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EPRG Working Paper 1604

Cambridge Working Paper in Economics 1605

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Keywords Tight oil, shale oil, fracking revolution, oil price decline, oil supply, global macroeconometric modeling, and international business cycle

JEL Classification C32, E17, F44, F47, O13, Q43

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Publication January 2016
Financial Support Economic Research Forum (ERF)

The U.S. Oil Supply Revolution and the Global Economy*

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January 9, 2016

Abstract

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*We are grateful to Paul Cashin, Ibrahim A. Elbadawi, Akito Matsumoto, Sergio L. Rodriguez, Hoda Selim, SeokHyun Yoon and seminar participants at the IMF for helpful comments and suggestions. Kamiar Mohaddes gratefully acknowledges financial support from the Economic Research Forum (ERF). The views expressed in this paper are those of the authors and do not necessarily represent those of the International Monetary Fund, IMF policy, or the ERF.

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1 Introduction

The technological advancements over the last decade have not only reduced the costs associated with the production of unconventional oil, but also made extraction of tight oil resemble a manufacturing process in which one can adjust production in response to price changes with relative ease. This is in stark contrast to other extraction methods (e.g. off-shore extraction), which require large capital expenditure and involve relatively long lead times, and more importantly, once the process is operational changing the quantity produced can be difficult. Therefore, one of the implications of the recent oil revolution is that U.S. production can play a significant role in balancing global demand and supply, and this in turn implies that the current low oil price environment could be persistent.

This paper investigates the macroeconomic consequences of the U.S. oil revolution for the global economy in general and the Middle East and North Africa (MENA) region in particular in terms of its effects on real output, oil prices and financial markets. We integrate an oil price equation, which takes account of developments in the world economy as well as the prevailing oil supply conditions, within a compact quarterly model of the global economy using a dynamic multi-country framework first advanced by Pesaran et al. (2004), known as the Global VAR (or GVAR for short). This approach enables one to analyze the international macroeconomic transmission of shocks, taking into account not only the direct exposure of countries to the shocks but also the indirect effects through secondary or tertiary channels. To distinguish the U.S. oil revolution from other supply shocks, such as disruptions caused by geopolitical tensions in the Middle-East, and oil-demand shocks in general, we employ a set of dynamic sign restrictions on the impulse responses of our GVAR-Oil model. In addition to restricting oil prices and production levels, the global dimension of the GVAR-Oil model offers an intuitive way of imposing a large number of additional cross-country sign restrictions that greatly reduces the number of admissible structural models.

Our dynamic multi-country framework consists of 38 country/region-specific models, among which is a single Euro Area region (including 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 and serve as a proxy for common unobserved factors. The model has both real and financial variables: real GDP, inflation, real equity prices, real exchange rate, short and long-term interest rates, OPEC and non-OPEC oil production, and the price of oil. 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) and Pesaran et al. (2007). We estimate the oil price equation and the 38 individual vector autoregressive models with foreign variables (VARX* models) over the period 1979Q2–2011Q2. Having combined the estimates from the oil price equation with those of the country-specific VARX* models, we solve the GVAR-Oil model and examine the effects of a U.S. oil-supply shock (while keeping the level of oil supply in Saudi Arabia constant) on the macroeconomic variables of different countries (both commodity importers and exporters), including the MENA region.

The results indicate that while oil importers typically face a long-lived rise in economic activity (ranging between 0.04% and 0.95%) in response to a U.S. supply-driven fall in oil prices, the impact is negative for energy-exporters (being on average −2.14% for the GCC, −1.32% for other MENA oil exporters, and −0.41% for Latin America), mainly because lower oil prices weakens domestic demand as well as external and fiscal balances in these countries. To investigate the channels through which the fall in oil revenues affects oil exporters (as well as select oil importers), especially in the long run, and quantify its growth impact, we embed the long-run output relation of Esfahani et al. (2014) in individual VARX* models. Our results indicate that oil revenue shocks (such as those from the low oil price environment we are currently experiencing) have a large, long-lasting and significant impact on these economies' growth paths operating through the capital accumulation channel.

Negative growth effects (albeit smaller) are also observed for energy-importers which have strong economic ties with oil exporters, through spillover effects. In particular, for most oil-importers in the MENA region, gains from lower oil prices are offset by a decline in external demand/financing by MENA oil-exporters given strong linkages between the two groups through trade, remittances, tourism, foreign direct investment and grants.[1] These economies on average experience a fall in real output of about 0.28%. For this group, low pass-through from global oil prices to domestic fuel prices limits the impact on disposable incomes of consumers and profit-margins of firms, and thereby contains the positive effect on economic growth in these countries.

Finally, in response to a positive U.S. oil-supply disturbance, almost all countries in our sample experience long-run disinflation pressures and an increase in equity prices (apart from commodity-exporting nations). Overall, our results suggest that following the U.S. oil revolution, with oil prices falling by 51% in the first year and rebounding somewhat to 45% in year two below the pre-shock levels, global growth increases by $0.16 - 0.37$ percentage points. This is mainly due to an increase in spending by oil importers which exceeds the decline in expenditure by oil exporters.

[1] An exception is Egypt for which the impact is positive due to other idiosyncratic factors.

The collapse of oil prices from around \$114 in June 2014 to \$46 in January 2015,[2] has led to a large body of literature analyzing the causes of this steep oil price drop and its macroeconomic implications. However, most of this literature is based on descriptive analysis, mainly written by international organizations (see, for instance, the IMF blog by Arezki and Blanchard, 2014), investment banks (such as Goldman Sachs Global Investment Research division's report on "The New Oil Order"), various (energy) economists, and of course mostly internal reports by oil and gas companies (which are used to inform exploration, development, and hiring decision to name a few). There are yet only a handful of papers, which apply rigorous and quantitative analysis of the recent oil price shock. Most notably, Baumeister and Kilian (2015) argue that demand factors were most important in explaining the behavior of oil prices, while Baffes et al. (2015), Husain et al. (2015), and Mânescu and Nuño (2015) argue that supply (rather than demand) factors played the largest role.

More broadly, 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 analyses has predominantly been on net oil importers—see, for example, Hamilton (2009), Kilian (2009), and Peersman and Van Robays (2012). An exception is the work of Cashin et al. (2014), who look at the differential effects of oil demand and supply shocks on the global economy, Esfahani et al. (2014), who conduct a country-by-country VARX* analysis looking at the direct effects of oil-revenue shocks on domestic output for 9 major oil exporters (six of which are OPEC members), Kilian et al. (2009), who examine the effects of different types of oil-price shocks on the external balances of net oil exporters/importers, and Mohaddes and Pesaran (2015), who examine the effects of country-specific shocks (to Iranian and Saudi Arabian oil output) on the world economy.

In this paper, we extend the literature in a number of respects. Firstly, 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. We are therefore able to analyze the macroeconomic consequences of U.S. supply-driven oil-price shocks across a wide range of developed and developing countries (including oil exporters) that are structurally very diverse with respect to the role of oil and other forms of energy in their economies. Secondly, we provide a compact model of the world economy that takes into account the economic interlinkages and spillovers (direct exposure of countries to the shocks but also the

[2] Oil prices recovered somewhat in spring 2015 (peaking around \$65 in May) before falling back to below \$50 in September 2015.

indirect effects through secondary or tertiary channels) that exist between different regions (which may also shape the responses of different macroeconomic variables to oil price shocks), rather than undertaking a descriptive analysis or a country-by-country structural VAR study of the oil market. Thirdly, we include oil production endogenously in the U.S. and Saudi Arabian models, while modelling oil prices as determined in the global oil market. This is required to answer counterfactual questions regarding the possible macroeconomic effects of the U.S. oil revolution. Finally, we demonstrate how our GVAR-Oil model, covering over 90% of world GDP, 85% of world oil consumption, and 80% of world proven oil reserves, can be used for "set-identified" impulse response analysis and to obtain a better understanding of structural shocks. In particular, we set-identify the U.S. oil supply shock[3] by imposing dynamic sign restrictions on the impulse responses of oil production in the United States, Saudi Arabian oil supply, and GDP of major oil importers in our sample.[4]

The rest of the paper is organized as follows. Section 2 describes the GVAR methodology, outlines our model specifications, and illustrates how we integrate the oil market within our framework. Section 3 provides the estimates for the country-specific models, presents our identification strategy, and examines the direct and indirect effects of shocks to U.S. oil output on the world economy, on a country-by-country basis, and provide the time profile of the effects of country-specific oil shocks on real outputs, inflation, and real equity prices across countries. Section 4 investigates in greater detail the macroeconomic implications of the U.S. oil supply revolution, in terms of its real GDP effects, on individual countries in the MENA region over the short and long-term. Finally, Section 5 offers some concluding remarks.

2 Modelling the Oil-Macroeconomy Relationship in a Global Context

To analyze the international macroeconomic transmission of the U.S. oil revolution we need to model the oil-macroeconomy relationship in a global context. To this end we integrate an oil price equation within a compact quarterly model of the global economy using the GVAR framework. The resulting GVAR-Oil model takes into account both the temporal and cross-sectional dimensions of the data; real and financial drivers of economic activity; interlinkages and spillovers that exist between different regions; and the effects of unobserved or observed

[3] A positive U.S. oil supply shock is an exogenous shift of the oil supply curve along the oil demand schedule to the right, increasing oil production, and lowering oil prices.

[4] Cashin et al. (2014) show that the cross-sectional dimension of the GVAR provides a large number of additional cross-country identifying restrictions and reduces the set of admissible structural impulse responses.

common factors. This is crucial as the impact of the recent oil revolution cannot be reduced to just the United States (where the shock originates) but rather involves multiple regions, and may be amplified or dampened (through a number of channels) depending on the degree of openness of the countries and their trade structure. Before describing our approach in modeling individual countries and the global oil market, we provide a short exposition of the GVAR methodology below.

2.1 The Global VAR (GVAR) Methodology

We consider N countries in the global economy, indexed by $i = 1, ..., N$. With the exception of the United States, all other $N-1$ countries are modelled as small open economies. This set of individual country-specific vector autoregressive models with foreign variables (VARX* models) is used to build the GVAR framework. Following Pesaran (2004) and Dees et al. (2007), a VARX* (p_i, q_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), $\mathbf{x}_{it}^*$

$$\mathbf{\Phi}_i \left(L, p_i\right) \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \mathbf{\Lambda}_i \left(L, q_i\right) \mathbf{x}_{it}^* + \mathbf{u}_{it}, \tag{1}$$

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 $\mathbf{u}_{it} \sim i.i.d. \left(0, \mathbf{\Sigma}_{ii}\right)$. For algebraic simplicity, we abstract from observed global factors in the country-specific VARX* models. Furthermore, $\mathbf{\Phi}_i \left(L, p_i\right) = I - \sum_{i=1}^{p_i} \mathbf{\Phi}_i L^i$ and $\mathbf{\Lambda}_i \left(L, q_i\right) = \sum_{i=0}^{q_i} \mathbf{\Lambda}_i L^i$ are the matrix lag polynomial of the coefficients associated with the domestic and foreign variables, respectively. As the lag orders for these variables, p_i and q_i, are selected on a country-by-country basis, we are explicitly allowing for $\mathbf{\Phi}_i \left(L, p_i\right)$ and $\mathbf{\Lambda}_i \left(L, q_i\right)$ 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}

$$\mathbf{x}_{it}^* = \sum_{j=1}^{N} w_{ij} \mathbf{x}_{jt}, \tag{2}$$

where $j = 1, 2, ...N$, $w_{ii} = 0$, and $\sum_{j=1}^{N} w_{ij} = 1$. For empirical application, the trade weights are computed as three-year averages[5]

$$w_{ij} = \frac{T_{ij,2007} + T_{ij,2008} + T_{ij,2009}}{T_{i,2007} + T_{i,2008} + T_{i,2009}}, \tag{3}$$

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 $T_{it} = \sum_{j=1}^{N} T_{ijt}$ (the total trade of country i) for $t = 2007$, 2008 and 2009, in the case of all countries.[6]

Although estimation is done on a country-by-country basis, the GVAR model is solved 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*(p_i, q_i) model separately, all the $k = \sum_{i=1}^{N} k_i$ endogenous variables, collected in the $k \times 1$ vector $\mathbf{x}_t = (\mathbf{x}'_{1t}, \mathbf{x}'_{2t}, ..., \mathbf{x}'_{Nt})'$, 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

$$\mathbf{A}_i\left(L, p_i, q_i\right)\mathbf{z}_{it} = \boldsymbol{\varphi}_{it}, \tag{4}$$

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

$$\begin{aligned} \mathbf{A}_i\left(L, p_i, q_i\right) &= \left[\boldsymbol{\Phi}_i\left(L, p_i\right) - \boldsymbol{\Lambda}_i\left(L, q_i\right)\right], \quad \mathbf{z}_{it} = \left(\mathbf{x}'_{it}, \mathbf{x}'^{*}_{it}\right)', \\ \boldsymbol{\varphi}_{it} &= \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{u}_{it}. \end{aligned} \tag{5}$$

Note that given equation (2) we can write

$$\mathbf{z}_{it} = \mathbf{W}_i\mathbf{x}_t, \tag{6}$$

where $\mathbf{W}_i = (\mathbf{W}_{i1}, \mathbf{W}_{i2}, ..., \mathbf{W}_{iN})$, 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 (6) we can write (4) as

$$\mathbf{A}_i\left(L, p\right)\mathbf{W}_i\mathbf{x}_t = \varphi_{it}, \tag{7}$$

where $\mathbf{A}_i\left(L, p\right)$ is constructed from $\mathbf{A}_i\left(L, p_i, q_i\right)$ by setting $p = \max\left(p_1, p_2, ..., p_N, q_1, q_2, ..., q_N\right)$ and augmenting the $p - p_i$ or $p - q_i$ additional terms in the power of the lag operator by

[5] 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 national business cycle comovements. See, for instance, Baxter and Kouparitsas (2005).

[6] As a robustness check, we estimated the model using trade weights averaged over alternative time windows and found the results to be quantitatively similar. See also Cashin et al. (2016), who demonstrate that the choice of weights is of second-order importance when the underlying variables are sufficiently correlated, and that using trade, financial, or mixed weights produces very similar results.

zeros. Stacking equation (7), we obtain the Global VAR(p) model in domestic variables only

$$\mathbf{G}\left(L,p\right)\mathbf{x}_t = \varphi_t, \tag{8}$$

where

$$\mathbf{G}\left(L,p\right) = \begin{pmatrix} \mathbf{A}_1\left(L,p\right)\mathbf{W}_1 \\ \mathbf{A}_2\left(L,p\right)\mathbf{W}_2 \\ . \\ . \\ . \\ \mathbf{A}_N\left(L,p\right)\mathbf{W}_N \end{pmatrix}, \quad \varphi_t = \begin{pmatrix} \varphi_{1t} \\ \varphi_{2t} \\ . \\ . \\ . \\ \varphi_{Nt} \end{pmatrix}. \tag{9}$$

For an early illustration of the solution of the GVAR model, using a VARX*$(1,1)$ model, see Pesaran (2004), and for an extensive survey of the latest developments in GVAR modeling, both the theoretical foundations of the approach and its numerous empirical applications, see Chudik and Pesaran (2015). The GVAR(p) model in equation (8) can be solved recursively and used for a number of purposes, such as forecasting or impulse response analysis.

2.2 Country-Specific VARX* Models

We include as many major oil exporters as possible in our multi-country set up, subject to data availability, together with as many countries in the world to represent the global economy. 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 (2014), 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.[7]

Of the 50 countries included in our sample, 18 are classified as major commodity exporters as primary commodities constitute more than 40 percent of their exports (these countries are denoted by * in Table 1). Moreover, 15 are net oil exporters of which 10 are current members of the OPEC (denoted by [1] in Table 1) 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 (Canada, Mexico, and Norway) and the UK, which remained a net oil exporter for the majority of the sample (until 2006), and therefore is treated as an oil exporter when

[7] 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).

it comes to imposing sign-restrictions (see the discussion in Section 3.1). 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 2007-2009 period. Thus, as displayed in Table 1, our model includes 38 country/region-specific VARX* models.

Table 1: Countries and Regions in the GVAR Model

Systemic Countries	**MENA Oil Exporters**	**Latin America**
China	Algeria*[1,2]	Argentina*
Euro Area	GCC	Brazil*
Austria	*Bahrain**[2]	Chile*
Belgium	*Kuwait**[1,2]	Ecuador*[1]
Finland	*Oman**	Mexico
France	*Qatar**[1,2]	Peru*
Germany	*Saudi Arabia**[1,2]	Venezuela*[1]
Italy	*UAE**[1,2]	
Netherlands	Iran*[1]	**Southeast Asia**
Spain	Libya*[1,2]	Indonesia*
India		Korea
Japan	**MENA Oil Importers**	Malaysia
United Kingdom	Egypt*[2]	Philippines
United States	Jordan	Singapore
	Mauritania*	Thailand
Rest of Advanced Economies	Morocco*	
Australia	Syria*[2]	**Rest of the World**
Canada	Tunisia*[2]	Nigeria*[1]
New Zealand	Turkey	South Africa*
Norway*		
Sweden		
Switzerland		

Notes: GCC is the Gulf Cooperation Council Countries and MENA refers to the countries in the Middle East and North Africa region. * indicates that the country is a commodity exporter; countries are classified as commodity exporters if primary commodities constitute more than 40 percent of their exports. [1] and [2] denote countries which are members of the Organization of the Petroleum Exporting Countries (OPEC) and the Organization of Arab Petroleum Exporting Countries (OAPEC) respectively.

Making one region out of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates, is not without economic reasoning. The rationale is that these countries have in recent decades implemented a number of policies and initiatives to foster economic and financial integration in the region with a view to establishing a monetary union (loosely based on that of the Euro Area). Abstracting from their level of success with above objectives, the states of the GCC are relatively similar in structure, though in the short term they may face some difficulties in meeting the convergence criteria they have set for economic integration based on those of the European Union (EU). Inflation rates vary significantly across these countries and fiscal deficits, which have improved since the start of the oil boom in 2003, are about to re-emerge in some countries. However, these economies already peg their currencies to the U.S. dollar, except for Kuwait, which uses a dollar-dominated basket of currencies, and are accustomed to outsourcing their interest-rate policy. They also have relatively open capital accounts, and hence, it is reasonable to group these countries as one region.[8]

We specify two different sets of individual country-specific models. The first model is common across all countries, apart from the United States. These 37 VARX* models include a maximum of six domestic variables (depending on whether data on a particular variable is available), or using the same terminology as in equation (1)

$$\mathbf{x}_{it} = \left[y_{it},\ \pi_{it},\ eq_{it},\ r_{it}^{S},\ r_{it}^{L},\ ep_{it}\right]', \tag{10}$$

where y_{it} is the log of the real Gross Domestic Product at time t for country i, π_{it} is inflation, eq_{it} is the log of real equity prices, r_{it}^{S} (r_{it}^{L}) is the short (long) term interest rate, and ep_{it} is the real exchange rate. In addition, all domestic variables, except for that of the real exchange rate, have corresponding foreign variables computed as in equation (2)

$$\mathbf{x}_{it}^{*} = \left[y_{it}^{*},\ \pi_{it}^{*},\ eq_{it}^{*},\ r_{it}^{*S},\ r_{it}^{*L}\right]'. \tag{11}$$

Following the GVAR literature, the thirty-eight model (United States) is specified differently, mainly because of the dominance of the United States in the world economy. First, 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 appropriateness of exclusion of these variables was also confirmed by statistical tests, in which the weak exogeneity assumption was rejected for $eq_{US,t}^{*}$ and $r_{US,t}^{*L}$. Second, since e_{it} is expressed as the domestic currency price of a United States dollar, it is by construction determined outside this model. Thus, instead of the real exchange rate, we included $e_{US,t}^{*} - p_{US,t}^{*}$ as a weakly

[8] See Mohaddes and Williams (2013) for more details.

exogenous foreign variable in the U.S. model.[9]

2.3 The Global Oil Market

Given that we want to consider the macroeconomic effects of the U.S. oil revolution, we also need to include nominal oil prices in U.S. dollars in the country-specific VARX* models. If we follow the literature, we would include log oil prices, p_t^o, as an endogenous variable in the U.S. VARX* model and as a weakly exogenous variable in all other countries. See, for example, Cashin et al. (2014) and Chudik and Pesaran (2015). The main justification for this approach is that the U.S. is the world's largest oil consumer and a demand-side driver of the price of oil. However, it seems more appropriate for oil prices to be determined in global commodity markets rather in the U.S. model alone, given that oil prices are also affected by, for instance, any disruptions to oil supply in the Middle East. Therefore, in contrast to the GVAR literature, we model the oil price equation separately and then introduce p_t^o as a weakly exogenous variable in all countries (including the U.S.), thereby allowing for both demand and supply conditions to influence the price of oil directly rather than using the U.S. model as a transmission mechanism for the global economic conditions to the price of oil.[10]

To add oil prices to the conditional country models we simply augment the VARX* models (1) by p_t^o and its lag values

$$\mathbf{\Phi}_i\left(L, p_i\right) \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \mathbf{\Lambda}_i\left(L, q_i\right) \mathbf{x}_{it}^* + \Upsilon_i\left(L, s_i\right) p_t^o + \mathbf{u}_{it}, \tag{12}$$

where $\Upsilon_i\left(L, s_i\right) = \sum_{i=0}^{s_i} \Upsilon_i L^i$ is the lag polynomial of the coefficients associated with oil prices, see Chudik and Pesaran (2013) for more details. Here, p_t^o can be treated (and tested) as weakly exogenous for the purpose of estimation and the marginal model for the oil price equation can be estimated with or without feedback effects from $\mathbf{x}_t$. We incorporate the global oil market within the GVAR framework, by introducing an oil price equation defined as

$$p_t^o = c_p + \sum_{\ell=1}^{m_p} \alpha_\ell p_{t-\ell}^o + \sum_{\ell=1}^{m_y} \beta_\ell y_{t-\ell} + \sum_{\ell=1}^{m_q} \gamma_\ell q_{t-\ell}^o + u_t^o, \tag{13}$$

which is a standard autoregressive distributed lag, ARDL(m_{p^o}, m_y, m_{q^o}), model in oil prices, world real income (y_t) and world oil supplies (q_t^o), with all variables being in logs. Conditional (12) and marginal models (13) can be combined and solved as a complete GVAR model as explained earlier (see Section 2.1).

[9] Weak exogeneity test results for all countries and variables are available upon request.

[10] See also Cashin et al. (2015) and Mohaddes and Pesaran (2015) for a similar approach.

To take into account developments in the world economy, the oil price equation includes a measure of global output, y_t, calculated as

$$y_t = \sum_{j=1}^{N} w_j^{PPP} y_{jt}, \tag{14}$$

where y_{jt} is the log of real GDP of country j at time t, $j = 1, 2, ...N$, w_j^{PPP} is the PPP GDP weights of country j, and $\sum_{j=1}^{N} w_j^{PPP} = 1$. We compute w_j^{PPP} as a three-year average to reduce the impact of individual yearly movements on the weights

$$w_j^{PPP} = \frac{GDP_{j,2007}^{PPP} + GDP_{j,2008}^{PPP} + GDP_{j,2009}^{PPP}}{GDP_{2007}^{PPP} + GDP_{2008}^{PPP} + GDP_{2009}^{PPP}}, \tag{15}$$

where GDP_{jt}^{PPP} is the GDP of country j converted to international dollars using purchasing power parity rates during a given year t and $GDP_t^{PPP} = \sum_{j=1}^{N} GDP_{jt}^{PPP}$.

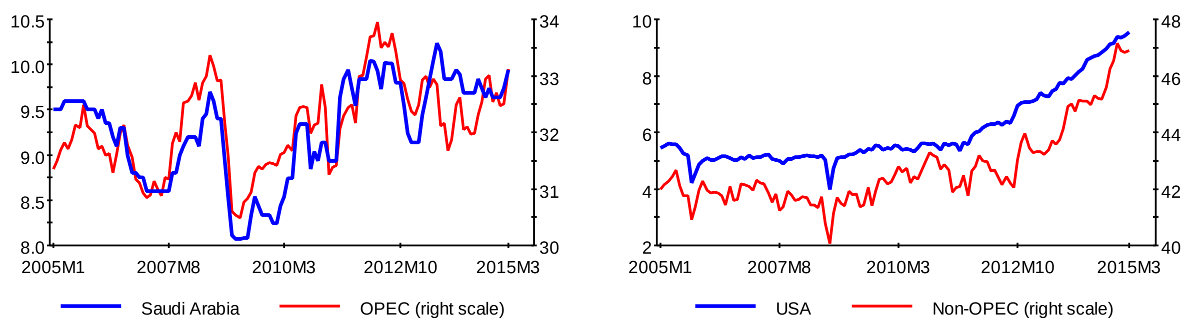
To capture global oil supply conditions we have also included a measure for the quantity of oil produced in the world in equation (13). A key question is how should q_t^o be included in our country-specific models? Looking at the twelve Organization of the Petroleum Exporting Countries (OPEC), of which some members are the largest oil producers in the world, we know that the amount of oil they produce in any given day plays a significant role in the global oil markets, however, they differ considerably from each other in terms of how much oil they produce (and export) and their level of proven oil reserves. Within OPEC, Saudi Arabia has a unique position as it is not only the largest oil producer and exporter in the world, but 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 (causing oil prices to drop from \$57.61 to \$29.62 in real terms) and more recently following the U.S. and the EU sanctions on Iran, Saudi Arabia has increased its production to stabilize the oil market. In fact as is shown in Figure 1 the relationship between Saudi Arabian oil production and total OPEC oil production is a very close one. In our application Saudi Arabia and the other five GCC countries (Bahrain, Kuwait, Oman, Qatar, and the UAE) are grouped as one region, with this region then playing an important role when it comes to world oil supply.[11] Not only do these six countries produce more than 22% of world oil and export around 30% of the world total, the six GCC countries also possess 36.3% of the world's proven oil reserves.[12] Therefore, given the status of the GCC

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

[12] Oil reserve and production data are from the British Petroleum *Statistical Review of World Energy* and

countries with regards to OPEC oil supply, we include log of OPEC oil production, as an endogenous variable in the GCC block.

Figure 1: Oil Production in million barrels per day, 2005M1–2015M3



Source: U.S. Energy Information Administration *Monthly Energy Review*.

We now turn to non-OPEC oil supply. As Figure 1 shows the increase in non-OPEC production over the last decade is more or less the result of the oil revolution which has increased U.S. production by 50% (from approximately 6 mbd to 9 mbd). The recent technological advancements has not only reduced the costs associated with the production of tight oil, but it has also made the extraction resemble a manufacturing process in which the quantity produced can be altered in response to price changes with relatively ease, which is not the case for conventional oil extraction which requires large capital expenditure and lead times. In other words, U.S. oil production can play a significant role in balancing global demand and supply. Given the developments in the last decade, we model non-OPEC oil production within the U.S. model.

3 Empirical Results

We obtain data on $\mathbf{x}_{it}$ for 33 out of the 50 countries included in our sample (see Table 1) from the GVAR website: https://sites.google.com/site/gvarmodelling, see Smith and Galesi (2014) for more details. Data for the remaining 17 countries: Algeria, Bahrain, Ecuador, Egypt, Iran, Jordan, Kuwait, Libya, Mauritania, Morocco, Nigeria, Oman, Qatar, Syria, Tunisia, Venezuela, and the UAE are from Cashin et al. (2012). Oil price data are also from the GVAR website, while data on oil production are from the U.S. Energy Information Administration *Monthly Energy Review*.

oil export data are from the OPEC *Annual Statistical Bulletin*.

We use quarterly observations over the period 1979Q2–2011Q2 to estimate the 38 country-specific VARX*(p_i, q_i) models. However, prior to estimation, we determine the lag orders of the domestic and foreign variables, p_i and q_i. For this purpose, we use the Akaike Information Criterion (AIC) applied to the underlying unrestricted VARX* models. Given data constraints, we set the maximum lag orders to $p_{\max} = q_{\max} = 2$. The selected VARX* orders are reported in Table 2. Moreover, for the lag order of the ARDL(m_{p^o}, m_y, m_{q^o}) model in oil prices, world real income, and world oil supplies AIC selects $m_{p^o} = m_y = m_{q^o} = 2$.

Table 2: Lag Orders of the Country-Specific VARX*(p,q) Models Together with the Number of Cointegrating Relations (r)

Country	VARX* Order		Cointegrating relations ($\widehat{r}_i$)	Country	VARX* Order		Cointegrating relations ($\widehat{r}_i$)
	$\widehat{p}_i$	$\widehat{q}_i$			$\widehat{p}_i$	$\widehat{q}_i$	
Algeria	2	2	1	Morocco	1	1	2
Argentina	2	2	2	Mauritania	2	1	1
Australia	1	1	4	Mexico	1	2	2
Brazil	2	2	2	Nigeria	2	1	2
Canada	1	2	4	Norway	2	1	2
China	1	1	1	New Zealand	2	2	3
Chile	2	2	2	Peru	2	2	2
Ecuador	2	1	1	Philippines	2	1	2
Egypt	1	1	2	South Africa	2	1	2
Euro Area	1	1	3	Singapore	2	1	3
GCC	2	1	3	Sweden	2	1	3
India	2	1	2	Switzerland	1	1	3
Indonesia	2	2	3	Syria	2	2	1
Iran	1	2	2	Thailand	2	1	2
Japan	2	2	3	Tunisia	2	1	2
Jordan	2	1	1	Turkey	2	2	1
Korea	2	2	2	UK	1	2	3
Libya	2	1	1	USA	2	1	3
Malaysia	1	1	1	Venezuela	2	1	1

Notes: $\widehat{p}_i$ and $\widehat{q}_i$ denote the estimated lag orders for the domestic and foreign variables, respectively, selected by the Akaike Information Criterion, with the maximum lag orders set to 2. The number of cointegrating relations ($\hat{r}_i$) are selected using the trace test statistics based on the 95% critical values from MacKinnon (1991) for all countries except for Algeria, Canada, China, Iran, Korea, and Tunisia for which we reduced r_i below that suggested by the trace statistic to ensure the stability of the global model. Source: Authors' estimations.

Having established the lag 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) using the trace test statistics based on the 95% critical values from MacKinnon (1991). 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 analysis of the PPs, we noticed that the speed of convergence was very slow for Algeria, Canada, China, Iran, Korea, and Tunisia and for a few of them the system-wide shocks never really died out, so we reduced r_i by one for each country, except for Korea for which we reduced $\widehat{r}_i$ from 5 to 2, resulting in well behaved PPs overall. The final selection of the number of cointegrating relations are reported in Table 2.

3.1 Identification Strategy

To discriminate oil-supply shocks due to the U.S. oil revolution from other supply shocks, such as disruptions caused by geopolitical tensions in the Middle-East, and oil-demand shocks in general, we rely on two sets of identifying restrictions within our GVAR-Oil framework: (a) dynamic sign restrictions and (b) cross-country sign restrictions arising from the global dimension of the GVAR-Oil model. Regarding these two conditions, we require the oil revolution to be associated with: (i) a decrease in oil prices; (ii) an increase in the level of U.S. oil production; (iii) a constant OPEC oil production; and (iv) an increase in the sum of real GDPs across all major oil importers in our sample. Since the effect of a positive oil-supply shock on the level of GDP of major oil and commodity exporters (for which primary commodities constitute more than 40 percent of their exports) in our sample is ambiguous, we do not impose any dynamic sign restrictions on them. Moreover, we do not impose any restriction on the GDP for Jordan as Mohaddes and Raissi (2013) 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. Note that other than y_{it} we do not impose any restrictions on the remaining variables in $\mathbf{x}_{it}$, that is inflation, the real exchange rate, equity prices and both the short and long-term interest rates.

We impose these sign restrictions, (i) to (iv), to hold for one year after the shock to allow for sluggish responses of quantity measures (oil production and real GDPs). This scheme is effective in identifying oil-supply disturbances as other shocks cannot move oil prices, oil production levels, and real GDPs (across all oil-importing countries) in opposite directions. We should stress that while the quantity restrictions help with the identification of supply shocks, the global dimension of the GVAR model offer an intuitive way of imposing a large number of additional sign restrictions and can therefore greatly reduce the number of admissible models to better identify the shock. Specifically, condition (iv) imposes that the cumulated sum of the relevant individual-country outputs are positive faced with a U.S. oil-supply shock.[13] Intuitively, this positive oil supply shock is perceived to be a tax reduction on oil consumers (with a high propensity to consume) at the expense of oil producers (with a lower propensity to consume) and is associated with an increase in global aggregate demand (hence the cross-country restrictions).

Given these identifying restrictions, the implementation procedure is as follows. 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 i $(= 1, ..., N)$ 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 and quantity 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

$$\tilde{\mathbf{P}} = \begin{pmatrix} \tilde{\mathbf{P}}_1 & \mathbf{0} & \cdots & \cdots & \mathbf{0} \\ \mathbf{0} & \ddots & & & \vdots \\ \vdots & & \tilde{\mathbf{P}}_i & & \vdots \\ \vdots & & & \ddots & \mathbf{0} \\ \mathbf{0} & \cdots & \cdots & \mathbf{0} & \tilde{\mathbf{P}}_N \end{pmatrix},$$

which can be used to obtain the impulse responses of all endogenous variables in the GVAR-Oil model to shocks to the error terms $\mathbf{v}_t = (\mathbf{v}_{1t}', \ldots, \mathbf{v}_{it}', \ldots, \mathbf{v}_{Nt}')' = \tilde{\mathbf{P}} \mathbf{u}_t$. We draw $10,000$

[13] We also considered a cumulated weighted average of the outputs, using PPP GDP weights, and obtained very similar results. We will thus focus on the results using the simple cumulated sum of the output responses in the remainder of the paper.

times and only retain those valid rotations that satisfy our set of *a priori* restrictions.[14]

Since there are a few impulse responses that satisfy our postulated identifying restrictions, we summarize them by reporting a central tendency and the 5th and 95th percentiles as measures of the spread of responses. Although the remaining models—after imposing identifying restrictions (a) to (b)—imply qualitatively and sometimes quantitatively similar responses, the central tendency measure (i.e. median) for impulse responses of different variables (across the 38 countries/regions) may come from different impulse vectors. We therefore follow Fry and Pagan (2011) and report a single model whose impulse responses are as close to the median values of the impulse vector as possible (this is called the median target). It is important to recognize that the distribution here is across different models and it has nothing to do with sampling uncertainty.

3.2 The Macroeconomic Effects of the U.S. Oil Revolution

Figures 2–4 show the estimated median (blue solid) and the median target (black long-dashed) impulse responses (for up to ten years) of key macroeconomic variables of oil exporters and oil-importing countries to a supply-driven oil-price shock (emanating from the oil revolution in the United States), together with the 5th and 95th percentile error bands.[15] The economic consequences of a positive oil-supply shock in the U.S., equivalent to a 51% fall in the oil prices after one year, are very different for oil-importing countries compared to energy exporters. With regard to real output, following the U.S. oil-supply shock, Euro Area and the U.S. (two major energy-importing countries) experience a long-lived boost to economic activity—0.56% and 0.60%, respectively—while similar responses are observed for the UK (a former oil exporter) and other advanced countries, being on average 0.57% and 0.42%, respectively.

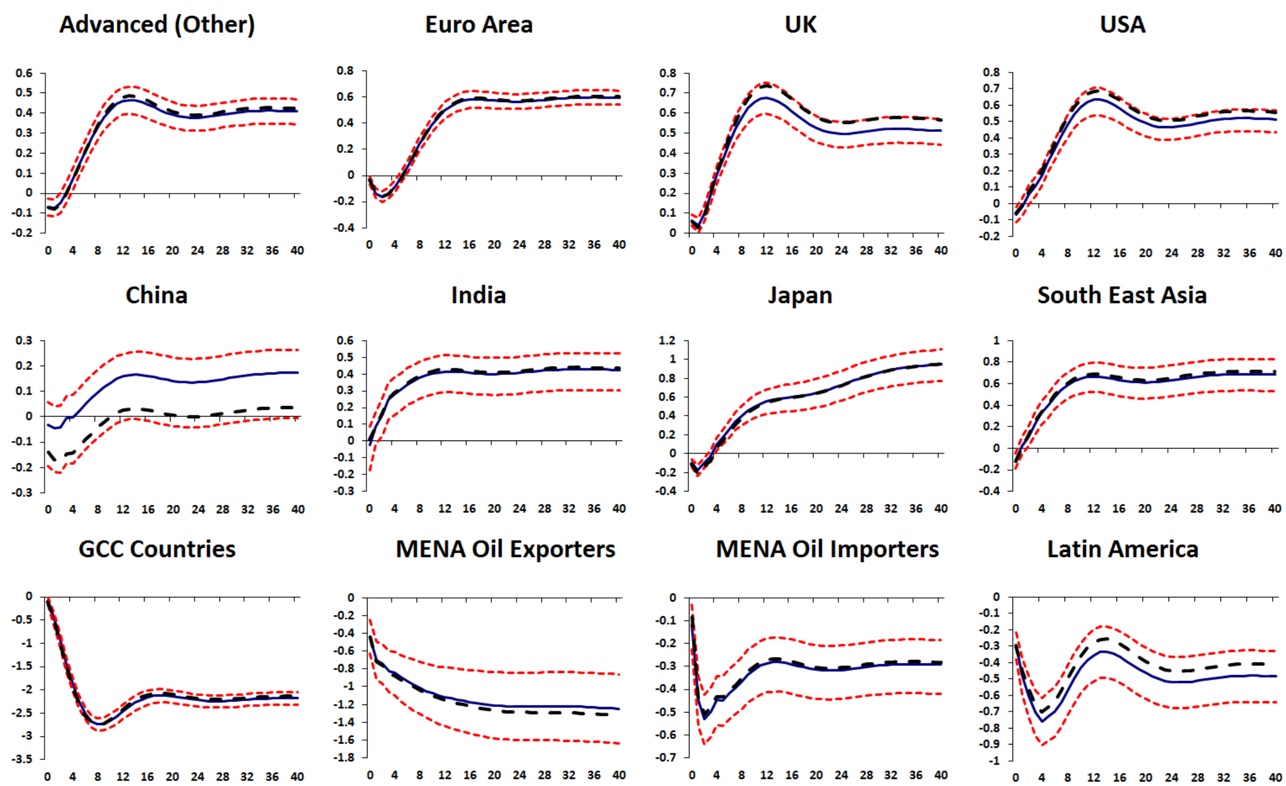
Our framework takes into account not only the direct exposure of countries to the oil shock but also the indirect effects through secondary or tertiary channels. For instance, as a result of the dominance of the United States in the world economy, any increase (or decrease) in economic activity in this country can bring about positive (or negative) spillovers to other economies, as the recent global economic crisis has shown. More generally, the history of past U.S. recessions usually coincides with significant reductions in global growth. Furthermore, the continuing dominance of U.S. debt and equity markets, backed by the still-strong global role of the U.S. dollar, is also playing an important role. This is clearly illustrated in Figure 2, where what was initially an increase in domestic output due to lower oil prices, translates

[14] See Chudik and Fratzscher (2011) for an application of Generalized Impulse Response Functions (GIRFs) for structural impluse response analysis.

[15] We attach more weight to median target responses as we would like to track a single model at all times.

into a pickup in economic activity even in the medium term due to spillovers through trade and financial channels. However, these spillovers do vary greatly from country to country and depend on, for instance, a particular country's trade exposure to the U.S. or the other advanced economies.

Figure 2: Impact of the U.S. Oil Supply Revolution on Real Output



Notes: Figures are median (blue solid) and median target (black long-dashed) impulse responses to a one standard deviation fall in the price of oil, equivalent to an annualized drop of 51% in year 1 and 45% in year 2, together with the 5th and 95th percentile error bands. The impact is in percentage points and the horizon is quarterly.

The GDP impact is also positive for most Asian countries (for instance, the South East Asia region experiences on average a long-run boost of 0.71%) apart from China where the median target response is negative initially, but becomes positive and around 0.04% over the long-term. However, given China's heavy dependence on coal, as opposed to oil, for its energy consumption needs and the composition of its export basket, this result might not be that surprising after all. The United States (Euro Area) met 36% (38%) and 20% (13%) of its primary energy needs from oil and coal sources in 2014, respectively. In contrast, coal provided over 66% of China's primary energy needs in 2014, while oil amounted to less than

18% of the total. In fact, China accounts for just over half of global coal consumption, and its coal use has almost tripled since 2000 (see British Petroleum's *Statistical Review of World Energy*). Considering the dominance of coal (rather than oil) in the Chinese economy, and given that most of its coal consumption (well over 90%) is met by domestic production, oil-supply shocks will have relatively less of an impact on the Chinese economy.

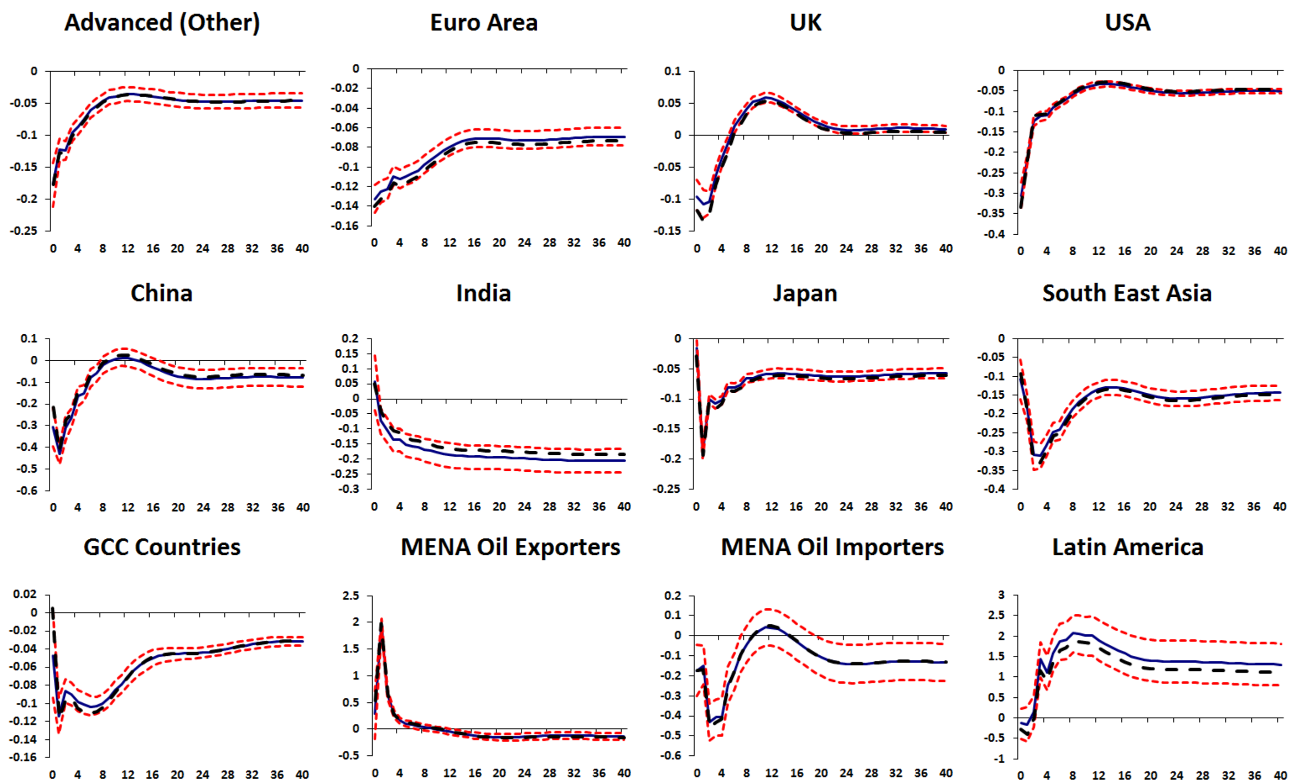
Turning to the commodity exporters in our sample, it appears that an oil-supply shock in the U.S. creates a slowdown in economic activity in these regions (GCC, MENA, and Latin America) to varying degrees (given lower commodity prices)—the extent of which, at least in the short-term, depends on the size of their buffers and availability of financing. The largest effects are in the GCC and the other MENA oil exporters of -2.14% and -1.32% with the effects in Latin America being on average much smaller at -0.41%. MENA oil importers also experience an economic slowdown of 0.28% on average following a U.S. oil-supply shock given their economic ties with oil exporters in the region. For example, remittances from Jordanians working in the region are an important source of national income (equivalent to 15–20 percent of GDP); the Persian Gulf region is the primary destination for Jordanian exports, and in turn, supplies most of its energy requirements; furthermore, the country receives substantial grants and FDI from other states in the region, see Mohaddes and Raissi (2013). Given these linkages, it is no surprise that any slowdown in the GCC region (due to lower oil prices) would adversely affect the Jordanian economy, but also through similar channels other MENA oil importers in general (See Section 4).

Looking at the GDP responses from a global perspective, our results suggest that following the U.S. oil revolution, with oil prices falling by 51% in the first year and rebounding somewhat to 45% below the pre-shock levels in year two, global growth increases by $0.16 - 0.37$ percentage points.[16] In response to lower supply-driven oil prices, we would expect the increase in spending by oil importers to exceed the decline in expenditure by oil exporters given their different marginal propensities to consume/invest. See also Arezki and Blanchard (2014), Baffes et al. (2015), and Husain et al. (2015) who obtain very similar magnitudes.[17]

[16] The global growth effects are calculated from the individual country responses aggregated using PPP GDP weights.

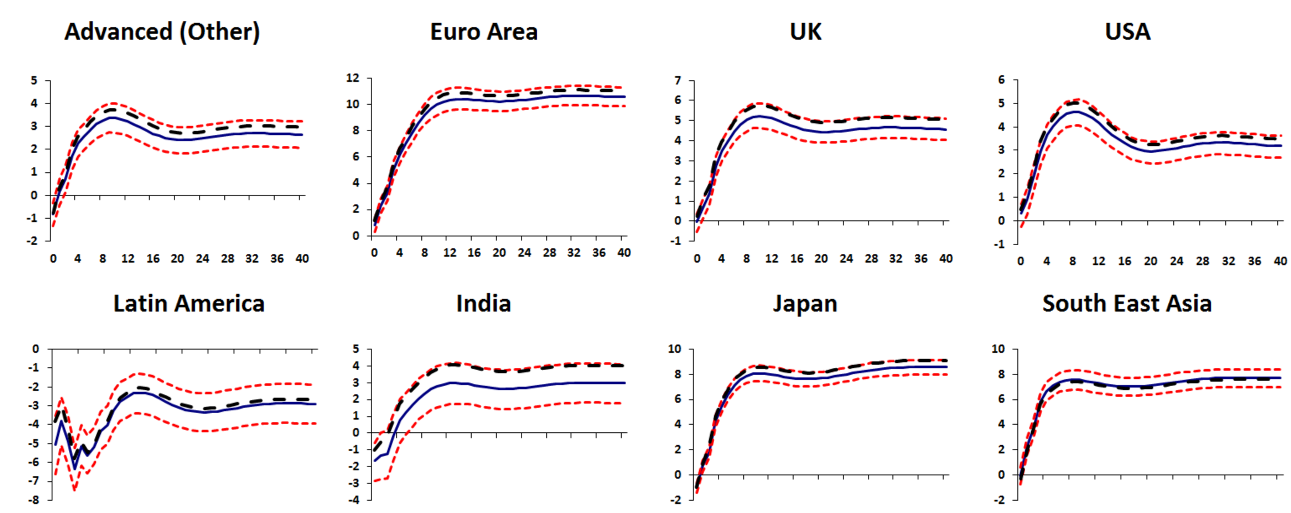
[17] Ex-post the boost from lower oil prices since mid-2014 has been offset by an adjustment to lower medium-term growth in most major economies due to idiosyncratic factors. For example, the rebalancing of the Chinese economy from an investment-led growth model to a consumption-driven one, and surges in global financial market volatility have adversely affected an already weak global economic recovery. Cashin et al. (2016) illustrate that a sharp increase in global financial market volatility could translate into (i) a short-run lower overall world economic growth of around 0.29 percentage points, (ii) lower global equity prices and long-term interest rates, and (iii) significant negative spillovers to emerging market economies (operating through trade and financial linkages). Moreover, they show that following a permanent one percent fall in Chinese GDP, global growth reduces by 0.23 percentage points in the long run.

Figure 3: Impact of the U.S. Oil Supply Revolution on Inflation



Notes: See notes to Figure 2.

Figure 4: Impact of the U.S. Oil Supply Revolution on Equity Markets



Notes: See notes to Figure 2.

Following an oil-supply shock in the U.S., we also find strong disinflation pressures on energy-importing countries in our sample (advanced countries, China, India, South East Asia, and MENA oil importers), with the peak responses ranging between 10 and 50 basis points (see Figure 3). On impact, inflation falls in all of these oil-importing countries but the persistence of the responses changes with the magnitude of second-round effects, and the stance of monetary policy. The different responses of MENA oil-exporters and Latin American countries are probably driven by movements of the real exchange rate in these economies. The real exchange rate tends to depreciate in these countries, limiting the pass-through effect of lower international oil prices to domestic markets (and inflation).

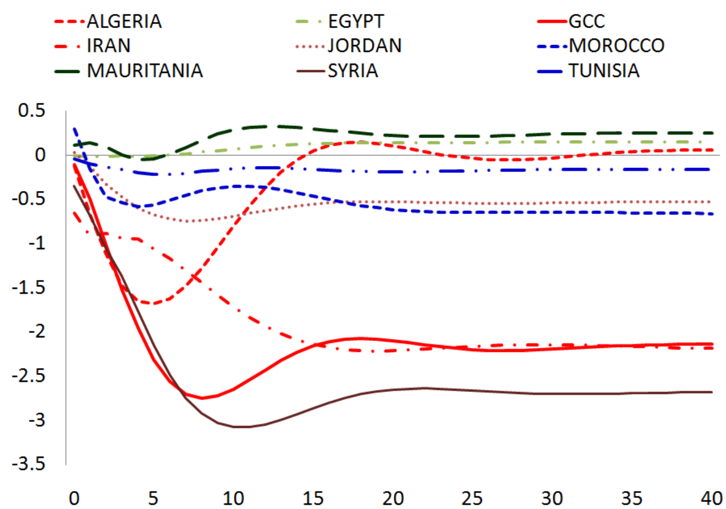
Furthermore, in all oil-importing countries/regions, equity prices rise following a positive oil-supply shock in the United States (see Figure 4). As shown in the equity pricing model of Huang et al. (1996), the equity price equals the expected present discounted value of future cash flows. Since a lower expected inflation reduces the discount rate, a fall in oil price has a positive impact on stock market returns. The positive effect of falling oil prices on stock markets in net oil-importers has also been supported by a number of other researches, including Cheung and Ng (1998); Sadorsky (1999); and Park and Ratti (2008) among others.

4 Focusing on the MENA Region

The results in Section 3.2, and Figure 2 in particular, indicate that the U.S. oil revolution, and the resulting lower oil prices, will likely have a negative growth impact on Middle East and North Africa (MENA) region for both primary-commodity exporters and importers. This section investigates in greater detail the macroeconomic implications of the U.S. oil supply revolution, in terms of its real GDP effects, on individual countries in the MENA region over the short and long-term. Note that the resulting low oil-price environment has also political economy implications. For instance, Elbadawi (2015), argues that a negative and sustained oil price shock, by reducing oil rents per capita, could weaken the government's effectiveness in managing the economy and maintaining civil peace (making the ruling elite more vulnerable to popular uprisings), thereby changing the developmental and sustainable political equilibrium in the GCC countries. While such political economy considerations are important, they are beyond the scope of this paper and will not be tested empirically.

The median-target impulse responses in Figure 5 show that Syria, the GCC and Iran face a long-lasting fall in their real output (more than -2% over the long-run) following a positive U.S. oil-supply shock as lower oil prices weakens the external and fiscal balances in these countries. For Algeria, an OPEC member, the median target response is negative for the first 14 quarters before stabilizing around zero over the long-run. While buffers and available financing allow most oil exporters in the region to avoid sharp cuts in government spending in the near-term (limiting the impact on short-term investment and growth), the long-term impact depends on their medium-term fiscal plans and capital spending. Table 3 shows that the fiscal break-even price for all major oil exporters, except Kuwait, is substantially above \$56.25—the average Brent spot price between January and August 2015.

Figure 5: Impact of the U.S. Oil Supply Revolution on Real Output in the MENA Region



Notes: Figures are median target impulse responses to a one standard deviation fall in the price of oil, equivalent to an annualized drop of 51% in year 1 and 45% in year 2. The impact is in percentage points and the horizon is quarterly.

Table 3: Fiscal Break-Even Prices for Major Oil Exporters (U.S. dollars/barrel)

Country	Break-even prices	Country	Break-even prices	Country	Break-even prices
Algeria	\$111.10	Libya	\$215.00	Saudi Arabia	\$103.00
Iran	\$92.50	Nigeria	\$87.90	U.A.E.	\$73.10
Iraq	\$70.90	Qatar	\$59.10	Venezuela	\$89.00
Kuwait	\$47.10	Russia	\$78.00		

Source: International Monetary Fund and Deutsche Bank.

For most oil-importers in the MENA region, gains from lower oil prices are offset by a decline in external demand/financing by oil-exporters over the medium-term given the strong linkages between the two groups through trade, remittances, tourism, foreign direct investment and grants. The resulting estimated long-run negative growth effects on these countries, although being non-trivial, are much smaller than those on oil-exporters— about -0.5%, -0.7%, and -0.2% for Jordan, Morocco and Tunisia, respectively. For Egypt (despite having a relatively large subsidy bill) and Mauritania the median target responses are positive and about 0.2% in the medium-term. In general, low pass-through from global oil prices to domestic fuel prices limits the impact on disposable income of consumers and profit-margins of firms in MENA oil importers, and thereby reduces the direct positive impact on economic growth in these countries. The next two sub-sections discuss the main channels through which long-term growth is being affected by sustained lower commodity prices for major oil-exporters as well as select oil importers in the region.

4.1 A Long-Run Structural Model for Oil-Exporters

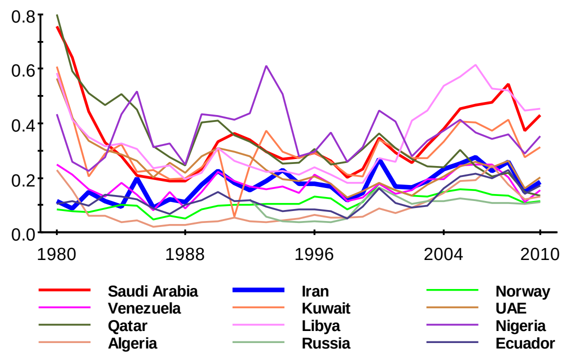
Given that oil exporters in our sample (except for Saudi Arabia) are producing at (or near) capacity, they cannot readily increase their production levels in response to lower oil prices to offset the substantial drop in oil revenues following the U.S. oil supply revolution. Even if they were able to increase production, this would only lead to an increase in global supply, which would in turn depress prices even further; at least in the short-run and until current projects from high-cost fields are completed. The question is whether the long-run growth effects of sustained lower oil revenues for major oil exporters can be modelled and empirically tested at the *country level* and based on a growth theory? If so this would allow one to explore the channels through which the fall in oil revenue affects these economies. Unfortunately most macroeconomic analysis of oil revenues/shocks tend to take a short-term perspective. They usually focus on the effects of oil revenues on the real exchange rate (Dutch disease) and government budget expansion, thus failing to consider their effects on long-run growth.

This approach makes sense for countries with a limited amount of oil reserves and those facing temporary shocks, but not for major oil exporting countries such as Iran, Kuwait and Saudi Arabia for which oil income should be treated more as a part of the steady state growth outcome and not as a transient state. While it is clear that the oil and gas reserves will be exhausted eventually, this is likely to take place over a relatively long period. Figure 6 shows that most OPEC members such as Algeria, Iran, Kuwait, Nigeria, Saudi Arabia, United Arab Emirates, and Venezuela, and a few countries outside OPEC such as Norway and Russia, have similar oil income to GDP ratios that have remained relatively stable.[18]

Given that there is little evidence to suggest that for the MENA oil exporting economies oil income will be diminishing any time soon and the fact that their oil income to output ratio is expected to remain high over a prolonged period, we can utilize the empirical growth model

[18] See Esfahani et al. (2013) for an extensive discussion.

Figure 6: Ratio of Oil Export Revenues to Real Output Across Oil Exporters, 1980–2010



Source: British Petroleum *Statistical Review of World Energy*, OPEC *Annual Statistical Bulletin*, and IMF *International Financial Statistics*.

for major oil exporting countries recently developed in Esfahani et al. (2014), to empirically investigate the direct effect of a fall in oil revenue for these economies. More specifically, by extending the stochastic growth model developed in Binder and Pesaran (1999) and allowing for the possibility that a certain fraction of oil revenues is invested in the domestic economy via the capital accumulation channel, Esfahani et al. (2014) show that the long-run output equation for major oil exporters is given by

$$y_{it} - \psi_{i1} y_{it}^* = \psi_{i2}(e_{it} - p_{it}) + \psi_{i3} o_{it} + c_{iy} + \gamma_{iy} t + \xi_{iy,t} \tag{16}$$

where o_{it} is oil revenue in US dollars for country i ($o_{it} = q_{it}^o \times p_t^o$) at time t, c_{iy} is a fixed constant, $\xi_{iy,t}$ is a mean zero stationary process, which represents the error correction term of the long-run output equation, and as before y_{it} (y_{it}^*) is the logarithm of real domestic (foreign) output, e_{it} is the log of the nominal exchange rate, and p_{it} is the logarithm of the domestic Consumer Price Index (CPI$_i$). As discussed in Section 2.1 in Esfahani et al. (2014), the coefficient of the variables in equation (16) have further restrictions imposed on them based on economic theory, namely

$$\psi_{i1} = \theta_i(1 - \psi_{i2}), \psi_{i2} = \psi_{i3} = \alpha_i, \text{ and } \gamma_{iy} = (1 - \alpha_i)(n_i - \theta_i n_i^*) \tag{17}$$

where α_i is the share of capital in output, n_i (n_i^*) is the domestic (foreign) population growth rate, and θ_i measures the extent to which foreign technology is diffused and adapted successfully by the domestic economy in the long run. In this relationship, y_{it}^*, acts as a proxy for global technological progress. The diffusion of technology is at par with the rest of the world if $\theta_i = 1$, whilst a value of θ_i below unity suggests inefficiency that prevents the adoption of best practice techniques, possibly due to rent-seeking activities and general economic mismanagement. Note that cross-section regressions in the resource curse literature most likely captures short-term deviations from the steady states and in view of the substantial heterogeneity that exists across countries can be quite misleading, particularly as far as the identification of θ_i is concerned, which most likely could differ across countries.

Rather than combining VARX*(p_i, q_i) models and solving the GVAR-Oil model as is done in Section 3.2, we test the output equation (16) on a *country-by-country* basis, imposing the additional theory restrictions in (17). To this end we estimate individual country-specific models as before, using equation (12) and quarterly observations over the period 1979Q2–2011Q2, but including oil revenue (o_{it}) rather than oil prices in $\mathbf{x}_{it}$. As predicted by the theory, we find that real output for the seven MENA oil exporters in the long run is shaped by: (i) oil revenue through its impact on capital accumulation, and (ii) technological spillovers through foreign output.

We then consider the output effects of a negative unit shock (equal to one standard error) to oil revenues using the Generalized Impulse Response Functions (GIRFs), developed in Koop et al. (1996) and Pesaran and Shin (1998).[19] The associated GIRFs together with their 95% error bands are given in Figure 7. These figures clearly show that a negative oil revenue shock significantly reduces real output in all seven countries, with the full impacts of oil revenue changes showing up in these economies quite fast, and peak within 2-3 years in most cases. The equilibrium levels of these effects are between 2% and 12% (quite heterogenous across countries), with the largest real output losses occurring in three GCC countries (Kuwait, Qatar, and the U.A.E.) where the steady state value of the effect of the oil revenue shock is $11 - 12\%$. This difference partly reflects the much higher historical volatility of oil revenues in Kuwait (due to invasion of Kuwait by Iraq in 1990 and its aftermath) and Libya. The quarterly standard deviation of oil revenue for Kuwait and Libya is around 42.8% and 37.7% as compared to between $20.3 - 23.8\%$ for the other countries.

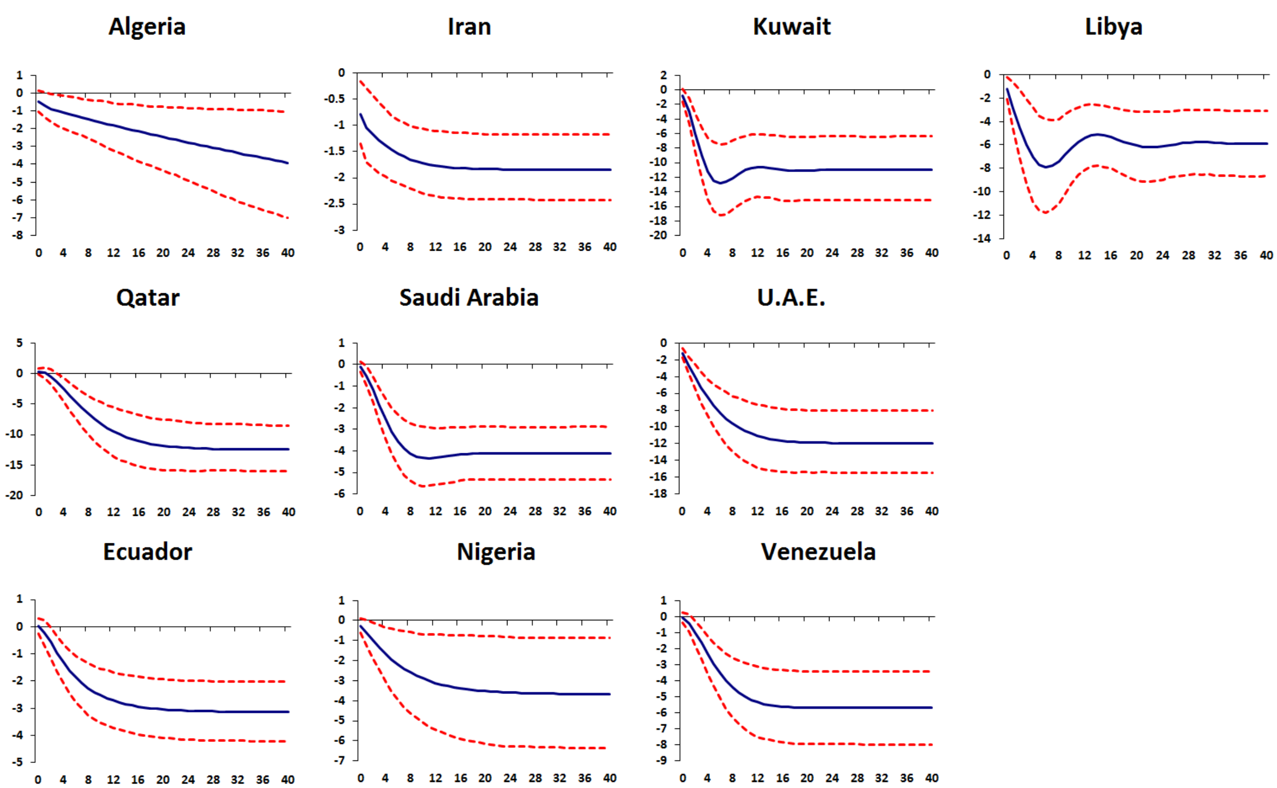
To contrast the results for the MENA oil exporters with the other three OPEC members in our sample, we also estimated VARX* models for Ecuador, Nigeria, and Venezuela, and found the results to be quite similar, see Figure 7. In particular the GIRFs illustrate that the equilibrium levels of these effects are between 3% and 6%, with the quarterly standard deviation of oil revenue for these economies being between $19.8 - 23.2\%$.

Overall, the results indicate that oil revenue shocks (such as those from the low oil price

[19] Unlike the orthogonalized impulse responses popularized in macroeconomics by Sims (1980), the GIRFs are invariant to the ordering of the variables in the VARX* model.

environment we are currently experiencing) have a large, long-lasting and significant impact on these economies' growth paths, operating through the capital accumulation channel. Moreover, the theoretical model for major oil exporters outlined above, and the fact that we could not reject the theory restrictions in (17), together with the impulse responses in Figure 7 indicate that these countries will be adversely affected whenever the international price of crude oil declines and will benefit whenever it rises. Therefore, macroeconomic and structural polices should be conducted in a way that the vulnerability of these countries to oil revenue (not just price) disturbances are reduced, see also Cavalcanti et al. (2015) and El-Anshasy et al. (2015).

Figure 7: Impact of a Negative Oil Revenue Shock for OPEC countries



Notes: Figures are median generalized impulse responses to a one standard deviation fall in oil revenue, together with 95 percent bootstrapped confidence bounds. The impact is in percentage points and the horizon is quarterly.

The empirical results presented here have strong policy implications. Oil exporters in the MENA region and beyond are faced with substantial losses in government revenues as a result of a seemingly long-lasting oil price fall. With buffers eroding over the medium-term, most countries will need to re-assess and re-align their medium-term spending plans. Improvements in the conduct of macroeconomic policies, better management of resource income volatility, and export diversification can all have beneficial growth effects; as do policies which increase the return on investment, such as public infrastructure developments and human capital enhancing measures.[20] Moreover, the creation of commodity stabilization funds, or Sovereign Wealth Funds in case of countries in the Persian Gulf, might be one way to offset the negative effects of commodity booms and slumps. Finally, recent academic research has placed emphasis on institutional reform. By establishing the right institutions, one can ensure the proper conduct of macroeconomic policy and better use of resource income revenues, thereby increasing the potential for growth.

4.2 Spillovers to MENA Oil-Importers

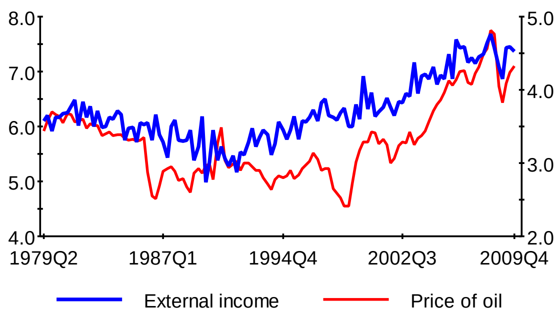
While it is no surprise that MENA oil exporters are affected negatively by lower oil prices, the overall long-term output effect for MENA oil importers is not clear cut (considering the direct and indirect effects of lower oil prices for these economies). While a fall in oil prices initially implies lower import costs for these economies, it also reflects a slow down in oil-exporting countries (see the discussion above), which in turn negatively impact these economies through trade, remittances, and foreign direct investment (FDI) channels. Overall, Figure 5 shows that the direct positive effect of lower oil price for all oil importers (except Egypt and Mauritania) is dominated by the indirect negative impact of spillovers from the exporters (in particular from the GCC). Below we explore the direct positive and the indirect negative channels focusing on Jordan to draw lessons for others.

Figure 8 shows the evolution of general government transfers, workers' remittances, and foreign direct investment (FDI), what we refer to as external income or x_{it}. Both remittances and external income account for a significant share of Jordan's output, with the share of the former being around 15–20% of GDP over 1979–2009, and the latter being on average 30%. Given that the majority of Jordanian migrant workers reside in the neighboring GCC countries and that most of the official government transfers (grants) are received either from Saudi Arabia or the United States, any economic/political developments in the oil-exporting states of the region would significantly affect the flow of external income to Jordan. Therefore, even though the country is an oil importer, as long as x_{it} from the oil-exporting economies are maintained, we expect lower oil prices to have a long-run negative growth

[20] For more details on oil price shocks and macroeconomic policy in resource-rich MENA countries see, for instance, the planned edited volume "Fiscal Institutions and Macroeconomic Management in Resource-Rich Arab Economies" (which is the outcome of an ERF funded research project) and the papers from the ERF project "Institutional Requirements for Optimal Monetary Policy in the Resource-Dependent Arab Economies" lead by Bassem Kamar.

effect on the Jordanian economy. That is, the direct positive effect of lower oil prices is dominated by the indirect negative impact; see also International Monetary Fund (2010) and the detailed discussion in Mohaddes and Raissi (2013).

Figure 8: External Income and Price of Oil, in Log Level



Sources: Authors' construction based on data from International Monetary Fund *Balance of Payments Statistics* and *International Financial Statistics*.

Figure 8 shows the relationship between log external income, x_{it}, and log oil prices, p_t^o. It is clear that both variables share the same trend over the long run, with some important short-run deviations. We estimate a cointegrating VAR(2) model for external income and oil prices and find that there is a long-run relation between x_{it} and p_t^o. It is also interesting that the co-trending restriction, which imposes a coefficient of zero on the trend component of the long-run relationship between the two variables, is not rejected and the hypothesis that the long-run elasticity of external income to oil prices is unity cannot be rejected either, and as a result: $x_{it} = p_t^o + \xi_{ix,t}$, where $\xi_{ix,t} \sim I(0)$. Therefore, oil prices represent an excellent proxy for external income in the Jordanian economy.

Given the discussion above, we augment the output gap equation (16), to include oil prices as opposed to oil revenues. Note that the inclusion of p_t^o will give us the net effect of lower oil prices on the equilibrium output level (the negative effect is due to less inflows of external income which in turn dampens real GDP, while the positive effect is due to the fall in the cost of importing oil), while the inclusion of x_{it} will only show the negative indirect impact of lower oil prices on GDP and not the direct positive effects.[21] The modified output

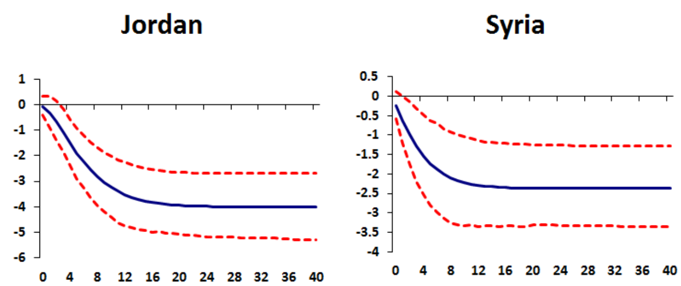
[21] The justification for our modelling strategy of using oil prices rather than external income as one of the main long-run drivers of real output for Jordan is given in the discussion above, where we established that the price of oil is an excellent proxy for external income. The above results also showed that from a long-run perspective, only one of the two variables (x_{it} or p_t^o) need to be included in the cointegrating model. Our decision to include oil prices rather than external income is further justified on the ground that p_t^o is likely to be exogenous to the Jordanian economy whilst the same cannot be said of x_{it}.

gap equation for Jordan is then given by

$$y_{it} - \psi_{i1} y^*_{it} = \psi_{i2}(e_{it} - p_{it}) + \psi_{i3} p^o_t + c_{iy} + \gamma_{iy} t + \xi_{iy,t}, \tag{18}$$

where all variables are defined in (16).[22] We estimate a VARX*(2,2) model for Jordan, imposing the restrictions in (17), and find that we cannot reject the theory derived output relation. The results therefore confirm that a fall in oil prices, by reducing external income, dampens capital accumulation and thus leads to a fall in real output. The GIRFs in Figure 9 illustrate the response of the Jordanian economy to a negative oil price shock (based on a historical quarterly standard deviation of 18.6%), where the equilibrium output effect of the shock is -4%, being similar to those in Figure 5 based on the GVAR-Oil model.

Figure 9: Impact of a Negative Oil Price Shock



Notes: Figures are median generalized impulse responses to a one standard deviation fall in oil prices, together with 95 percent bootstrapped confidence bounds. The impact is in percentage points and the horizon is quarterly.

Similar analysis can also be conducted for other oil-importing countries in the MENA region. To illustrate this, we also estimated the long-run output equation (18) for Syria, imposing the theory restrictions above, and found that we cannot reject them. The GIRFs for Syria also show that a negative oil price shock reduces real GDP by 2.4%, which is again in line with the results in Figure 5.

5 Concluding Remarks

We applied a set of dynamic sign restrictions on the impulse response of a GVAR-Oil model, estimated for 38 countries/regions over the period 1979Q2 to 2011Q2, to identify the U.S. supply-driven oil-price shock, and to study the global macroeconomic implications of the

[22] A similar relationship is also derived in Cavalcanti et al. (2011).

resulting fall in oil prices. We quantified the GDP impact of a 51 percent reduction in oil prices (caused by a U.S. driven supply glut) on net energy importers and net oil exporters. We found that while oil importers typically experience a long-lived rise in economic activity (between 0.04% and 0.95%) in response to a U.S. supply-driven fall in oil prices, the impact is negative for energy-exporters (-2.14% for the GCC, -1.32% for the other MENA oil exporters, and -0.41% for Latin America) and commodity-importing countries with strong economic ties with oil exporters. Specifically, we find that for most oil-importers in the MENA region, gains from lower oil prices are offset by a decline in external demand/financing by oil-exporters over the medium-term given strong linkages between the two groups through trade, remittances, tourism, foreign direct investment and grants. The resulting estimated long-run negative growth effects on these countries, although being non-trivial, are much smaller than those on oil-exporters; being on average -0.28%. Overall, our results suggest that following the U.S. oil revolution, global growth increases by $0.16-0.37$ percentage points. Furthermore, in response to a positive U.S. oil-supply disturbance, almost all countries in our sample experience a decrease in inflation and a rise in equity prices.

The sensitivity of MENA countries (both oil exporters and importers) to oil market developments raises the question of which policies and institutions are needed in response to such shocks. While countercyclical fiscal policies (using existing buffers) are key to insulate the exporters from commodity price fluctuations, the other priority for commodity exporters should be to enhance their macroeconomic policy frameworks and institutions (such as more autonomy in conducting the monetary and exchange rate policies). Oil importers in the region should not overestimate the positive impact of the decline in oil prices on their economies given considerable uncertainty about the persistence of lower oil prices and the availability of external financing and weak demand growth in oil-exporting trade partners. For the MENA countries the current low oil-price environment provides an opportunity for further subsidy and structural reforms.

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