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Paul Cashin, Kamiar Mohaddes,
Maziar Raissi, and Mehdi Raissi

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The Differential Effects of Oil Demand and Supply Shocks on the Global Economy*

Paul Cashin[a], Kamiar Mohaddes[b], Maziar Raissi[c], and Mehdi Raissi[a†]

[a] International Monetary Fund, Washington DC, USA

[b] Faculty of Economics and Girton College, University of Cambridge, UK

[c] Department of Mathematical Sciences, George Mason University, USA

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Abstract

We employ a set of sign restrictions on the generalized impulse responses of a Global VAR model, estimated for 38 countries/regions over the period 1979Q2–2011Q2, to discriminate between supply-driven and demand-driven oil-price shocks and to study the time profile of their macroeconomic effects for different countries. The results indicate that the economic consequences of a supply-driven oil-price shock are very different from those of an oil-demand shock driven by global economic activity, and vary for oil-importing countries compared to energy exporters. While oil importers typically face a long-lived fall in economic activity in response to a supply-driven surge in oil prices, the impact is positive for energy-exporting countries that possess large proven oil/gas reserves. However, in response to an oil-demand disturbance, almost all countries in our sample experience long-run inflationary pressures and a short-run increase in real output.

JEL Classifications: C32, E17, F44, F47, Q41.

Keywords: Global VAR (GVAR), interconnectedness, global macroeconomic modeling, impulse responses, international business cycle, oil-demand and oil-supply shocks.

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[†] Corresponding author. Email address: mraissi@imf.org.

1 Introduction

How do oil-price shocks affect real output, inflation, the real effective exchange rate, interest rates, and equity prices in different countries, including major oil exporters? We identify two groups of explanatory factors as the main drivers of the evolution of crude oil prices: (i) fast-growing demand due to high global economic growth; and (ii) declining supply or anticipated production shortfalls in the future. We employ a set of sign restrictions on the generalized impulse responses of a Global VAR (GVAR) model to identify the underlying demand and supply shocks in the world crude oil market, and to study the macroeconomic consequences of oil-price fluctuations across different countries (including both commodity importers and exporters). Compared to Dees et al. (2007), the current paper advances the work on GVAR modelling in the following directions: (i) we extend the geographical coverage of the GVAR model to major oil exporters as well as other countries in the Middle East and North Africa region; (ii) we extend the sample period until the second quarter of 2011, thus including both the recent oil price boom (2002–2008) as well as the initial oil-supply disruptions which accompanied the Arab Spring (December 2010 onwards); (iii) we allow for the simultaneous determination of oil prices, oil production, and several macroeconomic variables in a global setting; and (iv) we demonstrate how a GVAR model, covering over 90% of world GDP, 85% of world oil consumption, and 80% of world proven oil reserves, can be used for 'structural' impulse response analysis following an oil-price shock.

There is a growing literature that employs sign restrictions on impulse responses as a way of identifying shocks in structural VARs— see, for example, Faust (1998), Uhlig (2005), and Canova and Nicoló (2002). This paper extends this approach to a GVAR framework in which the cross-sectional dimension of the model is utilized to identify shocks that are global in nature—i.e. shocks that affect many countries simultaneously. Fry and Pagan (2011) argue that sign restrictions solve the parametric identification problem present in structural VARs but leave the model identification problem unresolved. The latter refers to the fact that there are many models with identified parameters that provide the same fit to the data. We show that the global dimension— by offering a large number of additional sign restrictions— can significantly narrow the number of plausible models that satisfy a priori restrictions, and therefore can move us one step closer to calculating the true structural impulse responses.

The GVAR literature almost exclusively focuses on business cycle linkages among advanced and major emerging market economies, with limited attention to growth spillovers to/from major oil exporters (e.g. the Organization of the Petroleum Exporting Countries (OPEC) member states). While the international business cycle is very important for the economic performance of commodity exporters, macroeconomic and political developments in this group of countries also have large consequences for the rest of the world through their impact on global oil prices. In contrast to the existing literature, we use a GVAR model including major oil exporters to disentangle the size and speed of the transmission of different oil-price shocks to the global economy. This approach employs a dynamic multi-country framework for the analysis of the international transmission of shocks. The framework comprises 38 country/region-specific models, among which is a single Euro Area region (comprising 8 of the 11 countries that joined Euro in 1999) as well as the countries of the Gulf Cooperation Council (GCC). These individual models are solved in a global setting where core macroeconomic variables of each economy are related to corresponding foreign variables, which have been constructed to match the international trade pattern of the country under consideration. The model has both real and financial variables: real GDP, inflation, real equity prices, real effective exchange rate, short and long-term interest rates, a measure of global oil production, and the price of oil. We treat the latter endogenously as the question of whether oil prices are demand-driven or supply-driven often reignites debate about their exogenous or endogenous treatment in macroeconomic models. Our framework is able to account for various transmission channels, including not only trade relationships but also financial linkages through interest rates, equity prices, and exchange rates (see Dees et al. (2007) for more details).

We estimate the 38 individual VARX* models over the period 1979Q2–2011Q2. Having solved the GVAR model, we examine the effect of oil-demand and oil-supply shocks on the macroeconomic variables of different countries. Our results indicate that the economic consequences of a supply-driven oil-price shock are very different from those of an oil-demand shock driven by changes in global economic activity; and very different for oil-importing countries when compared with energy exporters. We find that while oil importers typically face a long-lived fall in economic activity in response to a supply-driven surge in oil prices, the impact is positive for energy-exporting countries that possess large proven oil/gas reserves. However, in response to an oil-demand disturbance, almost all countries in our sample experience long-run inflationary pressures, and a short-run increase in real outputs.

Our paper is related to several important contributions in the literature. Using a VAR framework for the case of the United States, Kilian (2009) decomposes oil-price shocks into three types— an oil-supply shock, an oil-demand shock driven by economic activity, and an oil-specific demand shock driven by expectations about future changes in oil conditions— and concludes that the macroeconomic effect of the most recent oil price surge was generally moderate until mid-2007. This observation could be interpreted as evidence of the key role played by the demand side in explaining the recent boom in oil prices. Had the shock been triggered by supply-side factors, global aggregate demand would have fallen, because a negative supply shock is perceived to be a tax on oil consumers (with a high propensity to consume) in favor of oil producers (with a lower propensity to consume). Following a supply-driven oil price shock and in the presence of non-linearities in the product and labor markets (for example price and wage rigidities), production costs increase and as a result inflation rises; often prompting central banks to raise their policy rates, and placing additional downward pressure on growth.[1] However, in response to a demand-driven oil price shock, combined with a near vertical oil supply curve, inflation rises temporarily, see for instance Kilian (2009). Overall, while the increase in oil prices in the run-up to financial crisis (2002-07) can be attributed to booming economic activity in emerging economies, and higher demand for oil (as well as other commodities), the stagflationary situation post-2007, can be associated with supply side factors. Indeed, Hamilton (2009) argues that the economic recession of the past few years was precipitated by high oil prices.

Most papers in the literature that investigate the effects of oil shocks on macroeconomic variables have focused on a handful of industrialized/OECD countries, and in most cases they have looked at the impact of oil shocks exclusively on the United States (and in isolation from the rest of the world). Moreover, the focus of those analysis has predominantly been on net oil importers— see, for example, Blanchard and Gali (2007), Hamilton (2009), Kilian (2009), and Peersman and Van Robays (2012). Esfahani et al. (2012a) is an exception, as they look at the direct effects of oil-revenue shocks on domestic output for 9 major oil exporters, six of which are OPEC members. But they do not investigate the differential effects of demand- versus supply-driven oil-price shocks. Another exception is Chapter 4 of International Monetary Fund (2012) World Economic Outlook (WEO), which provides a discussion of the effects of commodity price shocks on commodity exporters, using the methodology in Kilian (2009).[2] Therefore, our paper is complementary to the analysis of the effects of oil-price shocks on advanced economies, given its wide country coverage, including both major oil exporters (located in the Middle East, Africa and Latin America) as well as many developing countries.

The rest of the paper is organized as follows. Section 2 describes the GVAR methodology while Section 3 outlines our modelling approach and presents the country-specific estimates and tests. Moreover, we provide evidence for the weak exogeneity assumption of the country-specific foreign variables and discuss the issue of structural breaks in the context of our GVAR model. Section 4 explains the identification procedure used in this paper and investigates the macroeconomic effects of oil-supply and oil-demand shocks. Finally, Section 5 concludes

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[1] See Raissi (2011) for a discussion of the optimal monetary policy in the presence of labor market inefficiencies.

[2] See also Cavalcanti et al. (2011) and Cavalcanti et al. (2012) for two recent panel studies.

and offers some policy recommendations.

2 The Global VAR (GVAR) Methodology

We consider $N+1$ countries in the global economy, indexed by $i = 0, 1, ..., N$. With the exception of the United States, which we label as 0 and take to be the reference country, all other N countries are modelled as small open economies. This set of individual VARX* models is used to build the GVAR framework. Following Pesaran (2004) and Dees et al. (2007), a VARX* (s_i, s_i^*) model for the ith country relates a $k_i \times 1$ vector of domestic macroeconomic variables (treated as endogenous), $\mathbf{x}_{it}$, to a $k_i^* \times 1$ vector of country-specific foreign variables (taken to be weakly exogenous), $\mathbf{x}_{it}^*$, and to a $m_d \times 1$ vector of observed global factors, $\mathbf{d}_t$, which could include such variables as commodity prices:

$$\mathbf{\Phi}_i (L, s_i) \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \mathbf{\Lambda}_i (L, s_i^*) \mathbf{x}_{it}^* + \mathbf{\Upsilon}_i (L, s_i^*) \mathbf{d}_t + \mathbf{u}_{it}, \tag{1}$$

for $t = 1, 2, ..., T$, where $\mathbf{a}_{i0}$ and $\mathbf{a}_{i1}$ are $k_i \times 1$ vectors of fixed intercepts and coefficients on the deterministic time trends, respectively, and $\mathbf{u}_{it}$ is a $k_i \times 1$ vector of country-specific shocks, which we assume are serially uncorrelated with zero mean and a non-singular covariance matrix, $\mathbf{\Sigma}_{ii}$, namely $\mathbf{u}_{it} \sim i.i.d. (0, \mathbf{\Sigma}_{ii})$. Furthermore, $\mathbf{\Phi}_i (L, s_i) = I - \sum_{i=1}^{s_i} \mathbf{\Phi}_i L^i$, $\mathbf{\Lambda}_i (L, s_i^*) = \sum_{i=0}^{s_i^*} \mathbf{\Lambda}_i L^i$, and $\mathbf{\Upsilon}_i (L, s_i^*) = \sum_{i=0}^{s_i^*} \mathbf{\Upsilon}_i L^i$ are the matrix lag polynomial of the coefficients associated with the domestic, foreign, and global variables, respectively. As the lag orders for these variables, s_i and s_i^*, are selected on a country-by-country basis, we are explicitly allowing for $\mathbf{\Phi}_i (L, s_i)$, $\mathbf{\Lambda}_i (L, s_i^*)$, and $\mathbf{\Upsilon}_i (L, s_i^*)$ to differ across countries.

The country-specific foreign variables are constructed as cross-sectional averages of the domestic variables using data on bilateral trade as the weights, w_{ij}:

$$\mathbf{x}_{it}^* = \sum_{j=0}^{N} w_{ij} \mathbf{x}_{jt}, \tag{2}$$

where $j = 0, 1, ...N$, $w_{ii} = 0$, and $\sum_{j=0}^{N} w_{ij} = 1$. For empirical application, the trade weights are computed as fixed weights based on the average trade flows measured over the period 2006 to 2008. However, the weights can be based on any time period and can be allowed to be time-varying.[3]

Although estimation is done on a country-by-country basis, the GVAR model is solved

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[3] The main justification for using bilateral trade weights, as opposed to financial weights, is that the former have been shown to be the most important determinant of business cycle comovements (see Baxter and Kouparitsas (2005) among others).

for the world as a whole, taking account of the fact that all variables are endogenous to the system as a whole. After estimating each country VARX*(s_i, s_i^*) model separately, all the $k = \sum_{i=0}^{N} k_i$ endogenous variables, collected in the $k \times 1$ vector $\mathbf{x}_t = (\mathbf{x}_{0t}', \mathbf{x}_{1t}', ..., \mathbf{x}_{Nt}')'$, need to be solved simultaneously using the link matrix defined in terms of the country-specific weights. To see this, we can write the VARX* model in equation (1) more compactly as:

$$\mathbf{A}_i \left(L, s_i, s_i^*\right) \mathbf{z}_{it} = \boldsymbol{\varphi}_{it}, \tag{3}$$

for $i = 0, 1, ..., N$, where

$$\begin{aligned} \mathbf{A}_i \left(L, s_i, s_i^*\right) &= \left[\boldsymbol{\Phi}_i \left(L, s_i\right) - \boldsymbol{\Lambda}_i \left(L, s_i^*\right)\right], \quad \mathbf{z}_{it} = \left(\mathbf{x}_{it}', \mathbf{x}_{it}'^{*}\right)', \\ \boldsymbol{\varphi}_{it} &= \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \boldsymbol{\Upsilon}_i \left(L, s_i^*\right) \mathbf{d}_t + \mathbf{u}_{it}. \end{aligned} \tag{4}$$

Note that given equation (2) we can write:

$$\mathbf{z}_{it} = \mathbf{W}_i \mathbf{x}_t, \tag{5}$$

where $\mathbf{W}_i = (\mathbf{W}_{i0}, \mathbf{W}_{i1}, ..., \mathbf{W}_{iN})$, with $\mathbf{W}_{ii} = 0$, is the $(k_i + k_i^*) \times k$ weight matrix for country i defined by the country-specific weights, w_{ij}. Using (5) we can write equation (3) as:

$$\mathbf{A}_i \left(L, s\right) \mathbf{W}_i \mathbf{x}_t = \varphi_{it}, \tag{6}$$

where $\mathbf{A}_i \left(L, s\right)$ is constructed from $\mathbf{A}_i \left(L, s_i, s_i^*\right)$ by setting $s = \max\left(s_0, s_1, ..., s_N, s_0^*, s_1^*, ..., s_N^*\right)$ and augmenting the $s - s_i$ or $s - s_i^*$ additional terms in the power of the lag operator by zeros. Stacking equation (6), we obtain the Global VAR(s) model in domestic variables only:

$$\mathbf{G} \left(L, s\right) \mathbf{x}_t = \varphi_t, \tag{7}$$

where

$$\mathbf{G}\left(L, s\right) = \begin{pmatrix} \mathbf{A}_0 \left(L, s\right) \mathbf{W}_0 \\ \mathbf{A}_1 \left(L, s\right) \mathbf{W}_1 \\ . \\ . \\ . \\ \mathbf{A}_N \left(L, s\right) \mathbf{W}_N \end{pmatrix}, \quad \varphi_t = \begin{pmatrix} \varphi_{0t} \\ \varphi_{1t} \\ . \\ . \\ . \\ \varphi_{Nt} \end{pmatrix}. \tag{8}$$

For an illustration of the solution of the GVAR model, using a VARX*$(1, 1)$ model, see Pesaran (2004), and for a detailed exposition of the GVAR methodology see Dees et al. (2007). The GVAR(s) model in equation (7) can be solved recursively and used for a number of purposes, such as forecasting or impulse response analysis.

3 A Global VAR Model Including Major Oil Exporters

We extend the country coverage of the GVAR dataset used in Dees et al. (2007) by adding 11 major oil exporters located in the Middle East, Africa, and Latin America, as well as another six oil-importing countries in the Middle East and North Africa (MENA) region, see Table 1.[4] Thus our version of the GVAR model covers 50 countries as opposed to the "standard" 33 country set-up used in the literature, see Smith and Galesi (2010), and extends the coverage both in terms of major oil exporters and also by including an important region of the world when it comes to oil supply, the MENA region.[5]

Of the 50 countries included in our sample, 17 are oil exporters, of which 10 are current members of the OPEC and one is a former member (Indonesia left OPEC in January 2009). We were not able to include Angola and Iraq, the remaining two OPEC members, due to the lack of sufficiently long time series data. This was also the case for Russia, the second-largest oil exporter in the world, for which quarterly data is not available for the majority of our sample period. Our sample also includes three OECD oil exporters and the United Kingdom, which remained a net oil exporter for the majority of the sample (until 2006), and therefore is treated as an oil exporter when it comes to imposing sign-restrictions (see the discussion in Section 4). These 50 countries together cover over 90% of world GDP, 85% of world oil consumption, and 80% of world proven oil reserves. Thus our sample is rather comprehensive.

For empirical applications, we create two regions; one of which comprises the six Gulf Cooperation Council (GCC) countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE); and the other is the Euro Area block comprising 8 of the 11 countries that initially joined the euro on January 1, 1999: Austria, Belgium, Finland, France, Germany, Italy, Netherlands, and Spain. The time series data for the GCC block and the Euro Area block are constructed as cross-sectionally weighted averages of the domestic variables (described in detail below), using Purchasing Power Parity GDP weights, averaged over the 2006-2008 period. Thus, as displayed in Table 1, the GVAR model that we specify includes 38 country/region-specific VARX* models.

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[4] Although Bahrain and Oman are not OPEC member countries, we include them in the OPEC block as we treat all the GCC countries as a region. Note that using GDP PPP weights, Bahrain and Oman are less than 8% of the total GDP of the GCC.

[5] For an extensive discussion on the impact of three systemic economies (China, Euro Area, and the U.S.) on the MENA region, see Cashin et al. (2012).

Table 1: Countries and Regions in the GVAR Model with Major Oil Exporters

Oil Exporters	Oil Importers	
OPEC Members	**Major Importers**	**Latin America**
Algeria*	China	Argentina
Ecuador*	Euro Area	Brazil
GCC Countries	_Austria_	Chile
_Bahrain_*	_Belgium_	Peru
_Kuwait_*	_Finland_	
_Oman_*	_France_	**Emerging Asia**
_Qatar_*	_Germany_	Korea
Saudi Arabia	_Italy_	Malaysia
_UAE_*	_Netherlands_	Philippines
Indonesia	_Spain_	Singapore
Iran*	Japan	Thailand
Libya*	United States	
Nigeria*		
Venezuela*	**MENA**	**Rest of the World**
	Egypt*	Australia
OECD Exporters	Jordan*	India
Canada	Mauritania*	New Zealand
Mexico	Morocco*	South Africa
Norway	Syria*	Sweden
United Kingdom	Tunisia*	Switzerland
		Turkey

Notes:* indicates that the country has been added to the Smith and Galesi (2010) database. OECD refers to the Organization for Economic Cooperation and Development, OPEC is the Organization of the Petroleum Exporting Countries, and MENA refers to the countries in the Middle East and North Africa region.

3.1 Variables

The macroeconomic variables included in the individual VARX* models depend on both the modelling strategy employed as well as whether data on a particular variable is available. Each country-specific model has a maximum of six domestic (endogenous) variables and five foreign (exogenous) variables. We also include two global variables, each of which is treated endogenously in only one country, while being weakly exogenous in the remaining 37 country models. Below we describe the different variables included in our model and provide justification for our modelling specification. For various data sources used to build the quarterly GVAR dataset, covering 1979Q2 to 2011Q2, see the Data Appendix.

3.1.1 Domestic Variables

Real GDP, y_{it}, the rate of inflation, π_{it}, short-term interest rate, r_{it}^S, long-term interest rate, r_{it}^L, and real equity prices, eq_{it} are the five domestic variables that are included in our model, as well as most of the GVAR applications in the literature. These five variables are constructed as:

$$\begin{aligned} y_{it} &= \ln(GDP_{it}), \quad \pi_{it} = p_{it} - p_{it-1}, \quad p_{it} = \ln(CPI_{it}), \quad eq_{it} = \ln\left(EQ_{it}/CPI_{it}\right), \\ r_{it}^S &= 0.25\ln(1 + R_{it}^S/100), \quad r_{it}^L = 0.25\ln(1 + R_{it}^L/100), \end{aligned} \tag{9}$$

where GDP_{it} is the real Gross Domestic Product at time t for country i, CPI_{it} is the consumer price index, EQ_{it} is a nominal Equity Price Index, and R_{it}^S (R_{it}^L) is the short-term (long-term) interest rate.

The GVAR literature also includes a sixth domestic variable, representing the real exchange rate and defined as $e_{it} - p_{it}$, that is the log of the nominal exchange rate of country i, $\ln\left(E_{it}\right)$, deflated by the domestic CPI. However, in a multi-country set-up, it might be better to consider a measure of the real effective exchange rate, rather than $e_{it} - p_{it}$. We therefore follow Dees et al. (2007) and construct such a variable, $reer_{it}$.

To construct the real effective exchange rate for country i, we simply take the nominal effective exchange rate, $neer_{it}$, add the log of foreign price level (p_{it}^*) and subtract the domestic (p_{it}) price level. Note that $neer_{it}$ is a weighted average of the bilateral exchange rates between country i and all of its trading partners j, where $j = 0, ..., N$. In the current application we have a total of 36 countries and two regions in our model, $N = 37$, therefore we can use the nominal exchange rates denominated in U.S. dollars for each country, e_{it}, to calculate $reer_{it}$. More specifically:

$$\begin{aligned} reer_{it} &= neer_{it} + p^*_{it} - p_{it} \\ &= \sum_{j=0}^{37} w_{ij}\left(e_{it} - e_{jt}\right) + p^*_{it} - p_{it}, \end{aligned} \tag{10}$$

where the foreign price is calculated as the weighted sum of log price level indices (p_{jt}) of country i's trading partners, $p^*_{it} = \sum_{j=0}^{37} w_{ij} p_{jt}$, and w_{ij} is the trade share of country j for country i. Given that $\sum_{j=0}^{37} w_{ij} = 1$ and $e^*_{it} = \sum_{j=0}^{37} w_{ij} e_{jt}$, the real effective exchange rate can be written as:

$$\begin{aligned} reer_{it} &= e_{it} - e^*_{it} + p^*_{it} - p_{it} \\ &= \left(e_{it} - p_{it}\right) - \left(e^*_{it} - p^*_{it}\right). \end{aligned} \tag{11}$$

This constructed measure of the real effective exchange rate is then included in our model as the sixth domestic variable.

3.1.2 Foreign Variables

We include five foreign variables in our model. In particular, all domestic variables, except for that of the real effective exchange rate, have corresponding foreign variables. The exclusion of $reer^*_{it}$ is simply because $reer_{it}$ already includes both domestic, $e_{it} - p_{it}$, and foreign, $e^*_{it} - p^*_{it}$, nominal exchanges rates deflated by the appropriate price levels, see equation (11). Therefore, $reer^*_{it}$ does not by itself have any economic meaning. The foreign variables are all computed as in equation (2), or more specifically:

$$\begin{aligned} y^*_{it} &= \sum_{j=0}^{37} w_{ij} y_{jt}, \quad eq^*_{it} = \sum_{j=0}^{37} w_{ij} eq_{jt}, \quad \pi^*_{it} = p^*_{it} - p^*_{it-1} \\ r^{S*}_{it} &= \sum_{j=0}^{37} w_{ij} r^S_{jt}, \quad r^{L*}_{it} = \sum_{j=0}^{37} w_{ij} r^L_{jt}. \end{aligned} \tag{12}$$

The trade weights, w_{ij}, are computed as a three-year average to reduce the impact of individual yearly movements on the weights:[6]

$$w_{ij} = \frac{T_{ij,2006} + T_{ij,2007} + T_{ij,2008}}{T_{i,2006} + T_{i,2007} + T_{i,2008}}, \tag{13}$$

where T_{ijt} is the bilateral trade of country i with country j during a given year t and is calculated as the average of exports and imports of country i with j, and $T_{it} = \sum_{j=0}^{N} T_{ijt}$ (the total trade of country i) for $t = 2006, 2007, 2008$, in the case of all countries. The trade shares used to construct the foreign variables are given in the 38×38 matrix provided in Table 9 of the Data Appendix.

3.1.3 Global Variables

Given that we want to consider the macroeconomic effects of oil shocks on the global economy, we also need to include nominal oil prices (in U.S. dollars), P_t^{oil}, as well as the quantity of oil produced in the world, Q_t^{oil}. A key question is how should these two variables be included in the GVAR model? Since we will estimate the model over the second quarter of 1979 to the second quarter of 2011, we look at oil consumption over this period for the four largest oil importers in the world, as well as for different country groupings. Table 2 shows that the United States consumed on average about 27% of world oil between 1979–2010. Comparing this to the other three major oil importers (China, Euro Area, and Japan), we note that U.S. consumption is far larger than any of these countries or even the other regions in the world considered in this paper. In fact the sum of consumption of the other major oil importers is 26.6%, which is still below that of the United States. Therefore, as is now standard in the literature, we include log oil prices, p_t^{oil}, as a "global variable" determined in the U.S. VARX* model; that is the price of oil is included in the U.S. model as an endogenous variable while it is treated as weakly exogenous in the model for all other countries.

Turning to the largest oil exporters in the world, we notice from Table 3 that Saudi Arabia, and more specifically the GCC countries, play an important role when it comes to world oil supply. Not only do these six countries produce more than 22% of world oil and export around 30% of the world total, which is almost three times that of the OECD oil exporters, the six GCC countries also possess 36.3% of the world's proven oil reserves.[7] Moreover, Saudi Arabia is not only the largest oil producer and exporter in the world, but

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[6] A similar approach has also typically been followed in Global VAR models estimated in the literature. See, for example, Dees et al. (2007).

[7] Note that proven reserves at any given point in time are defined as "quantities of oil that geological and engineering information indicate with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions" (British Petroleum Statistical Review of World Energy), thus this measure could be uncertain.

it also has the largest spare capacity and as such is often seen as a global swing producer. For example, in September of 1985, Saudi production was increased from 2 million barrels per day (mbd) to 4.7 mbd, and more recently Saudi Arabia has increased its production to stabilize the oil market. Therefore, given the status of the GCC countries with regard to oil supply, we include log of oil production, q_t^{oil}, as an endogenous variable in the GCC block, and as a weakly exogenous variable in all other countries. Accordingly, q_t^{oil} is the second "global variable" in our model.

Table 2: Oil Consumption by Oil Importers, averages over 1979–2010

Major Importers	Million Barrels/day	Percent of World	Other Oil Importers	Million Barrels/day	Percent of World
China	3.1	4.8	Latin America	2.1	3.3
Euro Area	9.3	14.5	Emerging Asia	2.6	4.0
Japan	4.7	7.4	Rest of the World	3.5	5.5
United States	17.3	26.9	World	64.1	100.0

Source: Oil consumption data is from the British Petroleum *Statistical Review of World Energy*. For country groupings see Table 1.

Table 3: Oil Reserves, Production and Exports of Major Oil Exporters, averages over 2008–2010

Country	Oil Production		Oil Exports		Oil Reserves	
	Million Barrels/day	Percent of World	Million Barrels/day	Percent of World	Billion Barrels	Percent of World
OPEC Members	32.0	39.3	20.7	53.1	937	68.6
GCC Countries	18.0	22.1	11.7	29.9	496	36.3
Saudi Arabia	10.2	12.6	6.7	17.3	264	19.4
OECD Oil Exporters	8.6	10.6	4.6	11.7	51	3.7
World	81.5	100.0	39.0	100.0	1365	100.0

Source: Oil reserve and production data is from the British Petroleum *Statistical Review of World Energy* and oil export data is from the OPEC *Annual Statistical Bulletin*. For country groupings see Table 1.

Making one region out of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates, is not without any economic reasoning. The rationale is that the GCC countries have in recent decades implemented a number of policies and initiatives to foster economic and financial integration with a view to establishing a monetary union based on the Euro Area model. Given the increased integration of these economies over the last three decades, a peg to a common currency (the U.S. dollar), flexible labor markets, and open capital accounts, it is therefore reasonable to group these countries as one region.[8]

3.2 Model Specification

Given the discussion in Section 3.1, we specify three different sets of individual country-specific models. The first specification is common across all countries apart from the United States and the GCC block. These 36 VARX* models include six endogenous/domestic variables, when available, five country-specific foreign variables, and two global variables, see Table 4. Using the same terminology as in equation (1), the 6×1 vector of endogenous and the 5×1 vector of exogenous variables are given by $\mathbf{x}_{it} = \left[y_{it},\ \pi_{it},\ eq_{it},\ r_{it}^{S},\ r_{it}^{L},\ reer_{it}\right]'$ and $\mathbf{x}_{it}^{*} = \left[y_{it}^{*},\ \pi_{it}^{*},\ eq_{it}^{*},\ r_{it}^{*S},\ r_{it}^{*L}\right]'$ respectively, while the 2×1 vector of global variables is defined as $\mathbf{d}_t = \left[p_t^{oil}, q_t^{oil}\right]'$.

The second specification relates to the GCC block only, for which the log of oil production, q_t^{oil}, is included in the model endogenously in addition to the three domestic variables in $\mathbf{x}_{it}$, while $\mathbf{x}_{it}^{*}$ and the log of nominal oil prices, p_t^{oil}, are included as weakly exogenous variables.

Table 4: Variables Specification of the Country-specific VARX* Models

The U.S. Model		The GCC Model		All Other Models	
Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
$y_{US,t}$	$y_{US,t}^{*}$	$y_{GCC,t}$	$y_{GCC,t}^{*}$	y_{it}	y_{it}^{*}
$\pi_{US,t}$	$\pi_{US,t}^{*}$	$\pi_{GCC,t}$	$\pi_{GCC,t}^{*}$	π_{it}	π_{it}^{*}
$eq_{US,t}$	–	–	$eq_{GCC,t}^{*}$	eq_{it}	eq_{it}^{*}
$r_{US,t}^{S}$	$r_{US,t}^{*S}$	–	$r_{GCC,t}^{*S}$	r_{it}^{S}	r_{it}^{*S}
$r_{US,t}^{L}$	–	–	$r_{GCC,t}^{*L}$	r_{it}^{L}	r_{it}^{*L}
–	$e_{US,t}^{*} - p_{US,t}^{*}$	$reer_{GCC,t}$	–	$reer_{it}$	–
p_t^{oil}	–	–	p_t^{oil}	–	p_t^{oil}
–	q_t^{oil}	q_t^{oil}	–	–	q_t^{oil}

Notes: For the definition of the variables see equations (9) and (11).

Finally, the U.S. model is specified differently from the others, mainly because of the dominance of the United States in the world economy. Firstly, based on the discussion above regarding oil consumption, the price of oil is included in the model endogenously. Secondly, given the importance of U.S. financial variables in the global economy, the U.S.-specific foreign financial variables, $eq_{US,t}^{*}$ and $r_{US,t}^{*L}$, are not included in this model. The exclusion of these two variables was also confirmed by our preliminary analysis, in which

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[8] See Mohaddes and Williams (2012) for more details.

the weak exogeneity assumption was rejected for $eq_{US,t}^{*}$ and $r_{US,t}^{*L}$ in the U.S. model. Finally, since e_{it} is expressed as domestic currency price of a United States dollar, $e_{US,t} - p_{US,t}$, it is by construction determined outside this model. Thus, instead of the real effective exchange rate, we included $e_{US,t}^{*} - p_{US,t}^{*}$ as a weakly exogenous foreign variable in the U.S. model.

3.3 Country-Specific Estimates and Tests

Initial estimations and tests of the individual VARX*(s_i, s_i^*) models are conducted under the assumption that the country-specific foreign and global variables are weakly exogenous and integrated of order one, $I(1)$, and that the parameters of the models are stable over time. As both assumptions are needed for the construction and the implementation of the GVAR model, we will test and provide evidence for these assumptions in Sections 3.3.2 and 3.3.3.

For the interpretation of the long-run relations, and also to ensure that we do not work with a mixture of $I(1)$ and $I(2)$ variables, we need to consider the unit root properties of the core variables in our country-specific models, see Table 4. If the domestic, $\mathbf{x}_{it}$, foreign, $\mathbf{x}_{it}^{*}$, and global, $\mathbf{d}_t$, variables included in the country-specific models are indeed integrated of order one, $I(1)$, we are not only able to distinguish between short- and long-run relations, but also to interpret the long-run relations as cointegrating. Therefore, we perform Augmented Dickey-Fuller (ADF) tests on the level and first differences of all the variables. However, as the power of unit root tests are often low, we also utilize the weighted symmetric ADF test (ADF-WS) of Park and Fuller (1995), as it has been shown to have better power properties than the ADF test. This analysis results in over 3200 unit root tests, which overall, as a first-order approximation, support the treatment of the variables in our model as being $I(1)$. For brevity, these test results are not reported here but are available from the authors upon request.

3.3.1 Lag Order Selection, Cointegrating Relations, and Persistence Profiles

We use quarterly observations over the period 1979Q2–2011Q2, across the different specifications in Table 4, to estimate the 38 country/region-specific VARX*(s_i, s_i^*) models. However, prior to estimation we need to determine the lag orders of the domestic and foreign variables, s_i and s_i^*. For this purpose, we use the Akaike Information Criterion (AIC) applied to the underlying unrestricted VARX* models. However, given the constraints imposed by data limitations, we set the maximum lag orders to $s_{\max} = 2$ and $s_{\max}^{*} = 1$. The selected VARX* orders are reported in Table 5, from which we can see that for most countries a VARX*$(2, 1)$ specification seems satisfactory, except for seven countries (Australia, Egypt, Iran, Malaysia, Mexico, Singapore, and the United Kingdom) for which $s = s^* = 1$ is selected by AIC.

Table 5: Lag Orders of the Country-specific VARX*(s,s*) Models together with the Number of Cointegrating Relations (r)

Country	VARX* Order s_i	VARX* Order s_i^*	Cointegrating relations (r_i)	Country	VARX* Order s_i	VARX* Order s_i^*	Cointegrating relations (r_i)
Algeria	2	1	1	Morocco	2	1	1
Argentina	2	1	2	Mauritania	2	1	1
Australia	1	1	3	Mexico	1	1	2
Brazil	2	1	1	Nigeria	2	1	2
Canada	2	1	2	Norway	2	1	3
China	2	1	1	New Zealand	2	1	3
Chile	2	1	2	Peru	2	1	1
Ecuador	2	1	1	Philippines	2	1	1
Egypt	1	1	2	South Africa	2	1	1
Euro Area	2	1	1	Singapore	1	1	2
GCC	2	1	2	Sweden	2	1	3
India	2	1	1	Switzerland	2	1	2
Indonesia	2	1	2	Syria	2	1	2
Iran	1	1	1	Thailand	2	1	2
Japan	2	1	2	Tunisia	2	1	1
Jordan	2	1	3	Turkey	2	1	1
Korea	2	1	1	UK	1	1	1
Libya	2	1	1	USA	2	1	2
Malaysia	1	1	1	Venezuela	2	1	1

Notes: s_i and s_i^* denote the lag order for the domestic and foreign variables respectively and are selected by the Akaike Information Criterion (AIC). The number of cointegrating relations (r_i) are selected using the trace test statistics based on the 95% critical values from MacKinnon (1991) for all countries except for Australia, Euro Area, Indonesia, Iran, Japan, Malaysia, South Africa, Singapore, Switzerland, Thailand, Tunisia, and the United States, for which we use the 95% simulated critical values computed by stochastic simulations and 1000 replications, and for Canada, China, Korea, Peru, Philippines, the UK, for which we reduced r_i below that suggested by the trace statistic to ensure the stability of the global model.

Having established the order of the 38 VARX* models, we proceed to determine the number of long-run relations. Cointegration tests with the null hypothesis of no cointegration, one cointegrating relation, and so on are carried out using Johansen's maximal eigenvalue and trace statistics as developed in Pesaran et al. (2000) for models with weakly exogenous $I(1)$ regressors, unrestricted intercepts and restricted trend coefficients. We choose the number of cointegrating relations (r_i) based on the trace test statistics, given that it has better small sample properties than the maximal eigenvalue test, initially using the 95% critical values from MacKinnon (1991).[9]

We then consider the effects of system-wide shocks on the exactly identified cointegrating vectors using persistence profiles developed by Lee and Pesaran (1993) and Pesaran and Shin (1996). On impact the persistence profiles (PPs) are normalized to take the value of unity, but the rate at which they tend to zero provides information on the speed with which equilibrium correction takes place in response to shocks. The PPs could initially over-shoot, thus exceeding unity, but must eventually tend to zero if the vector under consideration is indeed cointegrated. In our preliminary analysis of the PPs we noticed that the speed of convergence was very slow for some countries, and for a few, the system-wide shocks never really died out. In particular, the speed of adjustment was very slow for the following 18 countries (with r_i based on critical values from MacKinnon (1991) in brackets): Australia (4), Canada (4), China (2), Euro Area (2), Indonesia (3), Iran (2), Japan (3), Korea (4), Malaysia (2), Peru (3), Philippines (2), South Africa (2), Singapore (3), Switzerland (3), Thailand (3), Tunisia (2), the United Kingdom (2), and the United States (3).

Moreover, we noticed that a couple of eigenvalues of the GVAR model were larger than unity; rendering the global model unstable. To deal with this issue, and the possible overestimation of the number of cointegrating relations (using asymptotic critical values), we estimated a cointegrating VARX* model using the lag orders in Table 5 for each of the 18 countries separately. We then used the trace test statistics together with the 95% simulated critical values (computed by stochastic simulations using 127 observations from 1979Q4 to 2011Q2 and 1000 replications), to determine the number of cointegrating vectors.[10]

We then re-estimated the global model reducing the number of cointegrating relations (for the 18 countries only) one by one, and re-examined the PPs after each estimation to ensure stability of the model. The final selection of the number of cointegrating relations are reported in Table 5. For 12 of the 18 countries we selected r_i based on the trace statistic and the simulated critical values. For four countries (China, Peru, Philippines, and the UK)

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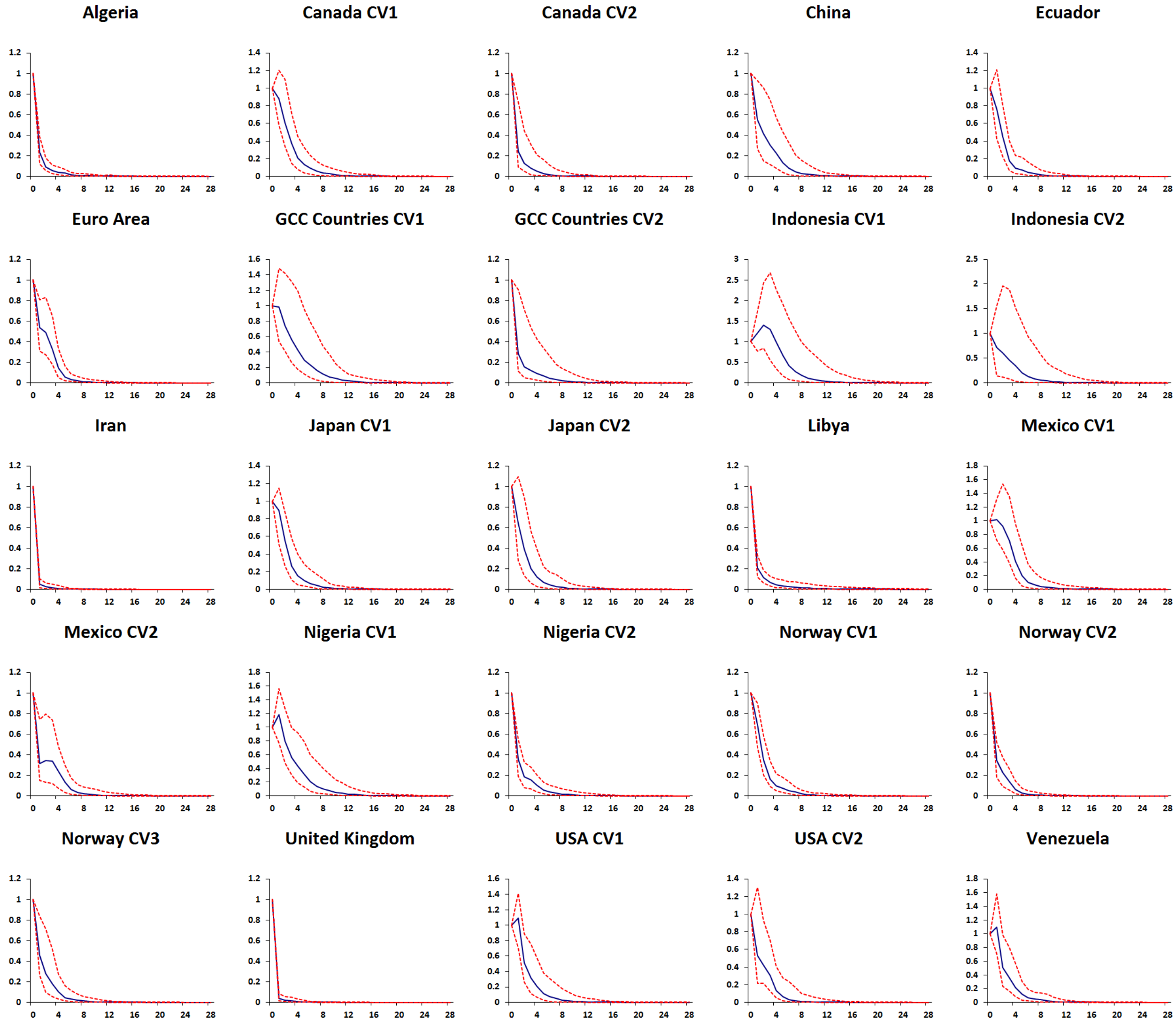
[9] To save space the lag order and cointegration test results are not reported here but are available on request.

[10] The estimations were done in Microfit 5.0. For further technical details see Pesaran and Pesaran (2009), Section 22.10.

Figure 1: Persistence Profiles of the Effect of a System-wide Shock to the Cointegrating Relations



Notes: Figures are median effects of a system-wide shock to the cointegrating relations with 95% bootstrapped confidence bounds.

the asymptotic and simulated critical values were the same so we reduced r_i until the PPs for each country were well behaved; this was also done for Canada and Korea.

The persistence profiles for the set of 16 focus countries, the four largest oil importers and 12 oil exporters in our model (see Table 1), together with their 95% bootstrapped error bands are provided in Figure 1. The profiles overshoot for only 5 out of the 25 cointegrating vectors before quickly tending to zero. The speed of convergence is very fast, the half-life of the shocks are generally less than 3 quarters, and equilibrium is established before 6 years in all cases except for Libya. Amongst the 16 countries, Iran shows the fastest rate of convergence (around 3 years),[11] and Libya the slowest rate of convergence (8-9 years). The 95% error bands are quite tight and initially widen somewhat before narrowing to zero. The speed of convergence, although relatively fast, is in line with that observed for major oil exporters in Esfahani et al. (2012a).

3.3.2 Testing the Weak Exogeneity Assumption

Weak exogeneity of the country-specific foreign variables, $\mathbf{x}_{it}^* = \left[y_{it}^*,\ \pi_{it}^*,\ eq_{it}^*,\ r_{it}^{*S},\ r_{it}^{*L}\right]'$, and the global variables, p_t^{oil} and q_t^{oil}, with respect to the long-run parameters of the conditional model is vital in the construction and the implementation of the GVAR model. We formally test this assumption following the procedure in Johansen (1992) and Harbo et al. (1998). To this end, we first estimate the 38 VARX*(s_i, s_i^*) models separately under the assumption that the foreign and global variables are weakly exogenous. We then run the following regression for each lth element of $\mathbf{x}_{it}^*$:

$$\Delta x_{it,l}^* = \mu_{il} + \sum_{j=1}^{r_i} \gamma_{ij,l} ECM_{i,t-1}^j + \sum_{k=1}^{s_i} \varphi_{ik,l} \Delta \mathbf{x}_{i,t-k} + \sum_{m=1}^{n_i} \vartheta_{im,l} \Delta \widetilde{\mathbf{x}}_{i,t-m}^* + \varepsilon_{it,l}, \tag{14}$$

where $ECM_{i,t-1}^j$, $j = 1, 2, ..., r_i$, are the estimated error correction terms corresponding to the r_i cointegrating relations found for the ith country model, $n_i = 2$ (although it could be set equal to s_i^*), and $\Delta \widetilde{\mathbf{x}}_{it}^* = \left[\Delta \mathbf{x}_{it}'^*,\ \Delta reer_{it}^*, \Delta p_t^{oil}, \Delta q_t^{oil}\right]'$.[12] Under the null hypothesis that the variables are weakly exogenous, the error correction term must not be significant; therefore, the formal test for weak exogeneity is an F-test of the joint hypothesis that $\gamma_{ij,l} = 0$ for each $j = 1, 2, ..., r_i$ in equation (14). The test results together with the 95% critical values are reported in Table 6, from which we see that the weak exogeneity assumption cannot be rejected for the overwhelming majority of the variables considered. In fact, only 7 out of 263 exogeneity tests turned out to be statistically significant at the 5% level.

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[11] The fast convergence for Iran is also documented in Esfahani et al. (2012b).

[12] Note that the models for U.S. and the GCC are specified differently, see the discussion in Section 3.2.

Table 6: F-Statistics for Testing the Weak Exogeneity of the Country-Specific Foreign Variables, Oil Prices, and Oil Production

	F test	Critical Value	y^*	Δp^*	r^{*s}	r^{*l}	(e^*-p^*)	eq^*	p^{oil}	q^{oil}
Algeria	F(1,109)	3.93	0.50	3.63	1.34	0.16	-	0.31	0.13	0.81
Argentina	F(2,106)	3.08	0.30	2.37	6.45*	0.43	-	0.19	0.72	0.04
Australia	F(3,109)	2.69	0.35	1.30	0.81	1.90	-	0.61	0.06	0.49
Brazil	F(1,109)	3.93	0.04	0.04	0.00	0.17	-	0.91	0.01	0.80
Canada	F(2,104)	3.08	0.46	2.42	1.93	0.01	-	0.00	3.37*	1.00
China	F(1,109)	3.93	0.04	2.02	1.33	2.66	-	0.21	0.21	0.43
Chile	F(2,106)	3.08	0.15	0.57	0.97	0.69	-	2.97	0.24	2.24
Ecuador	F(1,109)	3.93	1.57	0.62	0.04	0.23	-	0.05	0.23	0.07
Egypt	F(2,112)	3.08	0.50	0.81	0.93	0.13	-	0.26	0.10	1.05
Euro Area	F(1,105)	3.93	0.98	0.48	0.32	0.44	-	2.26	0.11	3.98*
GCC	F(2,109)	3.08	0.36	0.80	0.11	2.59	-	0.07	0.21	-
India	F(1,107)	3.93	0.03	0.00	0.23	0.42	-	0.22	0.02	0.02
Indonesia	F(2,108)	3.08	3.74*	0.89	0.16	0.37	-	1.24	0.07	0.27
Iran	F(1,114)	3.92	2.88	0.84	3.68	0.17	-	2.73	0.29	6.86*
Japan	F(2,104)	3.08	0.62	0.72	4.00*	2.87	-	0.46	2.47	1.98
Jordan	F(3,107)	2.69	1.36	0.89	1.14	1.56	-	0.77	0.04	1.16
Korea	F(1,105)	3.93	2.53	0.87	0.31	0.01	-	0.02	1.52	2.59
Libya	F(1,111)	3.93	0.28	0.00	0.26	0.19	-	0.06	1.06	0.77
Malaysia	F(1,112)	3.93	2.27	0.02	0.10	0.01	-	3.60	1.27	1.86
Morocco	F(1,111)	3.93	1.18	0.47	1.49	0.24	-	2.82	0.06	2.84
Mauritania	F(1,109)	3.93	0.03	0.45	1.52	0.75	-	1.16	0.67	0.49
Mexico	F(2,112)	3.08	1.17	2.13	1.08	0.40	-	0.81	0.68	0.13
Nigeria	F(2,108)	3.08	1.14	1.98	3.55*	0.77	-	1.26	0.78	0.95
Norway	F(3,103)	2.69	1.38	0.42	0.07	1.58	-	0.90	0.48	1.21
New Zealand	F(3,103)	2.69	2.01	0.67	1.78	0.24	-	1.04	0.58	0.20
Peru	F(1,109)	3.93	3.12	0.22	0.11	0.83	-	0.10	0.37	0.01
Philippines	F(1,107)	3.93	0.07	1.35	0.12	0.21	-	2.89	1.48	0.06
South Africa	F(1,105)	3.93	0.35	0.03	0.56	0.58	-	0.51	0.01	2.08
Singapore	F(2,111)	3.08	0.07	0.13	0.08	1.43	-	0.05	0.12	1.23
Sweden	F(3,103)	2.69	0.43	0.51	0.54	0.63	-	0.21	0.37	0.79
Switzerland	F(2,104)	3.08	1.07	1.15	0.57	0.43	-	1.63	0.89	1.92
Syria	F(2,110)	3.08	1.03	2.09	0.18	0.01	-	0.03	0.45	0.37
Thailand	F(2,106)	3.08	0.11	0.80	0.01	0.27	-	1.11	0.02	2.11
Tunisia	F(1,109)	3.93	1.56	0.52	0.00	0.58	-	1.52	0.75	0.57
Turkey	F(1,109)	3.93	0.00	1.53	3.00	0.16	-	0.07	0.01	0.01
United Kingdom	F(1,111)	3.93	0.54	0.92	0.67	0.32	-	0.11	0.00	0.01
USA	F(2,106)	3.08	0.43	0.89	0.64	-	1.03	-	-	0.35
Venezuela	F(1,109)	3.93	0.00	2.29	0.38	0.00	-	0.40	1.30	0.78

Notes: * denotes statistical significance at the 5% level.

More specifically, in terms of the variables in $\mathbf{x}_{it}^*$, only foreign output in the Indonesian model and foreign short-term interest rates in the model for Argentina, Japan, and Nigeria cannot be considered as weakly exogenous. This assumption is also rejected for the price of oil in the Canadian model, and oil production in the Euro Area and Iranian models. However, considering the significance level assumed here, even if the weak exogeneity assumption is always valid, we would expect up to 14 rejections, 5% of the 263 tests. Therefore, overall, the available evidence in Table 6 supports our treatment of the foreign and global variables in the individual VARX* models as weakly exogenous.

3.3.3 Testing for Structural Breaks

Although the possibility of structural breaks is a fundamental problem in macroeconomic modelling in general, this is more likely to be a concern for a particular set of countries in our sample (i.e., emerging economies and non-OECD oil exporters) which have experienced both social and political changes since 1979. However, given that the individual VARX* models are specified conditional on the foreign variables in $\mathbf{x}_{it}^*$, they are more robust to the possibility of structural breaks in comparison to reduced-form VARs, as the GVAR setup can readily accommodate co-breaking. See Dees et al. (2007) for a detailed discussion.

We test the null of parameter stability using the residuals from the individual reduced-form error correction equations of the country-specific VARX*(s_i, s_i^*) models, initially looking at the maximal OLS cumulative sum statistic (PK_{sup}) and its mean square variant (PK_{msq}) of Ploberger and Krämer (1992). We also test for parameter constancy over time against non-stationary alternatives as proposed by Nyblom (1989) (NY), and consider sequential Wald statistics for a single break at an unknown change point. More specifically, the mean Wald statistic of Hansen (1992) (MW), the Wald form of the Quandt (1960) likelihood ratio statistic (QLR), and the Andrews and Ploberger (1994) Wald statistics based on the exponential average (APW). Finally, we also examine the heteroscedasticity-robust versions of NY, MW, QLR, and APW.

Table 7 presents the number of rejections of the null hypothesis of parameter constancy per variable across the country-specific models at the 5% significance level. For brevity, test statistics and bootstrapped critical values are not reported here but are available on request. Overall, it seems that most regression coefficients are stable, however, the results vary considerably across different tests. In the case of the two PK tests, the null hypothesis is rejected between $3.4 - 7.8\%$ of the time. For the NY, MW, QLR, and APW tests on the other hand, we note that the rejection rate is much larger, between $17.9 - 52.5\%$. The QLR and APW rejection rates, for the joint null hypothesis of coefficient and error variance stability, are particularly high with 94 and 89 cases respectively out of 179 being rejected.

Table 7: Number of Rejections of the Null of Parameter Constancy per Variable across the Country-specific Models at the 5 percent Significance Level

Tests	y	π	eq	$(e-p)$	r^S	r^L	Total
PK_{sup}	5	4	2	1	2	0	14(7.8)
PK_{msq}	4	1	0	1	0	0	6(3.4)
NY	8	5	4	5	4	6	32(17.9)
robust-NY	5	2	5	2	1	3	18(10.1)
QLR	22	18	20	18	9	7	94(52.5)
robust-QLR	6	4	6	2	6	4	28(15.6)
MW	12	10	10	9	6	6	53(29.6)
robust-MW	10	6	3	3	6	5	33(18.4)
APW	17	18	20	18	9	7	89(49.7)
robust-APW	7	5	6	3	6	4	31(17.3)

Notes: The test statistics PK_{sup} and PK_{msq} are based on the cumulative sums of OLS residuals, NY is the Nyblom test for time-varying parameters and QLR, MW and APW are the sequential Wald statistics for a single break at an unknown change point. Statistics with the prefix 'robust' denote the heteroskedasticity-robust version of the tests. All tests are implemented at the 5% significance level. The number in brackets are the percentage rejection rates.

However, looking at the robust version of these tests, we note that the rejection rate falls considerably to between 10.1% and 18.4%. Therefore, although we find some evidence for structural instability, it seems that possible changes in error variances rather than parameter coefficients is the main reason for this. We deal with this issue by using bootstrapped means and confidence bounds when undertaking the impulse response analysis.

4 Identification of Oil Shocks

Understanding the factors driving crude oil-price developments is essential for assessing their economic effects. We compare the macroeconomic consequences of supply-driven versus demand-driven oil-price shocks across a set of developed and developing countries that are structurally very diverse with respect to the role of oil and other forms of energy in their economies.

To discriminate oil-supply disturbances from oil-demand shocks, we rely on a simple identification scheme within our GVAR framework. More specifically, we require negative oil-supply shocks to be associated with: (i) an increase in oil prices; (ii) a decrease in global oil production levels; and (iii) a decline in the sum of real output across all oil importers during the first year. We do not impose any restrictions on real output for the GCC region or the other 11 countries in our sample that have been net oil exporters over the sample period, as the effect of a negative supply shock on the level of GDP for this group is ambiguous, see Table 8. To the extent that no other economically meaningful shocks are able to produce a negative correlation between real output and real oil prices across all oil-importing economies, this identification scheme uniquely identifies oil-supply shocks. For oil-demand shocks on the other hand, we require an increase in: (i) oil prices; (ii) oil production levels; and (iii) the sum of real output across the 36 countries and two regions within the first year.[13]

Table 8: Identification of Structural Shocks

Structural shocks	p^{oil}	q^{oil}	$y^{importers}$	$y^{exporters}$	π	eq	r^S	r^L	$reer$
Oil supply	> 0	< 0	≤ 0	–	–	–	–	–	–
Oil demand	> 0	> 0	≥ 0	≥ 0	–	–	–	–	–

Notes: For the definition of the variables see equations (9) and (11). For the list of the 12 oil exporting and 26 importing countries/regions, see Table 1.

Sign restrictions alone are not sufficiently informative in identifying the macroeconomic effects of oil-demand and oil-supply shocks. Kilian and Murphy (2010) argue that it is important to augment these restrictions with other sets of identifying assumptions (such as quantity restrictions: bounds on impact price elasticities of oil demand and oil supply) to narrow the set of admissible structural models. We show that the global dimension of the GVAR model can be used as an alternative option to calculating the true structural impulse responses. Specifically, condition (iii) imposes that the cumulated sum of the relevant individual-country outputs are negative if faced with an oil-supply shock, and positive if an oil-demand shock prevails. We also considered a cumulated weighted average of the outputs, using PPP GDP weights, and obtained very similar results. We will therefore focus on the results using the simple cumulated sum of the output responses in the remainder of the paper.

Let $\mathbf{v}_{it}$ denote the structural VARX* model innovations given by:

$$\mathbf{v}_{it} = \tilde{\mathbf{P}}_i \mathbf{u}_{it},$$

where $\tilde{\mathbf{P}}_i$ is a $k_i \times k_i$ matrix of coefficients to be identified. We carry out a Cholesky decomposition of the covariance matrix of the vector of residuals $\mathbf{u}_{it}$ for each country model

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[13] Mohaddes and Raissi (2011) show that for an oil-importing but labor-exporting small open economy which receives large (and stable) inflows of external income (the sum of FDI, remittances, and grants) from oil-rich countries, the impact of oil shocks on the economy's macroeconomic variables can be very similar to those of the oil exporters from which it receives these large income flows.

i $(=0,...,N)$ to obtain the lower triangular matrix $\mathbf{P}_i$ that satisfies $\mathbf{\Sigma}_{\mathbf{v}_i} = \mathbf{P}_i\mathbf{P}_i'$. However, for any orthogonal $k_i \times k_i$ matrix $\mathbf{Q}_i$, the matrix $\tilde{\mathbf{P}}_i = \mathbf{P}_i\mathbf{Q}_i$ also satisfies $\mathbf{\Sigma}_{\mathbf{v}_i} = \tilde{\mathbf{P}}_i\tilde{\mathbf{P}}_i'$. To examine a wide range of possible solutions for $\tilde{\mathbf{P}}_i$ and construct a set of admissible models, we repeatedly draw at random from the orthogonal matrices $\mathbf{Q}_i$ and discard candidate solutions for $\tilde{\mathbf{P}}_i$ that do not satisfy a set of a priori sign restrictions on the implied impulse responses functions. These rotations are based on the QR decomposition.

More compactly, we construct the $k \times k$ matrix $\tilde{\mathbf{P}}$ as

$$\tilde{\mathbf{P}} = \begin{pmatrix} \tilde{\mathbf{P}}_0 & \mathbf{0} & \cdots & \cdots & \mathbf{0} \\ \mathbf{0} & \ddots & & & \vdots \\ \vdots & & \tilde{\mathbf{P}}_i & & \vdots \\ \vdots & & & \ddots & \mathbf{0} \\ \mathbf{0} & \cdots & \cdots & \mathbf{0} & \tilde{\mathbf{P}}_N \end{pmatrix},$$

which can be used to obtain the impulse responses of all endogenous variables in the GVAR model to shocks to the error terms $\mathbf{v}_t = (\mathbf{v}_{0t}', \ldots, \mathbf{v}_{it}', \ldots, \mathbf{v}_{Nt}')' = \tilde{\mathbf{P}}\mathbf{u}_t$. We draw until we retain 100 valid rotations that satisfy our set of a priori sign restrictions.

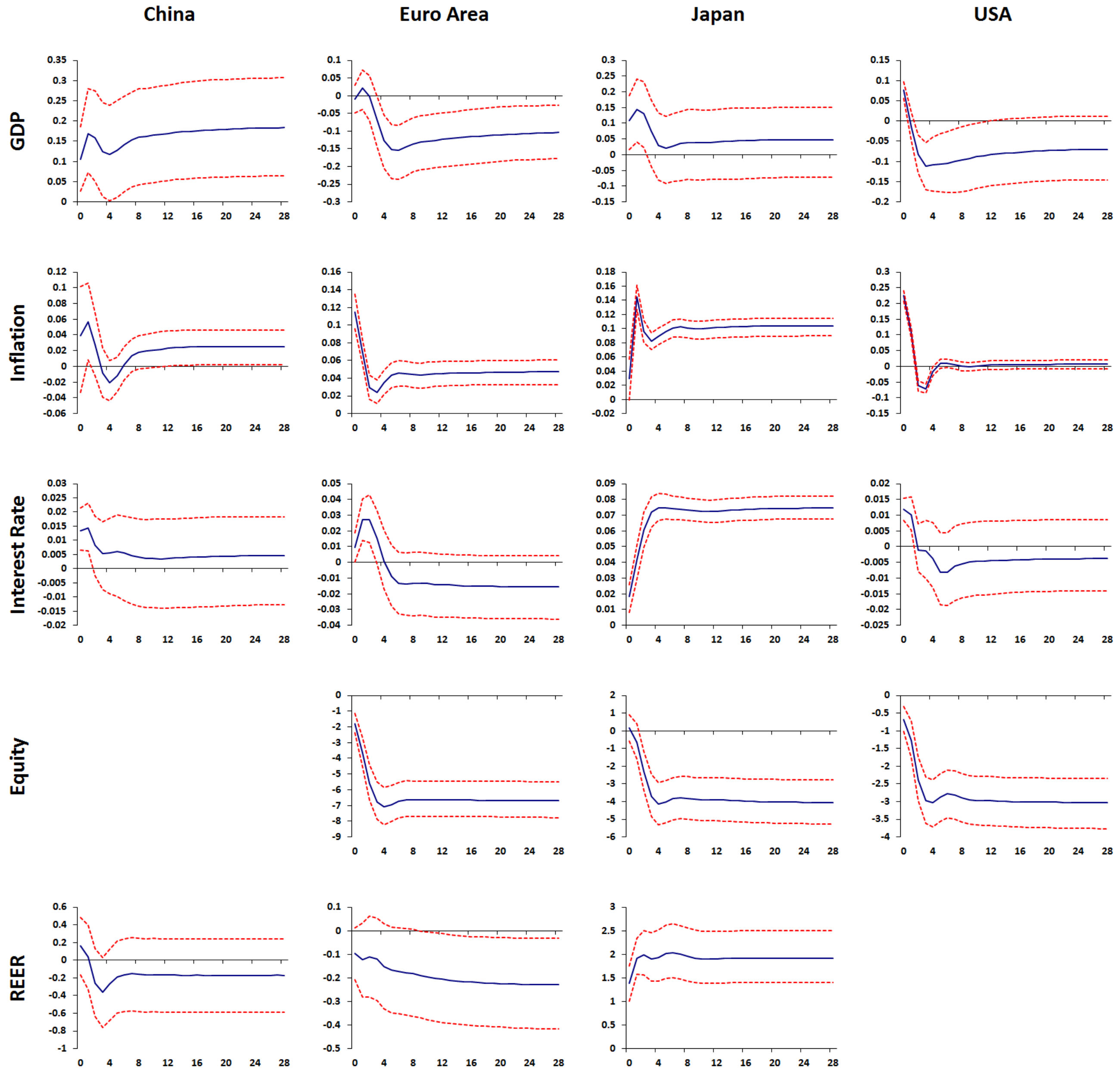
Since there are many impulse responses that satisfy the postulated signs, we summarize them by reporting a central tendency and the 16th and 84th percentiles as measures of the spread of responses. It is important to recognize that the distribution here is across different models and it has nothing to do with sampling uncertainty. The cross-sectional dimension of the GVAR model, as explained above, can help with reducing these spreads.

4.1 Oil-Supply Shocks

Figures 2–4 show the estimated median impulse responses (for up to seven years) of key macroeconomic variables of oil exporters and major oil-importing countries to a supply-driven oil-price shock, together with the 16th and 84th percentile error bands. The macroeconomic consequences of a negative oil-supply shock are very different for oil-importing countries compared to energy-exporters. With regard to real output, following an oil-supply shock, Euro Area and the United States (two major energy-importing countries) experience a long-lived fall in economic activity, while for China and Japan the impact is positive.

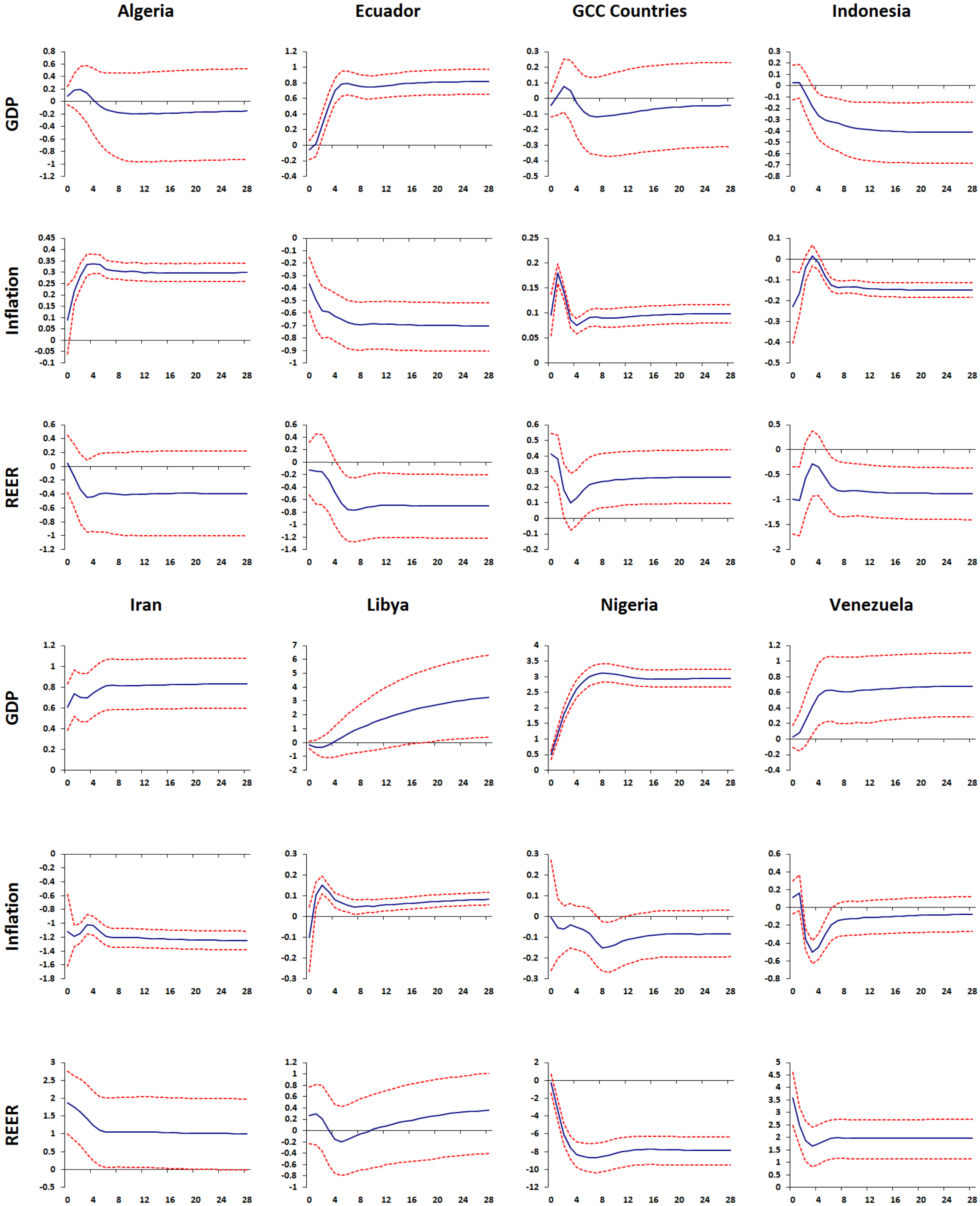
The results for the Euro Area and U.S. are as expected, but the positive output impact for China seems surprising at first. However, given China's heavy dependence on coal, as opposed to oil, for its energy consumption needs, this result might not be that surprising after all. In contrast to the United States (Euro Area) for which 37% (40%) and 23% (12%) of primary energy needs are met from oil and coal sources, respectively, coal provided

Figure 2: Impact of Oil-Supply Shocks on Major Oil Importers



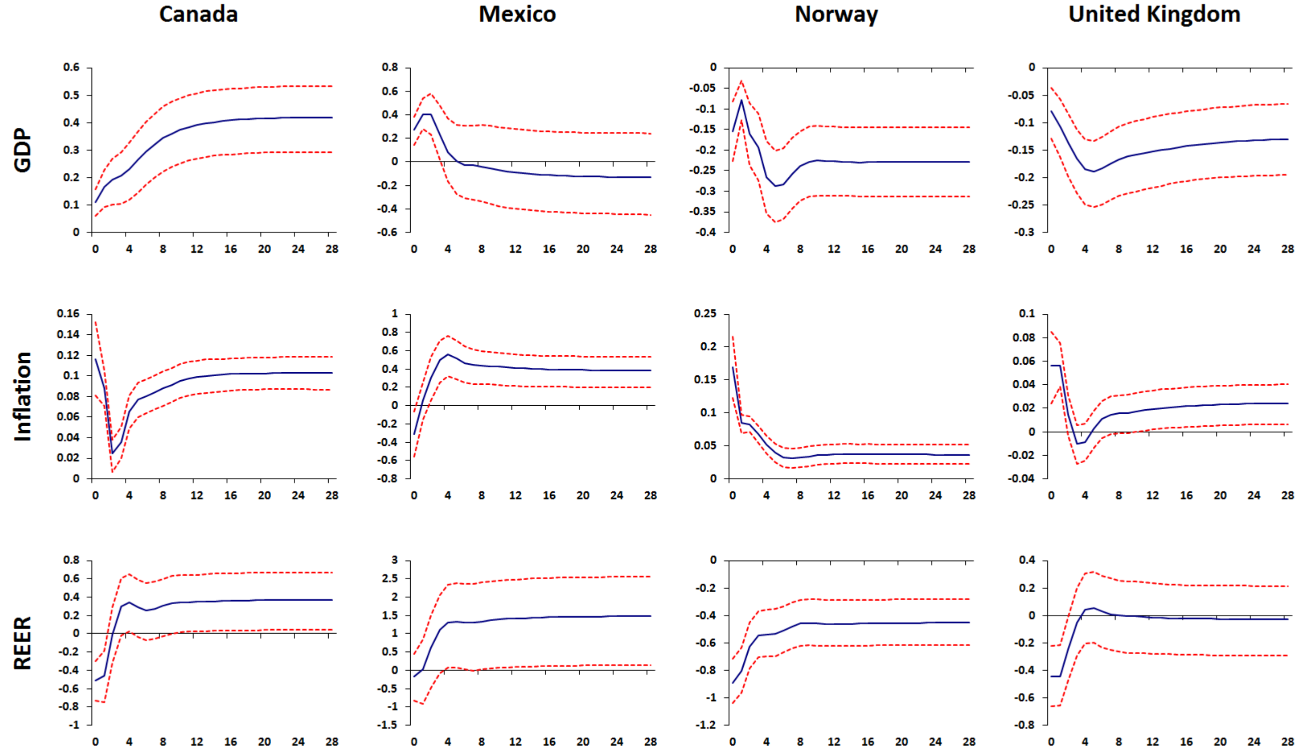
Notes: Figures are median impulse responses to a one standard deviation increase in the price of oil, equivalent to around a 12% rise per quarter, together with the 16th and 84th percentile error bands. The impact is in percentage points and the horizon is quarterly.

Figure 3: Impact of Oil-Supply Shocks on OPEC Countries



Notes: Figures are median impulse responses to a one standard deviation increase in the price of oil, equivalent to around a 12% rise per quarter, together with the 16th and 84th percentile error bands. The impact is in percentage points and the horizon is quarterly.

Figure 4: Impact of Oil-Supply Shocks on OECD Oil Exporters



Notes: Figures are median impulse responses to a one standard deviation increase in the price of oil, equivalent to around a 12% rise per quarter, together with the 16th and 84th percentile error bands. The impact is in percentage points and the horizon is quarterly.

over 70% of China's primary energy needs in 2010, while oil amounted to less than 18% of the total. In fact, China accounts for just under half of global coal consumption, and its coal use has almost doubled during the recent oil boom (2002-2008), and has more than doubled over the last decade (see British Petroleum's *Statistical Review of World Energy*). Therefore, considering the dominance of coal (rather than oil) in the Chinese economy, and given that most (if not all) of its coal consumption is met by domestic production, oil-supply disruptions (which may also increase global coal prices) will have relatively less of an impact on the Chinese economy. Moreover, given a near vertical oil-supply curve, oil exporters might experience a real GDP boost following an oil-price spike, and because China's trade with major oil exporters comprises more than 14% of its total trade, we would expect higher import demand by oil exporters to positively affect aggregate demand in China. Therefore, the negative effect on domestic output following an oil-supply shock may not necessarily manifest itself in China. The positive impact of a supply-driven oil-price shock on Japan's GDP can be explained through the trade channel, as Japan conducts more than 22% of its trade with major oil exporters.

The increase in real GDP following a decline in the rate of global oil production is also documented in Chapter 3 of International Monetary Fund (2011) WEO for the Emerging Asian countries (China, Hong Kong, India, Indonesia, Korea, Malaysia, Philippines, Singapore, and Thailand) and Japan. The prediction of this model is that a gradual (but moderate) increase in oil scarcity may not present a major constraint on emerging economies' growth (especially for Japan and China) in the medium to long term, although the wealth transfer from oil importers to exporters would increase capital flows and widen current account imbalances. More specifically, following a fall in global oil production, simulations of International Monetary Fund (2011) WEO show that the real GDP of Japan and China would increase for the first 20 quarters (under a number of alternative scenarios).

Turning to the major oil exporters in our sample, these can be split into two subsets. It appears that an oil-supply shock permanently increases output for those oil exporters that possess significant amounts of proven oil reserves, and for which the reserve-to-production ratio (given in the brackets in terms of years) is large: Canada (26), Ecuador (34), Iran (88), Libya (77), Nigeria (42), and Venezuela (>100), see Figure 3. On the other hand for those countries with limited oil reserves and low oil reserve-to-production ratios, the impact is muted. For example, for Algeria (18) and Mexico (11), we see a temporary increase in real output, while for Norway (9), we have a permanent decrease in output.

For the GCC countries, the income effect of an oil-supply shock is initially positive but turns negative in the long run. This is mainly due to the inclusion of the global oil production variable in the GCC model. Interestingly, for Indonesia and the UK, the impact of an oil-supply shock on domestic output is negative. This is expected for the UK, as its oil exports started to decline rapidly in 1999 and it has been a net oil importer since 2006. Indonesian oil production, on the other hand, peaked in mid 1990s, and the share of oil exports in GDP has been declining steadily over the past three decades, so the impact should be similar to that of the UK, which is in fact what we observe.

Overall, while oil-importing countries typically face a permanent fall (in the long run) in economic activity in response to a supply-driven surge in oil prices, the impact is positive for energy-exporting countries that possess large proven oil/gas reserves and those for which the oil income to GDP ratio is expected to remain high over a prolonged period. This result contrasts with the standard literature on "Dutch disease" and the "resource curse", which primarily focuses on short-run implications of a temporary resource discovery. For major oil exporters, many of which started oil extraction and exports at the beginning of the 20th Century, the reserve-to-extraction ratio indicates that they are capable of producing for many more decades even in the absence of new oil-field discoveries or major advances in oil exploration and extraction technologies. However, while it is clear that oil and gas reserves will be exhausted eventually, this is likely to take place over a relatively long period.

Our results are in line with those of Peersman and Van Robays (2012), who show that a negative oil-supply shock results in a permanent fall in economic activity of net oil-importing countries and a positive impact (though at times not statistically significant) on oil-exporters. Our results are also supported by Esfahani et al. (2012a), who develop an empirical growth model for major oil exporters and provide estimates for the positive long-run effects of oil income on GDP growth rates for six OPEC member states (Iran, Kuwait, Libya, Nigeria, Saudi Arabia, and Venezuela).

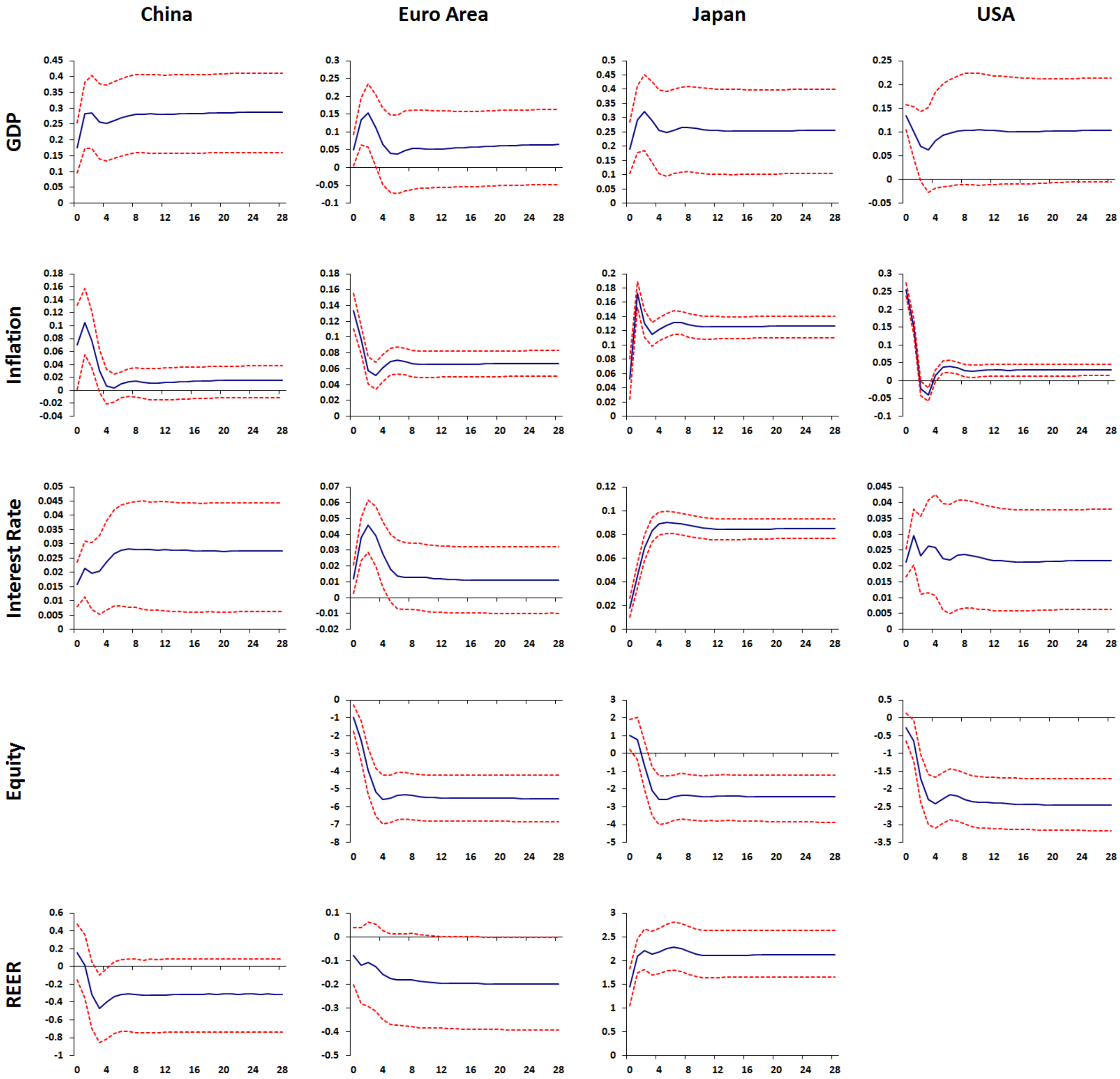
We also find strong inflationary pressures on the four energy-importing countries (China, Euro Area, Japan, and the U.S.), but the responses are negligible or even negative in net energy-exporting countries. These different responses are probably driven by movements of the real exchange rate of oil-exporting countries. The real exchange rate tends to appreciate in most oil-exporting countries, limiting the pass-through effect of higher international oil prices to domestic markets (and inflation). The interest rate responses after an oil-supply shock are generally in accordance with the effects on inflation, i.e. only in oil-importing countries, where monetary policy is tightened to stabilize inflation.

4.2 Oil-Demand Shocks

The rising demand for commodities by emerging markets— mainly by China and India, but also the Middle East and Latin America— is a frequently-cited factor in explaining the recent rise in oil-prices, see for instance Hamilton (2009) and Kilian (2009). While the long-term upward trend in commodity prices is reflective of growing demand, the short-term increases are often driven more by supply fluctuations.

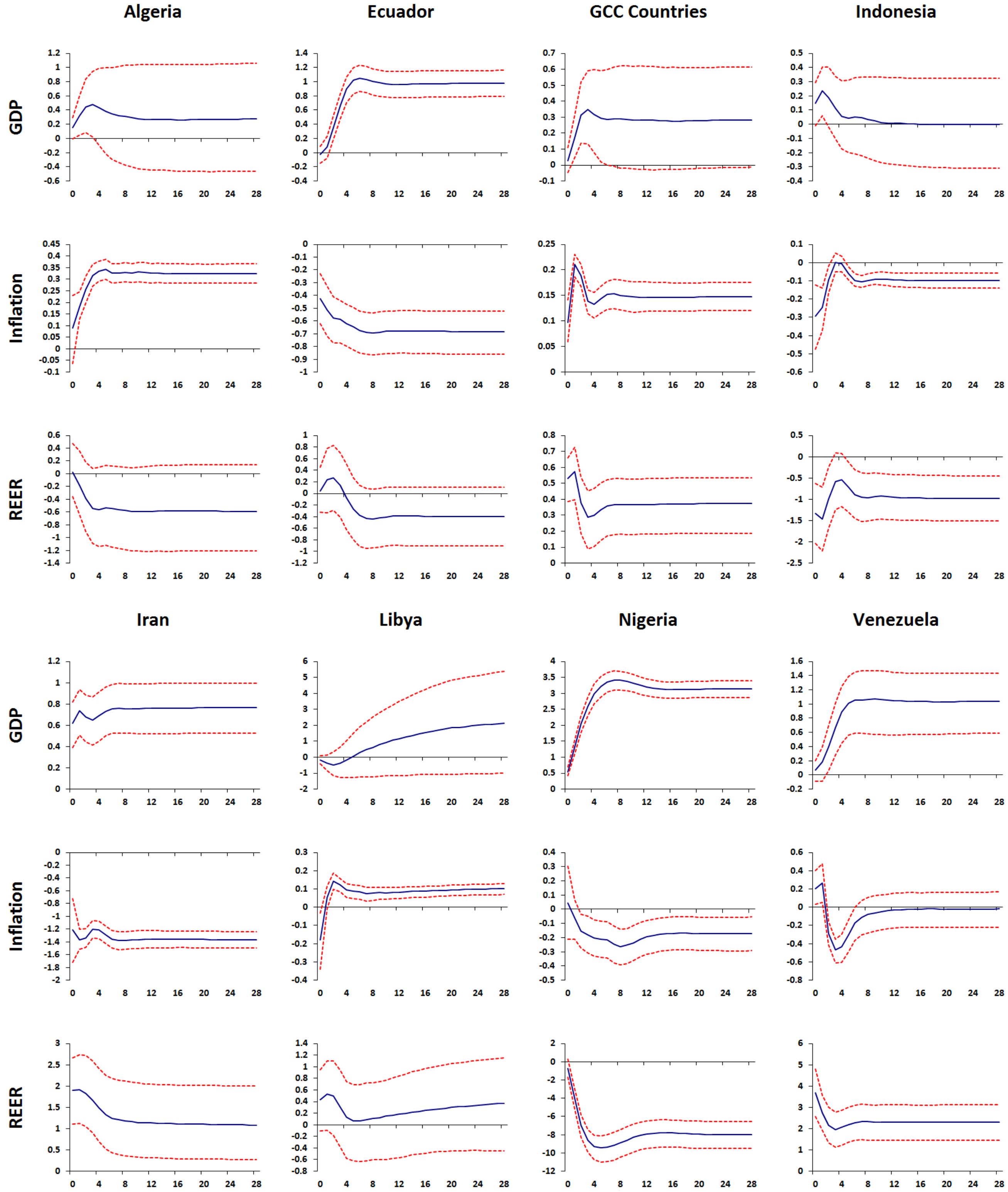
Figures 5–7 show the median impulse responses of key variables of oil-importing/exporting countries to a demand-driven oil-price shock, together with the 16th and 84th percentile error bands. The macroeconomic effects of a demand-driven oil-price shock are substantially different from those of an oil-supply disturbance (examined in Figures 2–4). Following an oil-demand shock, almost all countries in our sample experience long-run inflationary pressures and a short-run increase in real output. This finding is not surprising given that the oil-price spike is assumed to be determined endogenously by a shift in worldwide economic activity. Output can rise because the country itself is in a boom, or because it indirectly gains from trade with the rest of the world. These results are echoed by Peersman and Van Robays (2012) who show that a demand-driven oil-price shock results in a temporary increase of real GDP for their set of OECD countries. Furthermore, in all major oil-importing countries, interest rates increase while equity prices fall.

Figure 5: Impact of Oil-Demand Shocks on Major Oil Importers



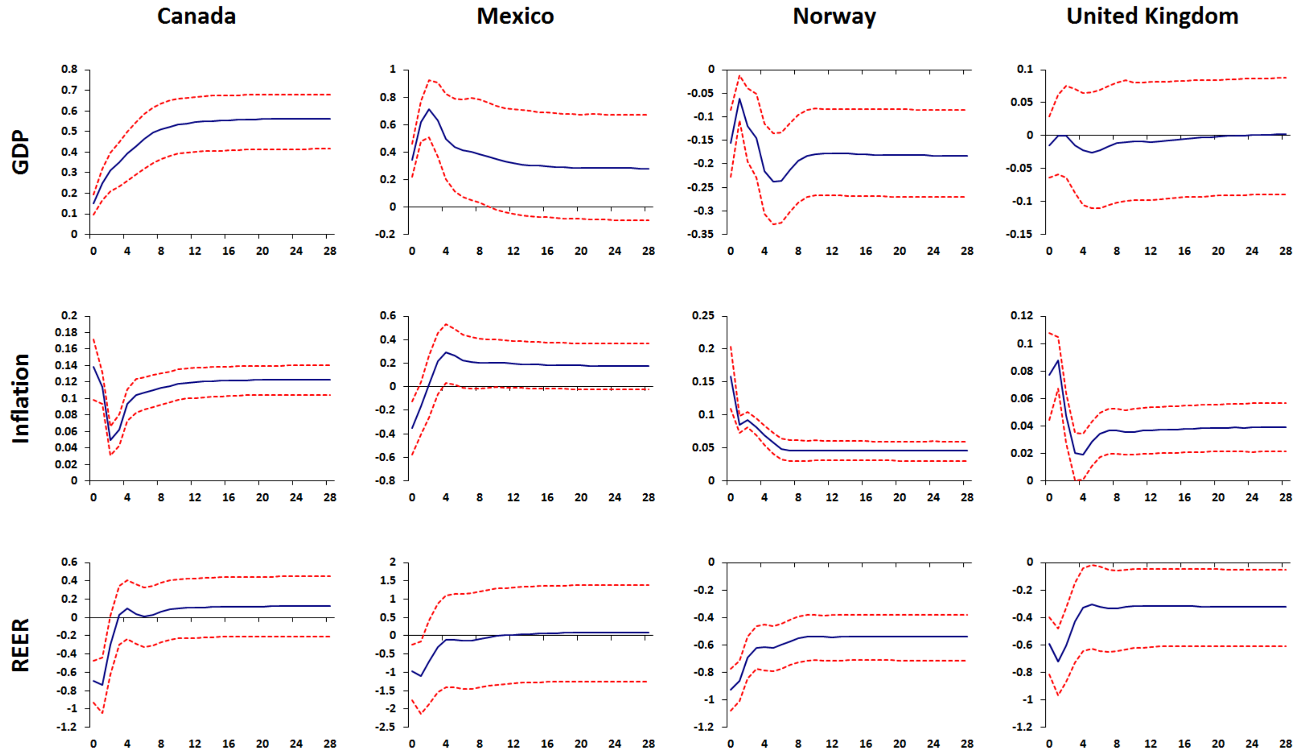
Notes: Figures are median impulse responses to a one standard deviation increase in the price of oil, equivalent to around a 12% rise per quarter, together with the 16th and 84th percentile error bands. The impact is in percentage points and the horizon is quarterly.

Figure 6: Impact of Oil-Demand Shocks on OPEC Countries



Notes: Figures are median impulse responses to a one standard deviation increase in the price of oil, equivalent to around a 12% rise per quarter, together with the 16th and 84th percentile error bands. The impact is in percentage points and the horizon is quarterly.

Figure 7: Impact of Oil-Demand Shocks on OECD Oil Exporters



Notes: Figures are median impulse responses to a one standard deviation increase in the price of oil, equivalent to around a 12% rise per quarter, together with the 16th and 84th percentile error bands. The impact is in percentage points and the horizon is quarterly.

5 Concluding Remarks

In this study we applied the sign restriction approach to a Global VAR model including major oil exporters, estimated for 38 countries/regions over the period 1979Q2 to 2011Q2, to identify the differential effects of supply-driven versus demand-driven oil-price shocks. In doing so we demonstrated that the global dimension of the GVAR model can provide a large number of additional sign restrictions, and is thus helpful in moving us closer to calculating true structural impulse responses.

Our results indicate that the underlying source of the oil-price shock is crucial in determining its macroeconomic consequence for oil-importing countries as well as major commodity exporters. In particular, the differentiation between a net energy importer and a net oil exporter is only important when studying the macroeconomic effects of a supply-driven oil-price shock. While oil importers typically experience a long-lived fall in economic activity in response to a supply-driven surge in oil prices, the impact is positive for energy-exporting countries that possess large proven oil/gas reserves. Cross-country differences are absent though when it comes to the demand side of the global crude oil market. In response to an oil-demand disturbance, almost all countries in our sample experience a short-run increase in real output and face additional inflationary pressures.

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Data Appendix

Real GDP

We use the International Monetary Fund (IMF) *International Financial Statistics* (IFS) and *World Economic Outlook* (WEO) databases to compile the real GDP data. The 18 countries that we add to the GVAR dataset of Smith and Galesi (2010) are divided into two groups. First, those for which quarterly data are available. Second, those for which annual data are available.

For the first group (Ecuador, Egypt, Iran, Jordan, Morocco, and Tunisia), we use the IFS 99BVPZF series (GDP VOL) when available—quarterly data on GDP are reported since 1991Q1, 2002Q1, 1988Q1, 1992Q1, 1990Q1, and 2000Q1 for Ecuador, Egypt, Iran, Jordan, Morocco, and Tunisia, respectively. We seasonally adjust these quarterly observations using the U.S. Census Bureau's X-12 ARIMA seasonal adjustment program.[14] Quarterly series are then interpolated (backwards) linearly from the annual series—either from the IFS or WEO—using the same method as that applied by Dees et al. (2007).

For the second group (Algeria, Bahrain, Kuwait, Lebanon, Libya, Mauritania, Nigeria, Oman, Qatar, Syria, Venezuela, and UAE), either the annual seasonally unadjusted IFS series (BVPZF and B..ZF) or the WEO real GDP series are interpolated to obtain the quarterly values. These series are then treated as the quarterly seasonally unadjusted data.

Consumer price index

We obtain seasonally adjusted quarterly observations on the consumer price index (CPI) for all added countries from the International Monetary Fund's INS database. Quarterly data on CPI are available since 1991Q1, 1980Q1, 2003Q2, and 1980Q1 for Lebanon, Oman, Qatar, and United Arab Emirates, respectively. Annual WEO CPI series are interpolated linearly (backwards) to obtain quarterly observations for the missing values for these four countries.

Exchange rates

The IFS AE.ZF series are collected for all added 18 countries from the IMF IFS database.

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[14] For further information see U.S. Census Bureau (2007): X-12-ARIMA Reference Manual at http://www.census.gov/srd/www/x12a/

Short term interest rates

The IMF IFS database is the main source of data for short term interest rates. The IFS discount rate (60...ZF series) is used for Algeria, Ecuador, Jordan, Lebanon, Mauritania, and Venezuela. The IFS deposit rate (60L..ZF series) is used for Bahrain, Egypt, Nigeria, Oman, Qatar, and Syria. The IFS three-month interbank deposit rate or the money market rate (60B..ZF series) is used for Kuwait and Tunisia.

PPP-GDP weights

The main source for the country-specific GDP weights is the World Development Indicator database of the World Bank.

Trade matrices

To construct the trade matrices, we use the direction of trade statistics from the International Monetary Fund's *Direction of Trade Statistics* (DOTS) database. For all the countries considered we downloaded the matrix of exports and imports (c.i.f.) with annual frequency. The 38 × 38 trade-weight matrix is provided in Table 9.

Table 9: Fixed Trade Weights Based on the Years 2006–2008

	Algeria	Argentina	Australia	Brazil	Canada	China	Chile	Ecuador	Egypt	Euro Area	GCC	India	Indonesia	Iran	Japan	Jordan	Korea	Libya	Malaysia	Morocco	Mauritania	Mexico	Nigeria	Norway	New Zealand	Peru	Philippines	South Africa	Singapore	Sweden	Switzerland	Syria	Thailand	Tunisia	Turkey	UK	USA	Venezuela
Algeria	0	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.01	0.00
Argentina	0.01	0	0.00	0.10	0.00	0.01	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.02
Australia	0.00	0.00	0	0.01	0.00	0.03	0.01	0.00	0.01	0.01	0.01	0.03	0.04	0.00	0.04	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.01	0.02	0.03	0.01	0.01	0.00	0.04	0.00	0.00	0.01	0.01	0.00
Brazil	0.03	0.29	0.01	0	0.01	0.02	0.08	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.03	0.01	0.07	0.01	0.00	0.07	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05
Canada	0.06	0.01	0.01	0.02	0	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.03	0.01	0.03	0.02	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.21	0.01
China	0.04	0.12	0.16	0.10	0.06	0	0.14	0.05	0.07	0.11	0.10	0.11	0.11	0.15	0.20	0.09	0.23	0.05	0.12	0.05	0.25	0.06	0.06	0.03	0.11	0.13	0.11	0.10	0.13	0.04	0.03	0.08	0.12	0.02	0.07	0.06	0.14	0.05
Chile	0.00	0.06	0.00	0.03	0.00	0.01	0	0.06	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Ecuador	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Egypt	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0	0.01	0.01	0.01	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.00
Euro Area	0.48	0.17	0.12	0.22	0.06	0.17	0.19	0.12	0.30	0	0.15	0.17	0.09	0.24	0.11	0.16	0.10	0.66	0.10	0.56	0.48	0.08	0.24	0.46	0.11	0.15	0.12	0.29	0.10	0.54	0.67	0.32	0.09	0.70	0.45	0.52	0.15	0.11
GCC	0.00	0.01	0.03	0.03	0.01	0.04	0.00	0.01	0.13	0.04	0	0.20	0.05	0.12	0.12	0.28	0.12	0.01	0.03	0.06	0.01	0.00	0.00	0.00	0.04	0.00	0.06	0.06	0.07	0.01	0.02	0.25	0.09	0.01	0.06	0.02	0.03	0.00
India	0.02	0.01	0.03	0.01	0.00	0.03	0.02	0.01	0.06	0.02	0.10	0	0.04	0.09	0.01	0.06	0.02	0.01	0.03	0.03	0.01	0.00	0.09	0.00	0.01	0.01	0.01	0.03	0.04	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.03
Indonesia	0.00	0.01	0.03	0.01	0.00	0.02	0.00	0.00	0.01	0.01	0.01	0.02	0	0.00	0.03	0.01	0.03	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.01	0.05	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.01	0.00
Iran	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.04	0.00	0	0.01	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00
Japan	0.02	0.02	0.16	0.04	0.03	0.15	0.09	0.03	0.04	0.05	0.18	0.03	0.18	0.12	0	0.03	0.13	0.01	0.13	0.02	0.04	0.04	0.02	0.02	0.10	0.06	0.17	0.10	0.08	0.02	0.03	0.02	0.19	0.01	0.02	0.03	0.08	0.01
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Korea	0.01	0.01	0.06	0.03	0.01	0.10	0.05	0.02	0.02	0.02	0.10	0.03	0.07	0.07	0.07	0.03	0	0.01	0.05	0.01	0.00	0.03	0.03	0.01	0.04	0.03	0.06	0.02	0.05	0.01	0.01	0.03	0.04	0.00	0.02	0.01	0.03	0.00
Libya	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.05	0.01	0.00	0.00	0.00
Malaysia	0.00	0.01	0.03	0.01	0.00	0.03	0.00	0.00	0.01	0.01	0.01	0.03	0.06	0.01	0.03	0.01	0.02	0.00	0	0.00	0.02	0.01	0.00	0.00	0.03	0.00	0.05	0.01	0.16	0.00	0.00	0.01	0.07	0.00	0.01	0.01	0.02	0.00
Morocco	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Mauritania	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.03	0.01	0.03	0.03	0.01	0.04	0.02	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.03
Nigeria	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Norway	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
New Zealand	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.01	0.00	0.01	0.00	0.00	0.03	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Philippines	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00
South Africa	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.03	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.03	0.00	0.01	0.00	0.00	0	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.01	0.00
Singapore	0.00	0.00	0.05	0.01	0.00	0.03	0.00	0.00	0.01	0.01	0.04	0.04	0.13	0.02	0.03	0.00	0.03	0.00	0.15	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.10	0.01	0	0.00	0.01	0.00	0.06	0.00	0.00	0.01	0.02	0.02
Sweden	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.05	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.10	0.01	0.01	0.00	0.01	0.00	0	0.01	0.00	0.00	0.01	0.01	0.02	0.01	0.00
Switzerland	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.08	0.01	0.03	0.00	0.01	0.01	0.01	0.00	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.06	0.00	0.02	0.01	0.01	0	0.01	0.01	0.02	0.03	0.02	0.01	0.01
Syria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.01	0.00	0.00	0.00
Thailand	0.00	0.01	0.04	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.03	0.01	0.04	0.00	0.04	0.01	0.01	0.00	0.06	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.04	0.02	0.05	0.00	0.01	0.01	0	0.00	0.01	0.01	0.01	0.00
Tunisia	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
Turkey	0.04	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.03	0.04	0.02	0.01	0.01	0.06	0.00	0.02	0.01	0.03	0.00	0.03	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.05	0.00	0.02	0	0.02	0.00	0.00
UK	0.03	0.01	0.05	0.02	0.03	0.03	0.01	0.01	0.03	0.18	0.03	0.04	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.04	0.02	0.01	0.03	0.23	0.04	0.01	0.01	0.07	0.03	0.09	0.05	0.02	0.02	0.03	0.07	0	0.04	0.01
USA	0.22	0.12	0.11	0.19	0.70	0.20	0.17	0.43	0.11	0.16	0.11	0.12	0.10	0.00	0.19	0.11	0.13	0.07	0.16	0.05	0.05	0.69	0.36	0.06	0.12	0.22	0.19	0.11	0.13	0.07	0.09	0.02	0.12	0.03	0.07	0.13	0	0.59
Venezuela	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0

Notes: Trade weights are computed as shares of exports and imports, displayed in columns by region (such that a column, but not a row, sum to 1).
Source: Direction of Trade Statistics, 2006-2008, IMF.