−0.84729	−0.84217	−0.99806	−2.37701
Dlts	ADF	−2.89	−11.0296	−11.722	−11.6707	−11.5006	−11.9066	−12.2165	−11.4838	−11.5632	−11.9497	−11.8384	−11.5626
Dlts	WS	−2.55	−11.1137	−11.8015	−11.7309	−11.5719	−11.942	−12.2856	−11.5584	−11.6076	−12.0185	−11.9115	−11.6419
DDlts	ADF	−2.89	−13.7254	−13.168	−13.1639	−13.5253	−13.2214	−14.096	−13.7417	−13.2391	−13.445	−13.392	−13.4647
DDlts	WS	−2.55	−13.8803	−13.3134	−13.3129	−13.6785	−13.3739	−14.2532	−13.8971	−13.3876	−13.5946	−13.5409	−13.6161
equs (with trend)	ADF	−3.45	−0.88626	−3.24755	−3.1121	−2.3851	−2.91112	−0.94578	−2.16381	−2.72238	−2.98318	−2.77838	−1.61901

(*continued on next page*)

Table B4 (*continued*)

Domestic variables	Statistic	Critical value	Australia	Austria	Belgium	Brazil	Canada	China	Chile	Finland	France	Germany	India
equs (with trend)	WS	−3.24	−1.16168	−2.44306	−2.39583	−2.48398	−2.10032	−1.21195	−2.35887	−2.77074	−2.61779	−2.74075	−1.87895
equs (no trend)	ADF	−2.89	−1.0222	−1.77692	−2.24345	−2.07533	−1.04033	−1.22952	−2.16813	−1.95392	−2.4444	−2.53351	−1.90971
equs (no trend)	WS	−2.55	−1.26301	−1.99897	−2.27765	−2.26934	−1.4027	−1.48455	−2.37187	−2.07125	−2.5489	−2.70967	−2.05041
Dequs	ADF	−2.89	−11.0611	−12.1016	−11.8387	−11.0985	−12.2429	−11.73	−11.4398	−10.8807	−11.7957	−11.2496	−7.03722
Dequs	WS	−2.55	−11.1449	−12.1037	−11.8367	−11.0883	−12.2543	−11.4899	−11.3875	−10.8951	−11.8124	−11.2624	−6.95529
DDequs	ADF	−2.89	−12.2612	−14.2855	−14.0677	−17.3453	−14.6194	−12.7109	−17.4249	−15.7366	−14.1207	−16.9076	−17.5088
DDequs	WS	−2.55	−12.392	−14.3278	−14.1509	−17.4228	−14.7765	−12.307	−17.5032	−15.7821	−14.215	−17.0005	−17.5823
rers (with trend)	ADF	−3.45	−1.17736	−1.91995	−1.94497	−1.47164	−1.74256	−1.72118	−1.25341	−1.30035	−1.9014	−1.70147	−2.20318
rers (with trend)	WS	−3.24	−1.50518	−1.6245	−1.69844	−1.53062	−1.85847	−1.788	−1.48903	−0.34942	−1.66656	−1.29185	−2.43608
rers (no trend)	ADF	−2.89	−1.46969	−2.35299	−2.27695	−1.79718	−1.65599	−1.82086	−1.64777	−2.55662	−2.24668	−2.44502	−0.7737
rers (no trend)	WS	−2.55	−0.23651	−0.75722	−0.76254	0.044028	−0.32399	−0.53282	−0.22918	−0.41601	−0.65583	−0.56367	−0.13016
Drers	ADF	−2.89	−10.1489	−10.6407	−10.5801	−10.2218	−10.4565	−10.2681	−10.1682	−7.8354	−10.5795	−9.97335	−11.1109
Drers	WS	−2.55	−10.2207	−10.6428	−10.5974	−10.281	−10.5371	−10.3495	−10.2502	−7.91801	−10.5901	−10.011	−11.1945
DDrers	ADF	−2.89	−13.2302	−12.3031	−12.2913	−13.5135	−13.2151	−12.0963	−13.0664	−12.018	−12.2935	−11.5232	−12.8688
DDrers	WS	−2.55	−13.3495	−12.2067	−12.1868	−13.6244	−13.3396	−12.0024	−13.1704	−12.1043	−12.2103	−11.5012	−13.0024
oilpros (with trend)	ADF	−3.45	0.145668	−0.19846	0.009444	−0.0698	−0.2162	0.057134	−0.0754	0.211318	−0.02893	0.016282	−0.07743
oilpros (with trend)	WS	−3.24	−0.37258	−0.68802	−0.50906	−0.59653	−0.7342	−0.46663	−0.60453	−0.31977	−0.50499	−0.49346	−0.58397
oilpros (no trend)	ADF	−2.89	−0.15552	−0.86708	−0.63892	−0.6214	−0.80154	−0.52735	−0.67191	−0.78406	−1.0287	−0.81301	−0.59742
oilpros (no trend)	WS	−2.55	−0.35723	−1.01171	−0.8079	−0.80466	−0.98965	−0.70775	−0.85263	−0.88398	−1.13466	−0.97158	−0.78781
Doilpros	ADF	−2.89	−12.0765	−12.0178	−12.0186	−12.0484	−12.0081	−12.1202	−12.0544	−12.0156	−12.0255	−12.0443	−12.0554
Doilpros	WS	−2.55	−12.1794	−12.1188	−12.1217	−12.1517	−12.1116	−12.2232	−12.1576	−12.1187	−12.128	−12.1477	−12.1586
DDoilpros	ADF	−2.89	−22.7657	−12.9069	−22.3368	−22.6508	−22.647	−22.7798	−22.7206	−22.4618	−13.581	−22.3568	−22.5157
DDoilpros	WS	−2.55	−22.7594	−13.6106	−22.3417	−22.6433	−22.6374	−22.7769	−22.7113	−22.4614	−14.1413	−22.3646	−22.5181
petcons (with trend)	ADF	−3.45	−3.55655	−4.37714	−3.46425	−3.3942	−4.11535	−3.69724	−3.84929	−3.2899	−3.88749	−3.11364	−3.35051
petcons (with trend)	WS	−3.24	−3.39958	−4.29841	−2.95444	−3.03985	−4.15508	−3.56118	−3.64599	−3.22779	−3.65709	−2.6093	−3.05501
petcons (no trend)	ADF	−2.89	−1.27123	−1.23562	−0.98451	−1.75998	−3.10046	−2.25649	−1.72962	−1.10312	−1.24216	−1.07889	−1.73369
petcons (no trend)	WS	−2.55	−1.34114	−1.22755	−1.20637	−2.00099	−3.28038	−2.45926	−1.93996	−1.1266	−1.44939	−1.37334	−1.97066
Dpetcons	ADF	−2.89	−16.2585	−11.5923	−11.3197	−10.0746	−15.7871	−9.81495	−9.98827	−10.6393	−10.5082	−10.6712	−9.97773
Dpetcons	WS	−2.55	−15.8238	−11.7345	−11.4627	−10.1847	−15.8814	−9.86147	−10.0432	−10.7413	−10.6464	−10.8024	−10.1062
DDpetcons	ADF	−2.89	−15.4007	−16.3211	−15.3185	−14.8659	−14.7589	−15.1574	−15.0028	−15.5659	−14.7911	−14.654	−14.7038
DDpetcons	WS	−2.55	−15.4777	−16.5314	−15.4897	−15.2538	−15.1409	−15.5473	−15.4657	−15.7186	−15.0118	−14.8153	−15.0477

(*continued on next page*)

Table B4 (*continued*)

Domestic variables	Statistic	Critical value	Australia	Austria	Belgium	Brazil	Canada	China	Chile	Finland	France	Germany	India
petinvs (with trend)	ADF	−3.45	−1.04322	−2.28117	−2.10755	−1.47809	−0.68656	−0.62395	−1.35958	−1.84032	−2.35754	−2.42459	−0.83706
petinvs (with trend)	WS	−3.24	−0.97551	−2.45397	−2.16051	−1.55802	−0.80081	−0.7005	−1.40801	−2.02433	−2.54151	−1.98636	−0.88375
petinvs (no trend)	ADF	−2.89	−0.94799	−1.82471	−0.941	−1.91268	−1.94993	−1.78661	−1.89424	−1.13667	−1.24089	−0.91347	−1.82568
petinvs (no trend)	WS	−2.55	−0.93214	−1.74358	−1.18276	−1.5712	−1.42875	−1.33255	−1.39706	−1.3709	−1.29147	−1.23918	−1.58466
Dpetinvs	ADF	−2.89	−12.7032	−13.8821	−15.1082	−7.1774	−6.51909	−7.84321	−7.04253	−13.6851	−13.9509	−14.7193	−7.58984
Dpetinvs	WS	−2.55	−12.7877	−13.9051	−15.218	−7.29644	−6.63254	−7.96074	−7.16035	−13.7765	−14.0439	−14.8037	−7.70807
DDpetinvs	ADF	−2.89	−14.3517	−14.0607	−13.2362	−13.8134	−20.7852	−13.0648	−12.3722	−15.0084	−13.497	−14.2143	−14.5054
DDpetinvs	WS	−2.55	−14.2094	−14.1033	−13.455	−13.9688	−20.9079	−13.1817	−12.5414	−15.1581	−13.6315	−14.4635	−14.6672

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B5
Unit root test results for the foreign variables for the second set of countries

Domestic variables	Statistic	Critical value	Indonesia	Iran	Italy	Japan	South Korea	Malaysia	Mexico	Netherlands	Peru	Philippines
ys (with trend)	ADF	−3.45	1.170705	−0.89455	−0.31076	0.064133	0.140077	0.014445	−0.16112	−0.5649	−0.50899	0.772395
ys (with trend)	WS	−3.24	1.189754	−0.71953	0.926828	1.05494	0.742601	0.242186	−0.14733	1.020807	0.155708	1.174096
ys (no trend)	ADF	−2.89	0.552564	−1.57126	1.692803	−1.8245	−0.12471	−1.05012	1.553739	1.211662	1.535082	0.099186
ys (no trend)	WS	−2.55	0.919583	−0.79355	1.462623	0.661357	0.694717	−0.1005	1.110883	1.343887	1.086541	0.96806
Dys	ADF	−2.89	−8.05056	−11.8305	−11.8234	−11.0502	−11.7068	−10.3306	−12.2899	−11.6875	−11.9347	−10.506
Dys	WS	−2.55	−8.15878	−11.9323	−11.9242	−11.1543	−11.8098	−10.431	−12.3924	−11.7823	−12.0306	−10.6112
DDys	ADF	−2.89	−10.4737	−12.9976	−14.0674	−12.4052	−13.6969	−12.0028	−13.4451	−14.1877	−13.7345	−12.584
DDys	WS	−2.55	−10.5717	−13.1452	−14.2324	−12.654	−13.8864	−12.0486	−13.6803	−14.3721	−13.9177	−12.7772
infs (with trend)	ADF	−3.45	−10.1438	−9.07768	−7.92342	−8.83557	−8.54694	−9.82724	−11.0972	−7.51678	−8.57165	−8.31563
infs (with trend)	WS	−3.24	−10.2453	−9.15747	−8.02692	−8.83135	−8.53301	−9.92859	−11.1871	−7.62164	−8.66742	−8.30797
infs (no trend)	ADF	−2.89	−10.1401	−9.04867	−7.85803	−8.84957	−8.56346	−9.84392	−11.0569	−7.44774	−8.41582	−8.33579
infs (no trend)	WS	−2.55	−10.2416	−9.1383	−7.95684	−8.84667	−8.52524	−9.94543	−11.1532	−7.54811	−8.51835	−8.31706
Dinfs	ADF	−2.89	−13.5454	−13.1345	−12.7933	−12.8965	−13.0525	−13.894	−14.9012	−13.5416	−14.368	−12.6757
Dinfs	WS	−2.55	−13.8027	−13.4934	−13.0001	−13.0322	−13.0937	−14.2213	−15.038	−13.6967	−14.5198	−12.8752
DDinfs	ADF	−2.89	−17.2233	−16.0572	−16.4669	−16.2696	−16.5949	−17.5427	−14.3142	−14.9523	−17.485	−16.4246
DDinfs	WS	−2.55	−17.6082	−16.2523	−16.7924	−16.0596	−16.4762	−18.0727	−14.5074	−15.0495	−17.9882	−16.2418
sts (with trend)	ADF	−3.45	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921	−1.89211	−1.8921	−1.8921	−1.8921
sts (with trend)	WS	−3.24	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523
sts (no trend)	ADF	−2.89	−1.09444	−1.09443	−1.09444	−1.09444	−1.09444	−1.09444	−1.09443	−1.09443	−1.09443	−1.09444
sts (no trend)	WS	−2.55	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579
Dsts	ADF	−2.89	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416
Dsts	WS	−2.55	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451
DDsts	ADF	−2.89	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846
DDsts	WS	−2.55	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381
lts (with trend)	ADF	−3.45	−2.99164	−3.37011	−0.63868	−3.07071	−2.99702	−3.51883	−2.08272	−0.66481	−0.4887	−2.50252
lts (with trend)	WS	−3.24	−3.1651	−2.92783	−0.88709	−3.24113	−3.13676	−3.6142	−1.86226	−0.94469	−0.79289	−2.69018
lts (no trend)	ADF	−2.89	−2.78559	−2.11341	−1.6767	−2.77259	−3.02135	−3.28158	−2.47914	−1.65967	−1.61664	−2.26747
lts (no trend)	WS	−2.55	−2.77788	−2.35603	−0.95139	−2.88953	−3.12483	−3.1463	−1.32941	−0.86287	−0.78253	−2.07122
Dlts	ADF	−2.89	−11.3959	−12.5563	−11.8024	−11.2891	−10.7135	−10.9399	−11.779	−11.7745	−11.7535	−11.0522
Dlts	WS	−2.55	−11.4692	−12.6533	−11.8768	−11.3459	−10.7835	−10.9974	−11.8109	−11.834	−11.784	−11.0737
DDlts	ADF	−2.89	−13.7291	−13.9093	−13.2335	−13.9288	−12.9629	−13.2718	−13.5107	−13.264	−13.1847	−13.3342
DDlts	WS	−2.55	−13.8858	−14.0349	−13.3817	−14.0831	−13.1118	−13.4203	−13.6651	−13.4139	−13.3365	−13.4872
equs (with trend)	ADF	−3.45	0.100209	−2.7102	−2.89885	−2.28844	−0.61595	0.068755	−2.91907	−2.87091	−3.15348	0.369299
equs (with trend)	WS	−3.24	−0.19499	−2.3862	−2.72028	−2.53493	−0.92554	−0.20977	−1.99529	−2.66331	−2.33662	−0.35449
equs (no trend)	ADF	−2.89	−0.09459	−1.82843	−2.12302	−2.11114	−0.97116	−0.42484	−1.07447	−2.16552	−2.09101	−0.30128
equs (no trend)	WS	−2.55	−0.28998	−2.10353	−2.36735	−1.97271	−1.14367	−0.56108	−1.4347	−2.40293	−2.1876	−0.55849
Dequs	ADF	−2.89	−9.4633	−11.6729	−11.6744	−10.1726	−11.0647	−9.01266	−12.2159	−11.5566	−11.8801	−11.6341
Dequs	WS	−2.55	−9.46603	−11.7764	−11.6662	−9.47574	−10.8176	−8.96563	−12.2429	−11.5786	−11.9022	−7.74619
DDequs	ADF	−2.89	−15.1247	−13.5187	−13.9819	−15.7915	−16.8297	−14.6042	−14.6026	−13.8838	−14.1684	−11.9164
DDequs	WS	−2.55	−15.2183	−13.6534	−14.0688	−15.6929	−16.8759	−14.6944	−14.7611	−13.9864	−14.258	−10.2926
rers (with trend)	ADF	−3.45	−1.19679	−2.01931	−1.74227	−0.90159	−1.11873	−1.22538	−1.35728	−1.76172	−2.01759	−1.09734
rers (with trend)	WS	−3.24	−1.49424	−2.03178	−1.37232	−1.00848	−1.42431	−1.54906	−1.54792	−1.42984	−1.90347	−1.29885
rers (no trend)	ADF	−2.89	−1.55159	−1.98691	−2.40093	−1.93656	−1.49445	−1.45959	−1.64548	−2.39668	−2.1584	−1.80057
rers (no trend)	WS	−2.55	−0.22812	−0.83174	−0.55083	−0.06704	0.050968	−0.22142	−0.15401	−0.70244	−0.97544	−0.1945
Drers	ADF	−2.89	−10.1255	−11.112	−9.98345	−9.07319	−9.60766	−10.0533	−10.3359	−10.1123	−10.4148	−9.70456
Drers	WS	−2.55	−10.2124	−11.1911	−10.0135	−9.15435	−9.68711	−10.1171	−10.4148	−10.1351	−10.4445	−9.76497
DDrers	ADF	−2.89	−12.2303	−13.7425	−11.5664	−12.2086	−11.6064	−12.3065	−13.6214	−11.629	−11.8046	−12.7402
DDrers	WS	−2.55	−12.1289	−13.7997	−11.546	−12.3493	−11.6865	−12.2281	−13.7188	−11.5932	−11.7621	−12.8577
oilpros (with trend)	ADF	−3.45	0.253169	−0.0521	0.083008	−0.05206	0.012855	0.200037	−0.19774	0.051623	0.171295	−0.06791

(*continued on next page*)

Table B5 (*continued*)

Domestic variables	Statistic	Critical value	Indonesia	Iran	Italy	Japan	South Korea	Malaysia	Mexico	Netherlands	Peru	Philippines
oilpros (with trend)	WS	−3.24	−0.21115	−0.54805	−0.42841	−0.57947	−0.5105	−0.25047	−0.71661	−0.42609	−0.36016	−0.58842
oilpros (no trend)	ADF	−2.89	−0.20128	−1.01509	−0.82585	−0.50265	−0.20593	−0.21953	−0.87887	−0.8973	−0.59086	−0.20507
oilpros (no trend)	WS	−2.55	−0.37019	−1.14819	−0.9657	−0.69512	−0.41271	−0.39495	−1.05726	−1.02221	−0.75965	−0.4214
Doilpros	ADF	−2.89	−12.1099	−12.4398	−12.0117	−12.0775	−12.0285	−12.0803	−12.0093	−12.0127	−12.0262	−12.1103
Doilpros	WS	−2.55	−12.213	−12.5427	−12.1149	−12.181	−12.1317	−12.1834	−12.1128	−12.1155	−12.1294	−12.214
DDoilpros	ADF	−2.89	−22.5051	−22.9598	−22.3325	−22.7261	−22.6933	−22.3067	−22.6447	−13.4704	−22.4148	−22.6242
DDoilpros	WS	−2.55	−22.5212	−22.9784	−22.3411	−22.7182	−22.6845	−22.3311	−22.6354	−14.0501	−22.4193	−22.6273
petcons (with trend)	ADF	−3.45	−3.01818	−3.64949	−3.52634	−3.86736	−3.74888	−3.53103	−3.36568	−3.60109	−3.18798	−2.9892
petcons (with trend)	WS	−3.24	−2.88093	−3.76723	−3.21811	−3.82975	−3.44163	−3.31108	−3.36581	−3.4231	−3.00552	−2.77568
petcons (no trend)	ADF	−2.89	−1.38464	−2.69158	−1.3849	−3.84869	−1.68422	−1.55771	−3.19403	−1.40475	−1.11658	−2.70073
petcons (no trend)	WS	−2.55	−1.52799	−2.7929	−1.58889	−3.8528	−1.88489	−1.72254	−3.33814	−1.53764	−1.24693	−2.74588
Dpetcons	ADF	−2.89	−16.955	−17.8983	−10.4355	−9.62309	−9.8148	−16.6803	−16.2193	−10.68	−11.3124	−9.96935
Dpetcons	WS	−2.55	−16.5305	−17.9315	−10.5747	−9.7263	−9.83925	−16.3683	−16.3108	−10.8204	−11.453	−10.0675
DDpetcons	ADF	−2.89	−15.5108	−14.9708	−15.035	−14.0583	−15.3566	−15.6773	−14.7088	−15.3061	−15.1559	−14.4813
DDpetcons	WS	−2.55	−15.6309	−15.1309	−15.2049	−14.6094	−15.5985	−15.8808	−15.159	−15.4917	−15.3218	−14.841
petinvs (with trend)	ADF	−3.45	−0.96911	−1.46384	−1.66038	−1.31702	−1.22338	−0.66071	−1.44102	−2.09006	−2.91005	−0.87927
petinvs (with trend)	WS	−3.24	−0.94	−1.64755	−1.8332	−1.4852	−1.1376	−0.6532	−1.59083	−2.2822	−2.95552	−0.84169
petinvs (no trend)	ADF	−2.89	−1.33784	−1.86142	−1.15828	−1.88177	−0.7704	−0.82657	−1.95901	−1.05365	−1.20912	−1.11464
petinvs (no trend)	WS	−2.55	−1.02339	−1.22427	−1.42836	−1.14557	−0.89928	−0.69702	−1.3405	−1.15735	−1.28355	−0.89786
Dpetinvs	ADF	−2.89	−13.0339	−13.5873	−15.0002	−7.52784	−7.68417	−8.37166	−6.45522	−14.3733	−15.3131	−7.93012
Dpetinvs	WS	−2.55	−13.1189	−13.6931	−15.0991	−7.64126	−7.7987	−8.48379	−6.56702	−14.4649	−15.4246	−8.04789
DDpetinvs	ADF	−2.89	−14.4897	−13.049	−12.984	−16.2879	−13.8434	−14.1953	−20.7869	−15.1107	−14.2174	−13.0436
DDpetinvs	WS	−2.55	−14.4444	−13.5376	−13.2022	−16.4081	−13.7081	−14.0703	−20.8995	−15.2616	−14.2261	−13.0513

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B6
Unit root test results for the foreign variables for the third set of countries

Domestic variables	Statistic	Critical value	South Africa	Saudi Arabia	Singapore	Spain	Sweden	Switzerland	Thailand	Turkey	United Kingdom	United States
ys (with trend)	ADF	−3.45	−0.06143	0.347055	−0.08773	0.735963	−1.15999	−0.8297	0.635401	−0.03197	−2.16998	0.20973
ys (with trend)	WS	−3.24	−0.15424	0.745618	0.230762	0.721817	−0.28979	0.823017	0.769323	1.539851	0.329889	0.924391
ys (no trend)	ADF	−2.89	1.349868	0.754152	−0.36912	−0.37526	0.948303	1.69809	2.1554	−1.89215	−0.52251	1.975856
ys (no trend)	WS	−2.55	0.926319	0.938897	0.165082	0.245356	0.554279	1.30933	1.757249	1.28821	0.32171	1.619126
Dys	ADF	−2.89	−12.0126	−12.0059	−11.7416	−9.5241	−12.856	−12.0399	−12.1985	−16.0556	−11.7664	−11.7253
Dys	WS	−2.55	−12.1155	−12.1104	−11.8449	−9.64455	−12.9581	−12.139	−12.2971	−16.1578	−11.8697	−11.8239
DDys	ADF	−2.89	−13.2322	−13.1546	−12.7957	−12.759	−13.811	−14.9064	−14.5109	−14.6153	−13.7129	−14.0637
DDys	WS	−2.55	−13.396	−13.3651	−12.9561	−12.8918	−13.959	−15.0543	−14.6366	−14.9473	−13.8833	−14.2498
infs (with trend)	ADF	−3.45	−4.50132	−9.59629	−11.1511	−10.1257	−7.65173	−8.55657	−7.72486	−9.54813	−7.18638	−8.83729
infs (with trend)	WS	−3.24	−4.59655	−9.68935	−11.2535	−10.2096	−7.75613	−8.65788	−7.82883	−9.60834	−7.27049	−8.93563
infs (no trend)	ADF	−2.89	−4.40179	−9.55049	−11.1696	−10.0819	−7.56984	−8.46178	−7.61823	−8.39579	−7.1271	−8.7682
infs (no trend)	WS	−2.55	−4.48542	−9.64949	−11.2719	−10.175	−7.66989	−8.56301	−7.71899	−8.45918	−7.1832	−8.87007
Dinfs	ADF	−2.89	−14.1834	−13.2937	−14.3657	−12.4525	−12.4492	−12.7557	−13.7181	−14.0264	−14.3371	−14.4215
Dinfs	WS	−2.55	−14.2214	−13.2999	−14.5851	−12.6132	−12.5935	−12.9436	−13.8721	−14.1433	−14.4667	−14.5757
DDinfs	ADF	−2.89	−17.6175	−16.4834	−17.3979	−15.5919	−15.7384	−15.5589	−15.2875	−18.5582	−14.1912	−15.85
DDinfs	WS	−2.55	−18.0593	−16.445	−17.7221	−15.5545	−16.0107	−15.932	−15.4918	−18.7298	−14.3328	−16.1276
sts (with trend)	ADF	−3.45	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921	−1.8921	−1.89116	−1.8921	−1.8921
sts (with trend)	WS	−3.24	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00523	−2.00553	−2.00523	−2.00523
sts (no trend)	ADF	−2.89	−1.09444	−1.09444	−1.09444	−1.09444	−1.09443	−1.09443	−1.09443	−1.09561	−1.09444	−1.09443
sts (no trend)	WS	−2.55	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99579	−0.99754	−0.99579	−0.99579
Dsts	ADF	−2.89	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0416	−12.0294	−12.0416	−12.0416
Dsts	WS	−2.55	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1451	−12.1329	−12.1451	−12.1451
DDsts	ADF	−2.89	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9846	−12.9659	−12.9846	−12.9846
DDsts	WS	−2.55	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1381	−13.1192	−13.138	−13.1381
lts (with trend)	ADF	−3.45	−1.35879	−2.35485	−3.3415	−3.91894	−0.62078	−0.55368	−0.83287	−2.01986	−1.71206	−1.37219
lts (with trend)	WS	−3.24	−1.56845	−2.53458	−3.48276	−3.98949	−0.92365	−0.81681	−1.03811	−2.25478	−1.91078	−1.47073
lts (no trend)	ADF	−2.89	−1.89484	−2.41164	−3.23037	−3.88554	−1.585	−1.8678	−1.74884	−1.95453	−1.70852	−2.00949
lts (no trend)	WS	−2.55	−1.59728	−2.322	−3.28185	−3.90409	−1.01811	−1.01121	−0.95002	−2.12077	−1.19005	−1.14101
Dlts	ADF	−2.89	−11.8877	−11.0872	−11.3007	−10.9522	−11.9177	−11.6178	−11.7554	−10.7117	−11.7605	−11.6425
Dlts	WS	−2.55	−11.9661	−11.1556	−11.3912	−11.028	−11.9844	−11.6771	−11.8065	−10.7845	−11.8297	−11.7156
DDlts	ADF	−2.89	−12.317	−13.254	−14.1294	−12.2637	−11.9759	−11.8263	−13.2521	−13.4946	−13.627	−13.2527
DDlts	WS	−2.55	−12.3743	−13.4057	−14.2838	−12.3638	−12.016	−11.8347	−13.4036	−13.6504	−13.7781	−13.3999
equs (with trend)	ADF	−3.45	−2.98611	−1.96867	−1.3188	−0.4687	−2.98521	−2.90885	−3.05158	−1.68018	−1.56027	−2.89422
equs (with trend)	WS	−3.24	−2.34611	−2.08962	−1.55809	−0.77295	−2.69917	−2.6664	−2.61497	−1.90764	−1.74174	−2.61969
equs (no trend)	ADF	−2.89	−2.70815	−2.02793	−1.4896	−1.20295	−2.29404	−2.05545	−2.33183	−1.90382	−1.846	−2.01374
equs (no trend)	WS	−2.55	−2.46214	−2.25636	−1.73142	−1.35874	−2.47572	−2.30554	−2.48053	−1.88764	−1.95279	−2.26727
Dequs	ADF	−2.89	−11.7716	−11.2996	−11.282	−10.1415	−11.8956	−11.5621	−11.8997	−11.4529	−11.8152	−11.4902
Dequs	WS	−2.55	−11.826	−11.2141	−11.3615	−10.0029	−11.8768	−11.557	−11.8899	−11.3327	−11.8474	−11.4157
DDequs	ADF	−2.89	−12.4844	−17.0618	−12.373	−15.9871	−14.1159	−16.811	−17.259	−14.368	−14.312	−13.8513
DDequs	WS	−2.55	−12.5945	−17.1166	−12.4677	−15.9632	−14.2041	−16.8802	−17.294	−14.4601	−14.4352	−13.9451
rers (with trend)	ADF	−3.45	−1.85761	−1.60075	−1.25476	−1.1763	−1.88057	−1.79998	−1.95673	−2.27682	−2.45852	−1.78825
rers (with trend)	WS	−3.24	−1.83939	−1.73865	−1.55923	−1.40101	−1.65039	−1.3959	−1.88564	−2.47224	−2.23515	−1.57585
rers (no trend)	ADF	−2.89	−1.86937	−1.65743	−1.50666	−1.74834	−2.23011	−2.46034	−2.00416	−0.46499	−2.22798	−2.22679
rers (no trend)	WS	−2.55	−0.59382	−0.19205	−0.25167	−0.26221	−0.65251	−0.76176	−0.70293	0.071462	−0.69697	−0.6078
Drers	ADF	−2.89	−10.6071	−10.4121	−10.4033	−10.6124	−10.3983	−10.0783	−10.5889	−11.0177	−9.68186	−10.6467
Drers	WS	−2.55	−10.6344	−10.4482	−10.4836	−10.6727	−10.4233	−10.1035	−10.5947	−11.1008	−9.76615	−10.6696
DDrers	ADF	−2.89	−12.49	−13.3348	−13.699	−13.7964	−12.1038	−11.7252	−12.2977	−12.9285	−10.834	−12.4149
DDrers	WS	−2.55	−12.3659	−13.3712	−13.827	−13.9338	−12.0593	−11.6856	−12.1952	−13.0729	−10.8859	−12.3276
oilpros (with trend)	ADF	−3.45	0.051857	0.001579	0.118651	−0.03528	−0.02141	0.025284	0.022047	−0.05521	−0.10031	−0.03291

(*continued on next page*)

Table B6 (*continued*)

Domestic variables	Statistic	Critical value	South Africa	Saudi Arabia	Singapore	Spain	Sweden	Switzerland	Thailand	Turkey	United Kingdom	United States
oilpros (with trend)	WS	−3.24	−0.46052	−0.52367	−0.39984	−0.56483	−0.5312	−0.48144	−0.4893	−0.57512	−0.62037	−0.53778
oilpros (no trend)	ADF	−2.89	−0.91647	−0.50906	−0.39661	−0.21299	−0.73548	−0.72168	−0.5853	−0.53112	−0.62959	−0.90043
oilpros (no trend)	WS	−2.55	−1.01615	−0.69655	−0.57491	−0.42643	−0.89384	−0.88843	−0.75218	−0.71973	−0.80958	−1.04736
Doilpros	ADF	−2.89	−12.0805	−12.045	−12.1125	−12.0703	−12.0346	−12.0184	−12.0322	−12.0108	−12.0445	−12.0177
Doilpros	WS	−2.55	−12.1831	−12.1481	−12.2156	−12.1736	−12.1373	−12.1214	−12.1346	−12.114	−12.1471	−12.1207
DDoilpros	ADF	−2.89	−22.3267	−22.6063	−22.8149	−22.7701	−22.1677	−22.3147	−22.2144	−22.5035	−22.456	−22.2875
DDoilpros	WS	−2.55	−22.3354	−22.602	−22.8092	−22.7601	−22.1786	−22.3232	−22.2236	−22.5009	−22.4546	−22.2963
petcons (with trend)	ADF	−3.45	−3.34179	−3.42383	−3.12686	−3.65713	−3.55809	−3.42157	−3.62224	−3.41332	−3.49306	−3.48497
petcons (with trend)	WS	−3.24	−2.90722	−3.08936	−3.01323	−3.53352	−3.40447	−2.99254	−3.40724	−3.10092	−3.26036	−2.98928
petcons (no trend)	ADF	−2.89	−1.0919	−1.27817	−1.4469	−2.20684	−1.26858	−1.21441	−1.30767	−1.90585	−1.23673	−1.27888
petcons (no trend)	WS	−2.55	−1.30353	−1.45892	−1.55672	−2.40908	−1.32645	−1.4811	−1.4029	−2.15123	−1.32965	−1.54424
Dpetcons	ADF	−2.89	−10.928	−10.4735	−17.3541	−9.91377	−11.2608	−11.2534	−11.3264	−10.3666	−10.8554	−10.2651
Dpetcons	WS	−2.55	−11.0651	−10.5951	−16.9822	−9.98361	−11.402	−11.396	−11.4686	−10.5056	−10.9964	−10.4037
DDpetcons	ADF	−2.89	−15.0736	−15.4068	−15.434	−15.0711	−15.5297	−15.047	−15.4734	−15.0266	−15.2657	−15.0419
DDpetcons	WS	−2.55	−15.3091	−15.6493	−15.6378	−15.396	−15.6927	−15.2073	−15.6759	−15.2367	−15.498	−15.2793
petinvs (with trend)	ADF	−3.45	−1.96831	−1.08715	−1.00995	−0.74827	−2.6068	−2.09549	−2.14327	−1.19745	−1.95293	−1.07822
petinvs (with trend)	WS	−3.24	−1.98458	−1.18686	−0.99042	−0.79758	−2.50929	−2.25166	−2.24174	−1.48131	−2.00604	−1.22009
petinvs (no trend)	ADF	−2.89	−1.08901	−0.59035	−1.6059	−1.46129	−0.99364	−1.00007	−0.92455	−1.02696	−1.13502	−1.39634
petinvs (no trend)	WS	−2.55	−1.37005	−0.88068	−1.05764	−0.9106	−1.21796	−1.15326	−1.11293	−1.31056	−1.4132	−1.31728
Dpetinvs	ADF	−2.89	−13.6811	−12.3302	−12.981	−8.1903	−15.4662	−14.3021	−14.211	−12.601	−13.752	−8.63001
Dpetinvs	WS	−2.55	−13.7856	−12.4135	−13.0793	−8.30799	−15.5778	−14.4028	−14.3162	−12.6453	−13.8591	−8.73282
DDpetinvs	ADF	−2.89	−13.3959	−13.0163	−14.0682	−13.1069	−13.6756	−13.1864	−13.1843	−14.1428	−15.4675	−13.7661
DDpetinvs	WS	−2.55										−14.6893

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B7
Unit root test results for the global variables

Domestic variables	Statistic	Critical Value	Statistic
oilprice (with trend)	ADF	−3.45	−2.791031449
oilprice (with trend)	WS	−3.24	−2.84483494
oilprice (no trend)	ADF	−2.89	−2.810408156
oilprice (no trend)	WS	−2.55	−2.709200752
Doilprice	ADF	−2.89	−12.19111201
Doilprice	WS	−2.55	−12.28754617
DDoilprice	ADF	−2.89	−15.35325012
Doilprice	WS	−2.55	−15.51598514
petprice (with trend)	ADF	−3.45	−2.834883906
petprice (with trend)	WS	−3.24	−2.937137733
petprice (no trend)	ADF	−2.89	−2.849914981
petprice (no trend)	WS	−2.55	−2.836811669
Dpetprice	ADF	−2.89	−11.32552055
Dpetprice	WS	−2.55	−11.42680206
DDpetprice	ADF	−2.89	−12.7157393
Dpetprice	WS	−2.55	−12.89214215
bdti (with trend)	ADF	−3.45	−4.527633735
bdti (with trend)	WS	−3.24	−4.489685164
bdti (no trend)	ADF	−2.89	−4.203787323
bdti (no trend)	WS	−2.55	−4.313948437
Dbdti	ADF	−2.89	−13.24004308
Dbdti	WS	−2.55	−13.34641591
DDbdti	ADF	−2.89	−13.06353227
Dbdti	WS	−2.55	−13.0877752
bcti (with trend)	ADF	−3.45	−3.87264789
bcti (with trend)	WS	−3.24	−3.960218972
bcti (no trend)	ADF	−2.89	−3.514189914
bcti (no trend)	WS	−2.55	−3.675628551
Dbcti	ADF	−2.89	−15.84595145
Dbcti	WS	−2.55	−15.95277713
DDbcti	ADF	−2.89	−13.97099651
Dbcti	WS	−2.55	−14.12318868

Notes: ADF denotes the Augmented Dickey-Fuller test and WS denotes the Weighted Symmetric test of Park and Fuller (1995). Critical values are at the 5% significance level. The null hypothesis is a unit root. Specifications with trend include a linear deterministic trend; specifications without trend include only a constant. D and DD denote the first and second differences of the respective variable, respectively. Lag length for the ADF test is selected using the Akaike Information Criterion (AIC) with a maximum of 12 lags. Values exceeding the critical value in absolute terms indicate rejection of the null hypothesis of a unit root.

Table B8
Weak exogeneity test results

Country	F test	Critical value	ys	infs	sts	lts	equs	rers	oilpros	petcons	petinvs	oilprice	petprice	bdti	bcti
Australia	F(2,271)	3.029094	1.1415				1.337562			2.791994	0.24264	1.274933	2.332778		
Austria	F(3,268)	2.638286	0.577502			0.636799	0.125073			0.090565	1.128088	0.953572	0.757132	2.391726	0.417478
Belgium	F(2,269)	3.029343	1.066996			0.911863				2.121567	0.74671	0.250969	0.333506	2.281091	
Brazil	F(3,269)	2.638161	0.505595			0.13249	1.093292			1.298512	2.756867		2.081401	0.784686	
Canada	F(3,267)	2.638412				0.460668	0.588059			0.176553	2.674879	0.552326	0.560052	2.094667	1.000931
China	F(2,270)	3.029218				0.749771	1.65346			0.241882	0.229288	0.813018	1.376869	0.554666	1.072208
Chile	F(3,268)	2.638286	0.356812			1.038027	0.680906			1.087787	2.827861	1.135521		0.655158	1.90278
Finland	F(2,269)	3.029343	1.04217			1.007715	2.577841			0.243826	1.83682	1.348049	0.780217	1.870844	0.194207
France	F(5,265)	2.248079	0.428415			2.448527	0.858381			1.189097	1.333034	2.123059	1.218561	1.191513	
Germany	F(4,266)	2.40558	0.098838				0.625164			1.825265	1.393415	1.19489		1.635717	0.298832
India	F(3,269)	2.638161	0.676933			1.149206	1.398211			0.412497	0.791797	2.252844	2.309531	0.386101	1.084549
Indonesia	F(3,271)	2.637913				1.10779						0.41672	1.122274	1.864101	1.181144
Iran	F(3,271)	2.637913	0.782613				0.551534			1.481575	0.491059	0.418796	0.677477	0.543388	1.928358
Italy	F(3,269)	2.638161	0.508295			0.798255						1.280114	2.084166	2.184283	1.060806
Japan	F(4,266)	2.40558	0.895673			1.607428	0.218285			1.226851	0.580321	1.40279	0.839531	0.606272	2.112006
South Korea	F(5,267)	2.247822	1.276887			1.259009	2.043607					0.739703	0.518851	1.405044	0.561546
Malaysia	F(2,271)	3.029094	0.572884			0.084813	1.328957			0.108011	0.42396	1.423175	0.715473	1.456785	
Mexico	F(2,269)	3.029343	1.613506			0.001024	1.284048			0.580083	1.584904	2.543575	2.623348		0.687286
Netherlands	F(3,268)	2.638286	0.651195			1.021686	1.175839			1.505606	0.836216	0.274705	0.924921	1.313566	2.442135
Norway	F(4,267)	2.405453	1.017766				0.516672			0.523382	0.619933			1.190677	0.606674
New Zealand	F(2,271)	3.029094	1.114203			0.268916	0.205217			2.165113	2.790065	0.032228	0.341142	1.313983	
Peru	F(3,269)	2.638161	0.419317			0.067288	1.48046			0.232499		1.646776	0.45915	1.196562	
Philippines	F(2,271)	3.029094	0.712977			0.506265	0.282009			0.36418	0.75375	1.315772	2.416697	0.106475	2.262657
Russia	F(1,272)	3.875874	1.928921			0.185321	0.074894			0.072842	0.000951	1.122956	1.641155	1.702065	0.001329
South Africa	F(4,268)	2.405327	0.618793			1.291636	2.583103			1.073094	1.182984	1.044887	0.914491		1.517259
Saudi Arabia	F(2,272)	3.02897	1.350663			0.613538	1.892645			0.530965	0.05859			0.078847	0.108588
Singapore	F(2,273)	3.028847	0.57176			1.756516						0.847127	2.361402		0.561791
Spain	F(2,269)	3.029343				3.027544	0.457725				0.180291			0.617205	
Sweden	F(4,269)	2.405201	1.256868			1.76413								0.885028	0.68182
Switzerland	F(2,270)	3.029218				0.667984	0.468304			0.296055	1.834364			3.254	2.172608
Thailand	F(2,272)	3.02897	1.711382			0.77646	0.198978			0.901296	0.115679	0.727282	1.009738	2.612016	1.046111
Turkey	F(3,268)	2.638286	1.432565				1.433764				2.006207	0.447997	0.971507	1.243978	0.38493
United Kingdom	F(3,267)	2.638412	0.745664			2.285478	0.898984			1.512966	0.115533	1.537736	2.742057		0.876325
United States	F(4,267)	2.405453					1.904062			0.870669	3.083575	1.80746			

Notes: The weak exogeneity test follows Johansen (1992) and is implemented as an F-test for the significance of the error correction terms in the marginal model for each domestic variable. The null hypothesis is weak exogeneity of the respective variable with respect to the long-run parameters. Critical values are at the 5% significance level. Degrees of freedom vary across countries reflecting differences in the number of cointegrating relations and sample size. Empty cells indicate that the variable is treated as exogenous in the respective country model and is therefore not subject to the test.

Table B9
Structural stability test results (Ploberger and Krämer Sup-test statistic)

	inf	st	lt	equ	oilpro	petcon	y	rer	petinv
Australia	0.833950045	0.763791724	0.791542709	1.015958828	0.95088469	0.658605418			
Austria	0.383471698	0.597085005	0.701249843	1.369131502	0.756391159	0.600125594	0.761750664	0.801563789	
Belgium	0.354533497	0.495527499	1.438302639	0.692748594	0.601345294	0.566455033	0.673573785	0.639612767	
Brazil	0.544103738	0.8673842	0.908879236	0.590151743	0.948303605		0.802645713	0.524953633	
Canada	0.389494044	0.69002377	0.774408763	0.767147155	0.957159277	0.689950897	1.304293287	1.032943932	0.503967795
China	0.336602198	0.866971855	0.890856479	0.648240753	0.958593881		0.873558781	0.514866728	
Chile	0.415330954	0.69608925	0.831049471	1.089404009	0.695837305	0.889622367	0.7157466	0.521408275	
Finland	0.317963429	0.506596084	0.448928977	0.737491991	0.53700705	0.785665272	0.870687788	0.669227866	
France	0.417821122	1.179499	0.421496217	1.363087504	0.889033974	0.641549468	1.06332216	0.931018169	0.720285702
Germany	0.711110407	0.766832628	1.019119802	1.016441918	0.786280478	0.68045243	0.588772224	0.84533189	0.632508757
India	0.591627135	0.879279468	0.506648618	1.011026596	0.922971374		0.567529337	1.09502379	
Indonesia	0.374447381	0.626439194	0.822556296	0.705395434	0.968303124		0.826189721	0.728486038	
Iran	0.498118417	0.784454953		0.885544423	1.42737117			0.806571631	
Italy	0.658705663	0.740018754	1.377262468	1.325248011	0.884565926	0.675291096	1.062027324	1.086365541	0.394134864
Japan	0.333528372	0.538819906	0.506143317	0.837517962	0.925352422	0.842525692	0.821869495	0.746686534	0.750109076
South Korea	0.230306891	0.836381318	0.730175475	0.535390243	0.846731671	0.503897917	0.456663261	0.624093166	0.524185014
Malaysia	0.560802176	0.575844097	0.47600743	0.807684944	0.954103922		0.487417424		
Mexico	0.634409417	1.544999621	0.867843738	1.498134	0.931189762	0.840579298	0.641762757	0.75905318	
Netherlands	0.683550915	0.771926352	0.618072791	1.222923317	0.885062287	0.804244608	0.448703812	0.776100326	
Norway	0.381402812	0.906323501	0.774010875	0.930109161	0.895495276	0.581354485	0.553805033	0.769992464	
New Zealand	0.70431758	0.571442354	0.554231064	0.614375843	0.714167864	0.791014496			
Peru	0.507687646	0.616699311	0.436726979	0.999966985	0.92056891		0.577627805	0.619212502	
Philippines	0.515137592	1.051738555	0.873728371	0.827499249	1.12570446			1.123180188	
Russia	0.520592345	0.540652249		0.971855416	0.965519891		0.773811487	0.658981055	
South Africa	0.918113415	0.594048921	1.28422549	0.938893868	0.946938742		1.02695973	0.582858592	
Saudi Arabia	1.241130922	0.565458911		1.452251172	0.959001305			1.2302666	
Singapore	0.784681225	0.619666677	0.554015263	0.538471348	0.60556656		0.607709473		
Spain	0.591930863	0.499758549	1.228539612	0.725059965	0.795957577	0.666688406	0.922499726	0.872956809	
Sweden	0.488378889	0.710310992	0.619023202	1.414204987	0.876143921	0.734688445	0.732003004	0.775986988	
Switzerland	0.34625929	0.676251353	0.594938629	0.620037469	0.697846786	0.935786298		1.074529879	
Thailand	0.311524746	0.587594299	0.630443844	0.567100537	0.917525024				
Turkey	0.839766174	0.479934189	0.629580738	1.112053608	0.810158332	0.773157735	0.619658548	1.059344678	
United Kingdom	0.376988967	0.748162992	0.695761916	0.678050422	0.953933852	0.408215823	0.857192029	0.704692476	0.737320315
United States	0.941900951	0.915576564	1.275805655	1.822434266	0.963819863	0.799512905	0.923021087		0.958246641

Notes: The structural stability test follows Ploberger and Krämer (1992) and tests for parameter constancy in the error correction equations against the alternative of a structural break at an unknown date. The reported statistics are p-values. The null hypothesis is parameter stability over the full sample. Values above 0.05 indicate failure to reject the null of structural stability at the 5% significance level.

Appendix C. Granger Causality and Chow Test Results

Table C1
Granger causality test results

Causal relationship	Pre-Covid	Post-Covid
$p_t^O \rightarrow p_t^P$	0.006	0.570
$p_t^O \rightarrow b_t^O$	0.526	0.261
$p_t^O \rightarrow b_t^P$	0.001	0.025
$p_t^P \rightarrow p_t^O$	0.048	0.133
$p_t^P \rightarrow b_t^O$	0.385	0.305
$p_t^P \rightarrow b_t^P$	0.000	0.000
$b_t^O \rightarrow p_t^O$	0.118	0.043
$b_t^O \rightarrow p_t^P$	0.042	0.077
$b_t^O \rightarrow b_t^P$	0.615	0.462
$b_t^P \rightarrow p_t^O$	0.151	0.275
$b_t^P \rightarrow p_t^P$	0.010	0.262
$b_t^P \rightarrow b_t^O$	0.003	0.248

Notes: Granger causality test results pre- and post-Covid. P-values reported for the null hypothesis of no Granger causality.

Table C2
Chow test results for March 2020 break date

Equation	F-statistic	P-value
p_t^O	2.667	0.0056
p_t^P	2.352	0.0143
b_t^O	1.241	0.2697
b_t^P	3.991	0.0001

Notes: Chow test results for a break in March 2020. F-statistic and p-values reported for the null hypothesis of no break.

Data availability

Data will be made available on request.

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