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likka Korhonen and Aaron Mehrotra

Real exchange rate, output and oil:
Case of four large energy producers



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All opinions expressed are those of the authors and do not necessarily reflect the views of the Bank of Finland.

Iikka Korhonen and Aaron Mehrotra

Real exchange rate, output and oil: Case of four large energy producers¹

Abstract

We assess the effects of oil price shocks on real exchange rate and output in four large energy-producing countries: Iran, Kazakhstan, Venezuela, and Russia. We estimate four-variable structural vector autoregressive models using standard long-run restrictions. Not surprisingly, we find that higher real oil prices are associated with higher output. However, we also find that supply shocks are by far the most important driver of real output in all four countries, possibly due to ongoing transition and catching-up. Similarly, oil shocks do not account for a large share of movements in the real exchange rate, although they are clearly more significant for Iran and Venezuela than for the other countries.

JEL codes: E31, E32, F31, Q43

Key words: structural VAR model, oil price, Iran, Kazakhstan, Russia, Venezuela

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Iikka Korhonen and Aaron Mehrotra

Real exchange rate, output and oil: Case of four large energy producers

Tiivistelmä

Tässä työssä tutkitaan öljyn hintasokkien vaikutusta reaaliseseen valuuttakurssiin ja kokonaistuotantoon neljässä energiantuottajamaassa: Iranissa, Kazakstanissa, Venezuelassa ja Venäjällä. Tutkimuksessa estimoidaan neljän muuttujan rakenteellinen vektoriautoregressiivinen malli yleisesti käytettyjen pitkän aikavälin rajoitteiden avulla. Öljyn kalliimpi reaalihintana kasvattaa maiden tuotantoa, mikä ei ole yllättävää. On kuitenkin huomattava, että tarjontapuolen sokit selittävät suurimman osan tuotannon muutoksista, mikä voi johtua maiden talouksien rakennemuutoksista. Öljysokit eivät myöskään selitä kovinkaan suurta osaa reaalisesta valuuttakurssin muutoksista, vaikka ne ovatkin selvästi tärkeämpiä Iranille ja Venezuelalle kuin muille maille.

Asiasanat: rakenteellinen VAR-malli, öljyn hinta, Iran, Kazakstan, Venäjä, Venezuela

1 Introduction

In this paper we assess the effects of oil price shocks on real exchange rates and output in four major energy-producing countries: Iran, Kazakhstan, Russia, and Venezuela. Iran and Venezuela belong to the Organization of Petroleum Exporting Countries (OPEC), while Russia and Kazakhstan do not. However, they all are highly dependent on energy in their exports. For Russia, oil and oil products, together with natural gas, accounted for 60% of exports in 2007; for Kazakhstan the corresponding share was slightly over 50%. In the two OPEC countries, the share of energy in total exports is even higher, more than 80% in Iran and more than 90% in Venezuela. The price of energy is the most important determinant of the terms of trade for these countries.² Therefore, it is of interest to examine how the volatility of oil price affects their real exchange rates.

The analysis presented here has applicability for other countries as well. Many emerging market countries are major producers of raw materials and thus may be highly dependent on the price of a single commodity. Moreover, many emerging market countries exhibit 'fear of floating' (Calvo and Reinhart, 2002), i.e. they tightly manage their nominal exchange rates, even though their currencies are not officially pegged. This seems to be case with our countries as well, although they differ in specifics of exchange rate regimes. For example, Venezuela maintains a peg to the US dollar and relies heavily on capital controls. Both Russia and Kazakhstan have managed their exchange rates around central parities, while maintaining a degree of discretion as to the central parity.

Estimating structural vector autoregressive models (SVAR) with long-run restrictions, our results show that oil price shocks account for only a small share of overall shocks affecting the real exchange rates in these countries. Only in Iran and Venezuela does a positive oil price shock lead to appreciation of the real exchange rate, as the theory would suggest. In contrast, demand shocks explain 50% to 90% of variation in the real exchange rate. Our results are in line with those of Clarida and Galí (1994) who evaluate the importance of various structural shocks for exchange rate movements in four G7 economies. In fact, our estimated system is a direct extension of their open macro model, augmented with oil price shocks in the spirit of Huang and Guo (2007). Our results could thus be seen to suggest that recent movements in emerging economies' exchange rates have

² Even though there are no international spot markets for natural gas, like there are for crude oil, the price of natural gas tends to follow the price of crude oil, albeit with a lag.

been largely driven by the same shocks as in the advanced economies since the collapse of Bretton Woods.

While our main emphasis is on real exchange rates, we also estimate the effects of oil shocks on output. Oil price shocks are found to have a positive and statistically significant effect on domestic output, with the exception of Iran. However, oil shocks play a relatively minor role in the movements in real GDP. Supply shocks explain 45% to 90% of the movements in output. This suggests that the importance of oil for these economies should not be overemphasised, at least as an independent source of shocks driving GDP. A recent paper by Husain et al. (2008) estimates a panel VAR model for ten oil-producing countries and finds that oil prices have no statistically significant effect on the countries' non-oil output, and the effect on GDP is realised only via pro-cyclical fiscal policy.

We make several contributions in this paper. We extend the analysis of oil-producing economies by including explicit oil-price shocks in structural vector autoregressive models. To our knowledge, this has not been previously done in the literature. By estimating similar models for four countries, we are also able to compare the effects of oil shocks on their exchange rates. We are able to discern somewhat different responses e.g. to oil and monetary shocks in these countries, possibly because of differences in exchange rate policies. We are also able to determine that in our data sample the relationship between oil prices and domestic GDP is linear, with the possible exception of Venezuela. For that economy, linearity tests suggest that an alternative modelling strategy explicitly accounting for nonlinearities could be a possible alternative.

Our paper is structured as follows. Section 2 provides a brief overview of the economic policies of the four economies during the period under review. The third section offers a selective literature survey, and the fourth section presents the underlying theoretical model in more detail. The fifth section discusses the empirical methodology and data used, and in Section 6 we present the estimation results. The final section concludes.

2 Economic policies in our sample of oil-producers

In the four countries in our sample, the current decade has been characterised by very rapid economic growth. Growth has been given impetus by high prices of raw materials, which have boosted the countries' export revenues. Also, in Russia and Kazakhstan net exports have been helped by the steep depreciation of the countries' currencies in the wake of their financial crises in 1998-9. In Iran the currency was officially devalued in 2002, although the unofficial exchange rate had registered a sizeable depreciation already in 1999. Since 2002, the official exchange rate has depreciated steadily. For most of the period under study here, the authorities' main challenge has been to prevent overheating of the economies. In this, policy-makers have used both fiscal and monetary policies. Their task has been complicated by the external economic environment: as liquidity in the international capital markets increased abundantly so did capital inflows, especially into Kazakhstan and Russia.

As a result of rapid economic growth, all countries in our sample have seen their tax revenues increase. For the most part, the sizeable fiscal surpluses have been used to pay down public debt and set up sovereign wealth funds, which have invested fiscal surpluses in the international capital markets. However, the tightness of fiscal policy has varied across countries and over time. For example, in Iran fiscal policy was tightened considerably in 2007 after fiscal easing in 2005 and 2006. In Venezuela fiscal policy has been looser throughout the period under study.

As regards monetary and exchange rate policies the countries under review have behaved somewhat differently, although there are many similarities as well. Before their financial crises (August 1998 in Russia and April 1999 in Kazakhstan), both Russia and Kazakhstan used the nominal exchange rate as the nominal anchor - a common practice in the transition economies. However, especially in Russia fiscal policy was not compatible with the fixed exchange rate, and eventually the country was forced to allow the rouble to float and postpone its debt payments. Kazakhstan was forced to follow suit, because after the Russian devaluation its exports lost their competitiveness.

After abandoning the fixed exchange rate regime, Russia opted for a policy where the central bank and government agree on inflation targets, but there is also a publicly announced ceiling for appreciation of the real exchange rate (for a more detailed description of Russia's monetary policy regime, see Korhonen and Mehrotra, 2009). In addition, since

interbank markets do not yet function very efficiently, the Central Bank of Russia's main policy tool continues to be foreign currency intervention. These factors have led to a situation where the rouble's exchange rate has sometimes been rather tightly managed. In Kazakhstan, policy objectives have been somewhat more opaque, but the exchange rate against the US dollar was very stable between 2000 and 2004, after which it has been allowed to appreciate slightly. Therefore, both Russia and Kazakhstan can be said to manage their exchange rates fairly tightly, even though they are not officially pursuing a policy of fixed exchange rates.

Both Iran and Venezuela have maintained much tighter capital controls throughout the sample period than e.g. Russia and Kazakhstan. This allowed the official and market exchange rates in Iran to diverge considerably before 2002. Since then, the Iranian rial has followed a crawling peg, first against the US dollar, and from late 2007 against a basket of dollar, euro, and yen. During our sample period Venezuela went through several different exchange rate regimes. Before July 1996 it, like Iran, applied multiple exchange rates and extensive capital controls. From 1996 to 2002, Venezuela maintained an exchange rate band, whereas the currency was subject to a managed float in 2002 and 2003. Since 2003 there has been a peg to the US dollar.

All countries in our sample have maintained oil or stabilisation funds in the recent years. However, these have been relatively small until just recently (see e.g. Beck and Fidora, 2008). And the sizes differ considerably from one country to another. Therefore, the effect of stabilisation funds on the link between oil price and exchange rate has probably been relatively small during our sample period.

3 Brief literature survey

Our analysis is related to several strands of literature. In recent years a number of papers have estimated the effects of oil price shocks on different economies. However, most of these focus on countries that are net importers of energy products (see e.g. Kilian, 2008). Here, we are interested in energy exporting countries. In addition, there are a number of papers that focus on macroeconomic effects of oil price changes in Russia, as a rapidly developing transition economy. Our contribution has obvious links to these papers as well.

At least until recently, macroeconomists have viewed changes in the price of oil as an important source of economic fluctuations. However, there are several recent studies that indicate that the macroeconomic effects of oil price shocks have become less pronounced. Related to the more general effect of oil prices (as a proxy for energy prices in more general), one might mention Cologni and Manera (2008), who use a structural VAR to examine the effects of oil price shocks in G7 countries. They find that oil-price increases have a dampening effect on economic growth, but that the effect seems to mainly work via tighter monetary policy, as central banks try to prevent higher oil prices from feeding into general inflation. In a recent paper, Blanchard and Galí (2007) stress that the events of the past decade indicate that oil prices are not a significant source of economic fluctuations. They find at least four reasons for the milder effects on inflation and economic activity of the recent increase in the price of oil: (a) good luck (i.e. lack of concurrent adverse shocks), (b) smaller share of oil in production, (c) more flexible labour markets, and (d) improvements in monetary policy. Therefore, one might conclude that at least for developed countries the price of oil (and perhaps energy more generally) is not as important as it was a few decades ago.

Moving to somewhat less developed countries, Huang and Guo (2007) look at the effects of an oil price shock for an emerging market economy, more specifically China. They are interested in how the oil price impacts China's real exchange rate, and use a structural VAR methodology to study the relationship. They find that China's real effective exchange rate would actually appreciate as a result of a positive oil price shock. This result is apparently due to the fact that China's economy is less energy-intensive than those of its main trading partners. With an increase in the price of oil, China's GDP increases relative to its trading partners.

Closer to our analysis, there are a number of papers looking at the effects of oil price on oil-producing countries as well. Rautava (2004) develops a small VAR model to examine these dynamics in the Russian economy and shows that oil has played a significant role in movements of Russian GDP. Higher oil price leads to higher GDP, in both the short and long run. On the other hand, in the model, a higher oil price does not lead to a stronger real exchange rate, although the author conjectures that this may be because of the estimation strategy. Oomes and Kalcheva (2007) look at the factors affecting Russia's real exchange appreciation in a cointegration framework. They find that the oil price has a direct effect on the real effective exchange rate, and the elasticity of the real effective ex-

change rate with respect to the oil price is roughly 0.5, irrespective of the exact specification. Korhonen and Juurikkala (2009) investigate the effect of oil on real exchange rates in a sample of OPEC countries. In their panel cointegration framework, the estimated elasticity is again approximately 0.5. For another major oil producer, Norway, Bjornland (2004), using a structural vector autoregressive framework, shows that an oil price shock stimulates the economy temporarily but has no significant long-run impact. Price level effects are also found to be positive, but these are realised very slowly. The author finds no evidence to support the proposition that a major part of real exchange rate appreciation in Norway was driven by oil price shocks.

It should be noted that our contribution differs from the papers utilising cointegration methods. We for instance do not calculate the elasticity of real exchange rate with respect to oil price. The empirical framework requires that all variables be stationary in the estimated system and so the reduced form system consists of first-differenced variables. Importantly, the focus of the analysis is on the *relative* importance of oil price shocks with respect to the other structural shocks that we are able to identify within the chosen framework. In this sense, our paper is linked to studies that analyse shocks driving real exchange rate movements in an SVAR framework with long-run restrictions, such as Clarida and Galí (1994) for advanced economies, Hoffmaister and Roldós (2001) for Brazil and Korea, and Wang (2005) for China.

Our paper is also linked to those studies that analyse the possible asymmetric relationships between oil prices and macroeconomic variables, as we test the linear benchmark model against a smooth transition regression (STR) model. The latter allows the dynamics between variables to vary across regimes. Extending the results by Hamilton (1983), Mork (1989) showed that oil price increases do reduce economic growth in the US but that a fall in oil prices has a statistically insignificant impact on growth. Lee et al. (1995) find that the impact of an oil price change on aggregate output is greater in an environment where oil prices have been stable than in an environment of erratic energy prices. In the context of a multivariate threshold model for the US, Canada and Japan, Huang et al. (2005) argue that an oil price change has a larger impact on macroeconomic activity, once the change exceeds a certain threshold level.

Our paper is also related to the literature on the so-called resource curse. It is well-known in the literature that large rents from commodity exports can lead to sub-optimal economic outcomes in the medium and long run. In the short run the effect may still be

positive, often because fiscal policy is pro-cyclical. For example, Collier and Goderis (2007) provide evidence from oil price booms in African countries and find that in a vector error-correction framework higher oil prices are associated with higher GDP growth, but in the long run the correlation between GDP level and oil price is negative.

Based on this brief literature survey, one might expect that a positive oil price shock has a direct and positive effect on GDP in major oil producers, at least in the short run. However, the effect on the real exchange rate is not straightforward. Oil-producing countries may try to use the exchange rate as a policy instrument during oil booms, for example.

4 Theoretical framework

The theoretical model behind our empirics is a dynamic open economy Mundell-Fleming-Dornbusch model, augmented with an oil price variable, as in Huang and Guo (2007). The oil price enters the theoretical framework through the aggregate supply relation, and in the long run only oil price shocks are allowed to impact oil prices themselves. As detailed discussions of the model are already available in the literature, we only present the main features below. In the following, all variables except the world oil price are expressed as ratios of domestic variables to corresponding US variables, as in Clarida and Galí (1994).

The real oil price o_t , aggregate demand d_t and supply s_t as well as money m_t , are each assumed to follow an autonomous stochastic process:

$$o_t = o_{t-1} + \varepsilon^o \quad (1)$$

$$s_t = s_{t-1} + \varepsilon^s \quad (2)$$

$$d_t = d_{t-1} + \varepsilon^d \quad (3)$$

$$m_t = m_{t-1} + \varepsilon^m \quad (4)$$

The supply of output is determined by its own random walk process and the oil price as

$$y_s = s_t + \gamma o_t, \quad (5)$$

where γ denotes the inverse energy elasticity of output.

Demand for output is determined by its random walk process and the real exchange rate e_t as

$$y_t^d = d_t + \phi e_t \quad (6)$$

This can be considered an open economy IS equation, where domestic output (relative to foreign output) is increasing in the real exchange rate. As in Clarida and Galí (1994), we assume that d_t captures shocks to domestic relative to foreign absorption. In the goods market equilibrium, the following holds: $y_t^s = y_t^d = y$. We further assume a standard LM relation:

$$m_t = p_t + \delta y_t - \lambda i_t, \quad (7)$$

where the transactions demand for (real) money is increasing in output and decreasing in the rate of interest. Finally, there is an interest parity condition:

$$i_t = E_t(e_t). \quad (8)$$

Solving equations (1)-(8) yields:

$$\Delta o_t = \varepsilon_t^o \quad (9)$$

and

$$\Delta y_t = \gamma \varepsilon_t^o + \varepsilon_t^s \quad (10)$$

and

$$\Delta e_t = 1/\phi(\gamma \varepsilon_t^o + \varepsilon_t^s - \varepsilon_t^d) \quad (11)$$

Finally, using (7)-(11), we obtain the following expression for the change in price level:

$$\Delta p_t = \varepsilon_t^m + (-\delta + (\lambda/\phi))\varepsilon_t^s + (-\delta\gamma + (\lambda\gamma/\phi))\varepsilon_t^o - (\lambda/\phi)\varepsilon_t^d \quad (12)$$

From (9)-(12), we see that the relationships between structural shocks can be expressed in a triangular order. Namely, while oil price is determined solely by oil price shocks in the long run, the price level is determined by all four structural shocks in the long run. National (relative to foreign) output is affected by both supply shocks and oil price shocks in the long run, while the real exchange rate is determined by oil, demand and sup-

ply shocks. This allows us to fit the theoretical model to the data by utilizing structural vector autoregressions with Blanchard-Quah (1989) type long-run restrictions. These are discussed in the following section.

5 Methodology and data

The advantage of the SVAR approach is that the system dynamics can be easily investigated via impulse response analysis, and the statistical significance of the various shocks can be evaluated with confidence intervals. Moreover, the relative importance of stochastic shocks can be examined by forecast error variance decomposition. The different structural shocks are identified by means of long-run restrictions, whereby certain shocks are allowed to have long-run impacts on all or some of the system variables.

The following discussion on the SVAR approach relies to a large extent on Breitung et al. (2004). The starting point is a reduced form K -dimensional VAR model that can be written as:

$$x_t = A_1 x_{t-1} + \dots + A_p x_{t-p} + u_t. \quad (13)$$

In (13), x_t is a $(K \times 1)$ vector of endogenous variables. Our four system variables are real GDP (y_t), consumer price index (p_t), real exchange rate (e_t), and oil price (o_t). The A_i are fixed $(K \times K)$ coefficient matrices, and we assume that u_t follows a K -dimensional white noise process with $E(u_t) = 0$. Deterministic terms are omitted here for simplicity. While our focus is on the impacts of various structural shocks on real GDP and real exchange rate, these structural shocks are not directly observable. Hence, certain restrictions must be imposed in order to identify them from the data. A structural form representation of (14) is written as

$$Ax_t = A_1^* x_{t-1} + \dots + A_p^* x_{t-p} + B\varepsilon_t. \quad (15)$$

Here, the vector ε_t represents the structural shocks, i.e. supply shocks ε_t^s , demand shocks ε_t^d , monetary shocks ε_t^m , and oil price shocks ε_t^o . The structural shocks are assumed to be uncorrelated and orthogonal. The A_i^* 's ($i = 1, \dots, p$) are $(K \times K)$ coefficient matrices,

and B is a structural form parameter matrix. We note that the reduced form errors can be linked to the structural form disturbances through $u_t = A^{-1}B \varepsilon_t$. In general, the shocks to the system can be analysed in the framework of a Wold moving average representation:

$$x_t = \Phi_0 u_t + \Phi_1 u_{t-1} + \Phi_2 u_{t-2} + \dots, \quad (16)$$

where $\Phi_s = I_K$.

The $\Phi_0 = \sum_{j=1}^s \Phi_{s-j} A_j$ are computed recursively, given the A_j coefficients of the reduced form VAR, Eq. (13). Interpretation of the (a, b) th element of the matrices Φ_s is straightforward. It displays the response of $x_{at, t+s}$ to a unit change in x_{bt} . Thus the elements of Φ_s display the responses of endogenous variables x_t with respect to the u_t innovations.

Our focus on impacts of structural shocks is centred on their long-run effects on the system variables. These can be obtained from

$$\Phi = \sum_{s=0}^{\infty} \Phi_s = (I_K - A_1 - \dots - A_p)^{-1}. \quad (17)$$

The structure of the theoretical model allows us to examine the long-run impacts of the shocks by specifying a long-run impact matrix, Ψ , that is lower triangular. In such a matrix, all elements above the main diagonal are set to zero. Given the order of the variables in the reduced form VAR vector $x_t = [o_t, y_t, e_t, p_t]'$, the lower triangular form implies that no other shock is allowed to have a long-run impact on the world oil price. A permanent impact on output is allowed in the long-run for oil-price and supply shocks. The exchange rate can be affected in the long run by all the other structural shocks except a monetary shock, and we allow all the structural shocks to have a long-run impact on prices. All these restrictions are in line with the theoretical model specified in the previous section.

The impulse responses can be calculated by estimating the contemporaneous impact $C = A^{-1}B$. The long-run impact of structural shocks Ψ is obtained from $\Psi = \Phi C$, such that $\Psi \Psi' = \Phi \Sigma_u \Phi'$

$$(I_K - A_l - \dots - A_p)^{-1} \Sigma_u (I_K - A_l - \dots - A_p)^{-1}. \quad (18)$$

The lower triangular matrix Ψ can then be obtained from a Choleski decomposition of (18), and C is estimated by

$$\hat{C} = \hat{\Phi}^{-1} \hat{\Psi} = \hat{\Phi}^{-1} \text{chol} \left[\hat{\Phi} \hat{\Sigma}_u \hat{\Phi}' \right].$$

This procedure can be utilized only on condition that the VAR model is stationary. Evidence of this is provided in the section discussing the estimation of our system. The estimation samples are based on data availability as follows: Russia 1995Q2-2007Q1; Kazakhstan 1995Q2-2006Q4; Iran 1991Q2-2006Q4; Venezuela 1997Q2-2008Q1. While the relatively short samples weaken the statistical significance of the results, we feel they are long enough for inferences as to structural long-run shocks in these economies. Real oil prices are derived by deflating nominal oil prices by the US consumer price index. The data for oil, exchange rates and US variables are obtained from the IFS database. Other data series originate in the databases of the Russian and Kazakhstan central banks, and the Iranian and Venezuelan statistical offices. The time series for relative output and real exchange rate series – in relation to the US - as well as for oil price are depicted in Figures A.1 and A.2 in the appendix.

6 Estimation results

In order to evaluate the responses of output and real exchange rate to the various structural shocks in the four economies, we need a data-congruent reduced form VAR representation. The procedure presented in the previous section is estimable only when the underlying series are stationary. Consistently with previous studies utilizing an identical methodology, we include all series in first differences in the estimated system. This is also consistent with our theoretical model; we are not interested in potential cointegration between the time series. The stationarity of the first-differenced series is confirmed by the standard augmented Dickey-Fuller (ADF) test. Specifically, when a constant is included as a deterministic term, the null hypothesis of unit root can be rejected for all series for Kazakhstan,

Iran and world oil price at least at the 5% level.³ For Venezuela, a unit root can be rejected at least at the 5% level for all other series except the real exchange rate (10% level). For Russia, we reject the null hypothesis of unit root for both prices and the real exchange rate, although for the latter variable only at the 10% level. Due to the drop in output induced by the Russian crisis, a standard ADF test for GDP does not reject the null of unit root for this series. It is likely that the break point caused by the crisis renders the standard unit root test unreliable. Indeed, when a unit root test with a structural break is used instead, as suggested by Lanne et al. (2002), the null hypothesis of unit root for GDP is rejected even at the 1% level.⁴ We therefore continue on the assumption that all the series in first-differenced form are stationary.

Next, we estimate the reduced form VAR for our four oil producing countries, recalling that the vector of endogenous variables is written as $x_t = [o_t, y_t, e_t, p_t]'$. Ordering of the variables is dictated by our theoretical model; any other ordering would render the interpretation of results very difficult. The models are estimated with 3 lags, which is reasonable for first-differenced series of quarterly data. A constant is included as a deterministic term for all economies, corresponding to a trend in levels-form data. Due to the inclusion of the Russian crisis in the estimation sample, we need to include three dummy variables in the estimated system – two for removing the immediate impacts of the crisis and the remaining one to deal with a further residual outlier. For Iran, Kazakhstan and Venezuela, various dummies are similarly included in the estimated systems in order to remove residual outliers.⁵

Testing for residual autocorrelation in higher lag orders by the standard Portmanteau test and for ARCH effects (16 lags utilized in both tests) suggests that the models are satisfactory representations of the data, as the p -values for both tests never fall below 0.05. However, evidence of autocorrelation in lower lag orders is detected for Venezuela when the LM-F test with 1 lag is utilized. Stability tests are also of interest, given that these economies are undergoing structural change, which could theoretically make the dynamics between the endogenous variables unstable. Due to the short sample, we are able to utilize

³ This result is robust to using either the Akaike, Hannan-Quinn, or Schwarz criteria to determine lag length.

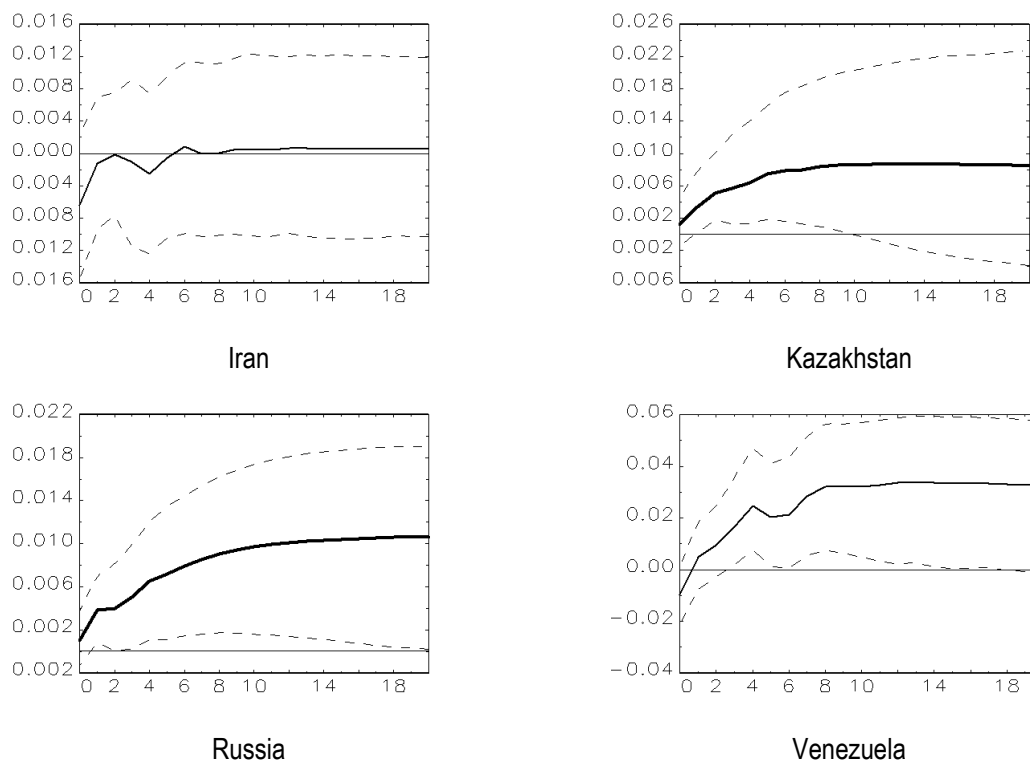
⁴ In the test by Lanne et al. (2002), we include an impulse dummy variable that takes the value one in 1998Q3 and zero otherwise.

⁵ In the case of Russia, the impulse dummies take the value one for 1998Q1, 1998Q3 and 1998Q4. For Kazakhstan, the dummy variables take the value one for 1998Q3 and 1999Q2. For Iran, we use a shift dummy that takes the value one for 2002Q1-2002Q2. In the case of Venezuela, impulse dummies take the value one in 2002Q3 and 2003Q2. For all other periods, the dummies take the value zero.

the Chow forecast test to search for a structural break for each observation during 2000Q4-2006Q3 for Kazakhstan, 2000Q4-2005Q1 for Iran, 2001Q1-2006Q4 for Russia, and 2002Q3-2007Q4 for Venezuela. We utilize bootstrapped p -values, as suggested by Candelon and Lütkepohl (2001), with 1,000 replications. Parameter stability cannot be rejected for any tested date at the 5% level for Russia, Iran or Kazakhstan. However, for Venezuela, p -values below 0.05 are detected for various different break dates, which advises caution in interpreting the results for this economy.

We investigate the effects of the various structural shocks via structural form impulse response analysis. We commence by looking at the impact of a positive oil price shock on domestic output in the four economies, depicted in Figure 1. The Hall 90% percentile bootstrapped confidence intervals are used in the analysis, computed with 1,000 replications. The level of GDP increases as a result of an oil price shock for all the countries except Iran. This is expected, as a positive shock to oil price represents a positive supply shock for a major oil-producing economy. It induces an increase in incomes and wealth and supports consumption, given a constant propensity to consumption from income and wealth. It should be noted that if we used data from several decades, the long-run GDP response could of course be negative, which would be consistent with the resource curse hypothesis.

The impacts of all the structural shocks on GDP are illustrated in Figure A.3 in the appendix. Consistently with theory and the restrictions imposed in the structural model, a supply shock leads to a permanent impact on the level of GDP in all economies. An anomaly is the impact of a demand shock on GDP in Kazakhstan, as real GDP falls. In Clarida and Galí (1994), positive money shocks lead to higher relative output, as is clearly the case in both Kazakhstan and Russia.

Figure 1. Effects of a positive oil price shock on GDP

Regarding the effects of a positive oil price shock on the real exchange rate in Figure 2, for Iran and Venezuela we obtain an appreciation in the real exchange rate. This impact could work *via* domestic pricing, whereby an increase in incomes and wealth in an oil-producing country puts upward pressure on domestic prices, especially through the increased demand for non-tradeables. This effect could work through pro-cyclical fiscal policy.⁶ Moreover, if a country improves its net foreign asset position through the accumulation of fiscal surpluses, its debt servicing costs fall. Lower debt servicing costs reduce the need to export, which enables appreciation of the real exchange rate. However, the impacts on the real exchange rate are not statistically significant for Kazakhstan or Russia. As these two economies have maintained discretion with regard to the level of the nominal exchange rate, one would expect oil-price induced price increases to result in real exchange rate appreciation. However, the real exchange rate may be a poor indicator of domestic price pressures, as

⁶ Since we do not have quarterly fiscal data for all the countries, we cannot directly control for the countries' fiscal stance in the estimations.

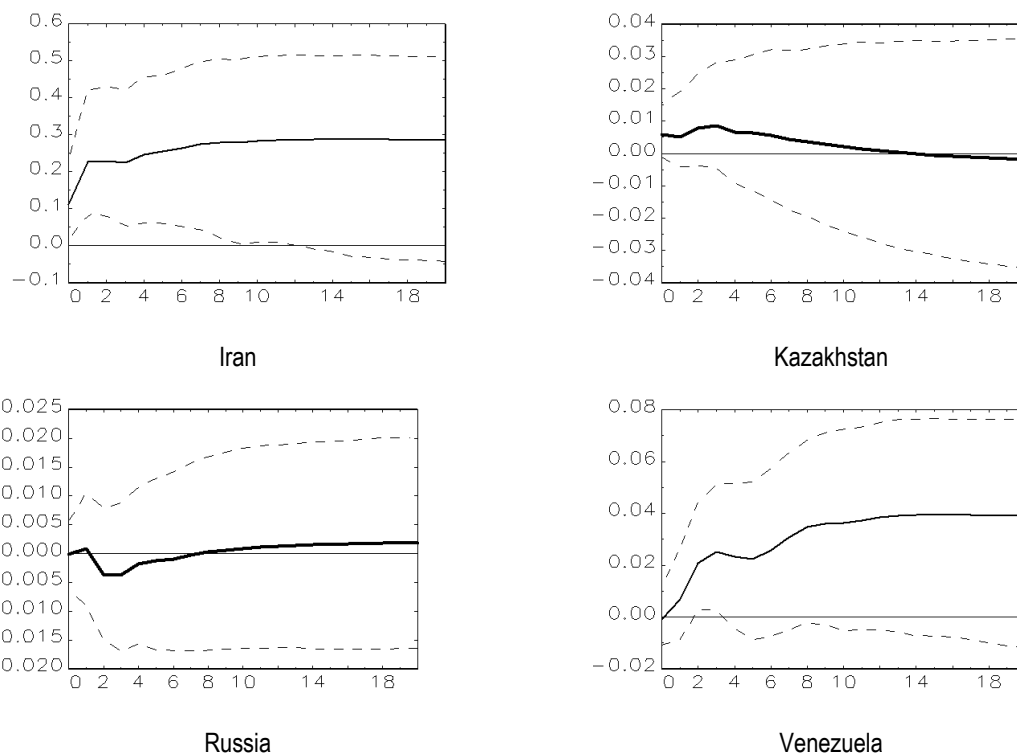
e.g. in Russia food prices carry a weight of 40% in the CPI.⁷ Similarly, after the financial crises of 1998/1999, fiscal tightening across the board may have eased appreciation pressures in Kazakhstan and Russia – in contrast to the more lax policies pursued in Iran and Venezuela.

The impacts of all structural shocks on the real exchange rate are depicted in Figure A.4 in the appendix. In all economies, in our model specification, a demand shock leads to an appreciation of the real exchange rate. As a supply shock should lead to a fall in the price of home country output, the real exchange rate should depreciate, which is indeed what we observe for Iran and Russia. For Kazakhstan and Venezuela, the impact is positive and at odds with the theoretical model.⁸

⁷ This result contrasts with the rouble depreciation pressure that emerged in autumn 2008. However, the recent depreciation is likely due to several different factors, e.g. significant investor risk aversion, leading to capital flight from most emerging markets.

⁸ The appreciation resulting from a supply shock is in line with the finding by Clarida and Galí (1994) for Germany (variables also expressed in relation to US) and the UK.

Figure 2 Effects of a positive oil price shock on the real exchange rate



Next, we look at the importance of different structural shocks in explaining movements in output and real exchange rate, using forecast error variance decomposition. Our interest is in examining the share of various shocks in movements of these variables when a specified number of quarters have passed since the shock. Table 1 shows that for all four economies an overwhelming share of output movements is explained by supply shocks. This is perhaps not surprising given the transitional nature of Russia and Kazakhstan and the possibility that labour productivity and technological innovations are important drivers of output in the catching-up process of all four countries. This result accords with Wang (2005) for China, Ahmed (2003) for Latin American economies, and Hoffmaister and Roldós (2001) for Korea, even though none of these authors include oil prices in their model. Oil price shocks are important structural innovations for output growth, especially in Venezuela but also in Russia, which is consistent with the statistically significant impact obtained in the impulse response analysis. In contrast, they do not appear to be very important for Iran or Kazakhstan. The quantitative importance of oil price shocks for output in the long run for

these countries is interestingly close to the finding of Bjornland (2004) for oil-producing Norway.

Table 1 Importance of structural shocks for domestic output

Horizon	Iran			
	Oil	Supply	Demand	Monetary
1	0.04	0.80	0.15	0.02
5	0.05	0.74	0.19	0.03
10	0.05	0.73	0.19	0.03
20	0.05	0.73	0.19	0.03
	Kazakhstan			
	Oil	Supply	Demand	Monetary
1	0.02	0.58	0.21	0.20
5	0.08	0.59	0.17	0.15
10	0.09	0.59	0.17	0.15
20	0.09	0.60	0.17	0.15
	Russia			
	Oil	Supply	Demand	Monetary
1	0.01	0.90	0.00	0.08
5	0.14	0.78	0.01	0.08
10	0.15	0.77	0.01	0.08
20	0.15	0.77	0.01	0.07
	Venezuela			
	Oil	Supply	Demand	Monetary
1	0.08	0.89	0.03	0.00
5	0.20	0.50	0.13	0.16
10	0.21	0.46	0.17	0.16
20	0.21	0.46	0.17	0.16

Table 2 Importance of structural shocks for real exchange rate against US dollar

Horizon	Iran			
	Oil	Supply	Demand	Monetary
1	0.12	0.14	0.73	0.01
5	0.19	0.12	0.69	0.01
10	0.19	0.12	0.68	0.01
20	0.19	0.12	0.68	0.01
	Kazakhstan			
	Oil	Supply	Demand	Monetary
1	0.04	0.10	0.78	0.07
5	0.04	0.14	0.68	0.13
10	0.04	0.17	0.65	0.14
20	0.05	0.17	0.65	0.14
	Russia			
	Oil	Supply	Demand	Monetary
1	0.00	0.06	0.93	0.02
5	0.03	0.08	0.88	0.02
10	0.03	0.08	0.87	0.02
20	0.03	0.08	0.87	0.02
	Venezuela			
	Oil	Supply	Demand	Monetary
1	0.00	0.07	0.67	0.26
5	0.09	0.10	0.51	0.29
10	0.11	0.11	0.50	0.29
20	0.11	0.11	0.50	0.29

Turning to the importance of structural shocks for the real exchange rate, demand shocks turn out to rank high for all the economies. In Russia, they account for roughly 90% of movements in the real exchange rate. Only for Iran and Venezuela do oil price shocks account for a notable share of movements of the real exchange rate, in line with their statistical significance in the impulse response setup. In Kazakhstan and Russia, oil shocks are of little importance for movements in the exchange rate. In Iran and Russia - where supply shocks lead to exchange rate depreciation, albeit with modest statistical significance – the share of supply shocks for exchange rate movements is roughly 10%. Together, the importance of supply shocks for exchange rate fluctuations is found to be smaller and that of demand shocks larger than for two other emerging economies, Korea and Brazil, studied in Hoffmaister and Roldós (2001).

It is of interest to examine the robustness of earlier results on real exchange rate determination by estimating the SVAR system without the oil price variable, but maintaining the same variable ordering. In this case, we can directly compare our results to Clarida

and Galí (1994) and Wang (2005), as our model is a direct extension of their trivariate system. The results are shown in Table A.1. in the appendix. Importance of demand shocks remains robust, although for Iran the importance of both supply and monetary shocks increases – the former possibly because an oil price shock also represents a positive supply shock for a major oil-producing economy. For Venezuela, the importance of monetary shocks increases when oil prices are not included. The main general difference between our results and those for the advanced economies (Germany, Japan, Britain, Canada) studied in Clarida and Galí (1994) is that we find supply shocks to be more important for exchange rate determination. This is echoed in the results by Wang (2005) for China, where structural reforms have played a major role in boosting productivity.

Recent literature has emphasized the possible nonlinearity between oil price shocks and real GDP. In particular, the effects may differ depending on the level of oil prices. We investigate possible non-linearity in the system by testing our linear model against a smooth transition regression (STR) model. The STR models include processes where the dynamics between the variables vary across regimes and the transition from one regime to the other is modeled as smooth by a logistic transition function. An LSTR1 model describes processes where the dynamics differ between regimes 1 and 2. In the context of an oil producing country, a large change in the world oil price may be more conducive to investment and growth (possibly in raw material extracting industries) than a minor change that may be expected to be quickly reversed. In an LSTR2 model, the dynamics are similar for small and large values of the transition variable, and different in the middle. Such a scenario is less intuitive, but in an environment of very erratic oil prices, companies may find it difficult to compute profit-maximizing levels of output and therefore postpone their investments while a small change in oil prices is again expected to be reversed, similarly dampening further investment.

We examine non-linearity in the equation for real GDP of the reduced form VAR model. Further, we select oil price as the transition variable between the regimes, assuming that the impact on real GDP depends on the dynamics of this variable. Since matrix inversion problems in the testing procedure can be avoided by omitting variables from the non-linear part, we omit the dummy variables, the real exchange rate and prices, given that the focus of the linearity tests is centred on real GDP and oil. The testing sequence is explained in detail in Teräsvirta (2004), while p -values from the tests are shown in the appendix. In the tests, we are not able to reject the null hypothesis of linearity for Iran, Kazakhstan or Russia. For Venezuela, evidence of non-linearity is detected in the sense that a linear model is rejected in the favour of a logistic smooth transition regression (LSTR1 or

LSTR2, depending on which lag of oil prices is used as the transition variable). This suggests that alternative modelling techniques that take non-linearity explicitly into account could be used. The actual estimation of an STR model is not feasible in our sample for Venezuela, due to a lack of observations. Nevertheless, in our view the possibility to conduct linearity tests *against* an STR model justify the use of this technique, as the latter model allows for regime-dependent dynamics, similarly to Huang et al. (2005).

We note that while these results enable evaluation of the different shocks' importance on output and the real exchange rate, these are probably conditional on the policy regime in the estimation period and the structure of the economy. While the SVAR model is theory-based, the shocks are based on estimation of a reduced form system, which may not be policy invariant. Thus the Lucas critique may be important, quantitatively and qualitatively, if the results are used to derive the future policy implications for the four oil producers.

7 Discussion and concluding remarks

In this paper we have estimated structural vector autoregressive models for four major oil-producing countries: Iran, Kazakhstan, Russia and Venezuela. In these four-variable models, we included the oil price, in addition to domestic GDP, prices and real exchange rate, which allows us to determine the effects of oil price shocks.

We find that a positive shock to real oil prices leads to an appreciation of the real exchange rate only in Iran and Venezuela. Oil price shocks explain only a relatively small portion of the forecast error variance in the real exchange rate, and especially in Kazakhstan and Russia their role is negligible. In all the countries demand shocks explain the majority of exchange rate variation, which accords with previous studies examining the determinants of exchange rate fluctuations in other economies. As expected, oil price shocks have a positive and statistically significant effect on GDP, with the exception of Iran. The share of oil price shocks in explaining GDP movements is highest in Russia and Venezuela. Nevertheless, supply shocks are much more important sources of shocks for output movements, possibly reflecting the on-going structural changes in all four economies.

To summarise, the empirical results from the estimated models allow us to draw some policy conclusions. For the real exchange rate, the direct influence of oil shocks is limited, especially for Kazakhstan and Russia. Structural demand shocks account for the majority of forecast error variance in the real exchange rate. This may be because of the importance of fiscal policy during the period. During our sample period the oil price has also had a smaller effect on output developments than perhaps previously thought. Supply shocks – which can in this connection be perhaps interpreted as productivity improvements in catching-up economies – are able to explain the majority of forecast error variance in GDP.

As linearity tests produce some evidence of non-linearity for Venezuela, future research could benefit from an estimation of a threshold model or a smooth transition regression for this economy, allowing for explicit modelling of the asymmetric relationships between oil prices and economic activity. Such a task could be feasible with higher frequency data for output, perhaps in the form of industrial production.

Finally, our results are of course subject to the Lucas critique. If any of the countries were to change its exchange rate regime, the estimated results might not be valid. At least in Russia the central bank seeks to move towards inflation targeting. In this connection, relatively tight management of the nominal exchange rate could be incompatible with the chosen regime. Somewhat paradoxically, this could very well strengthen the oil-shock effect on the real exchange rate, as the central bank would rely less on sterilisation of export revenues and capital inflows.

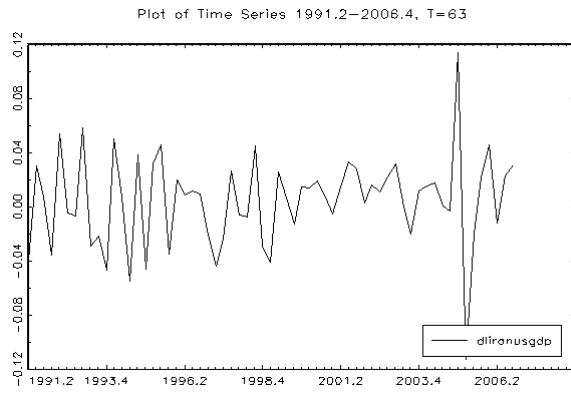
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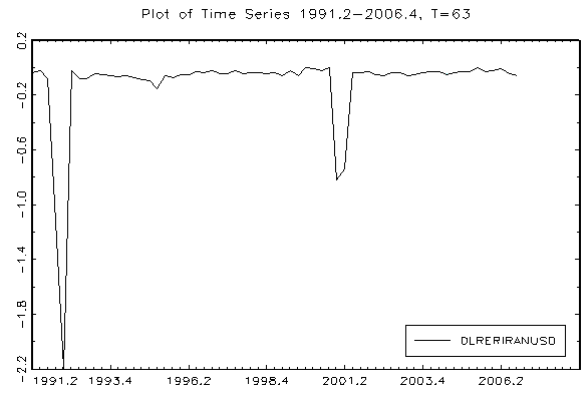
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Appendix

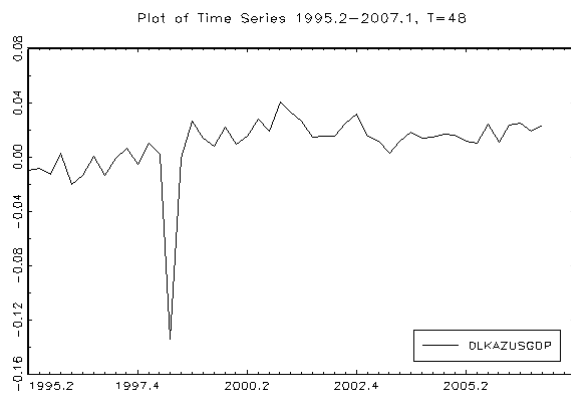
Figure A.1 First differences of relative output and real exchange rate



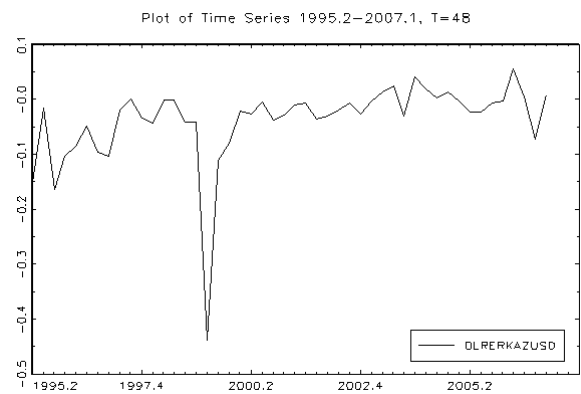
Iran-US GDP



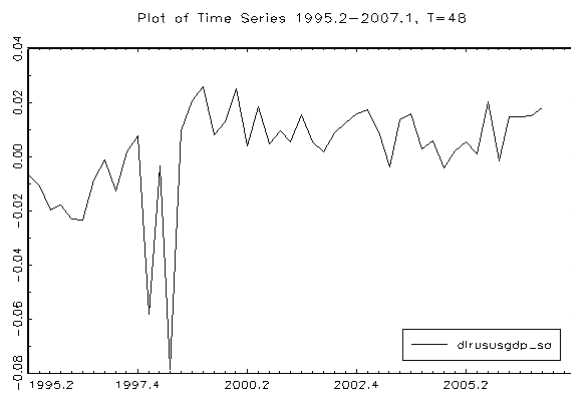
Iran-US real exchange rate



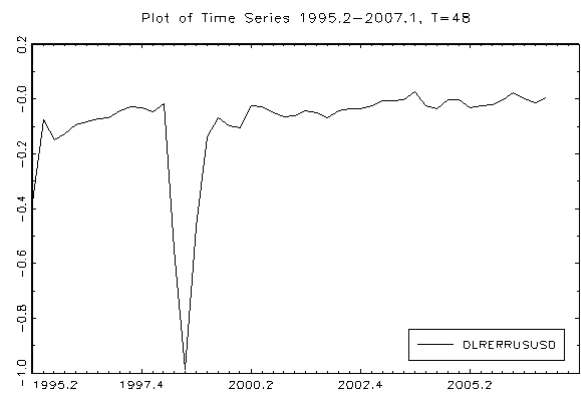
Kazakhstan-US GDP



Kazakhstan-US real exchange rate



Russia-US GDP



Russia-US real exchange rate

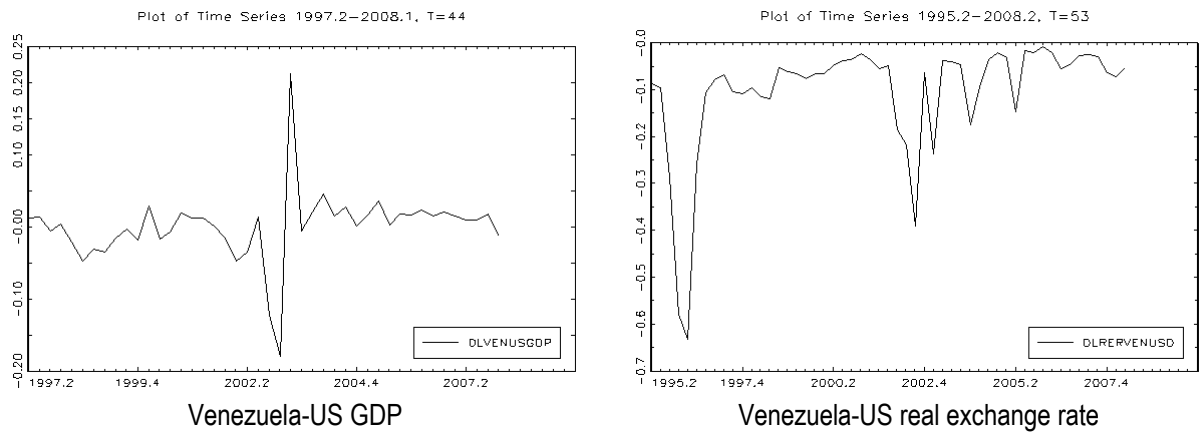
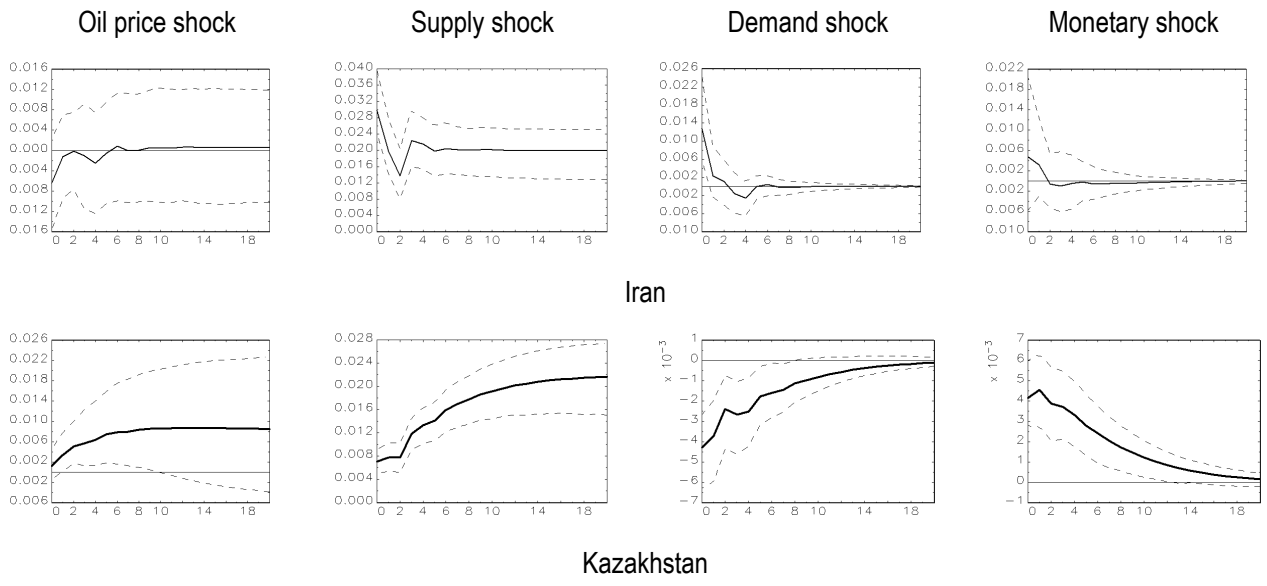
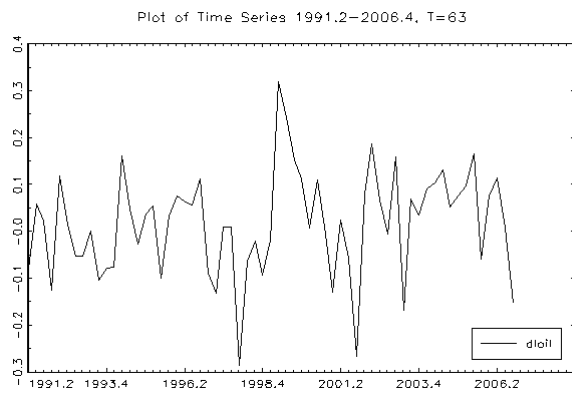


Figure A.2 First difference of real oil price



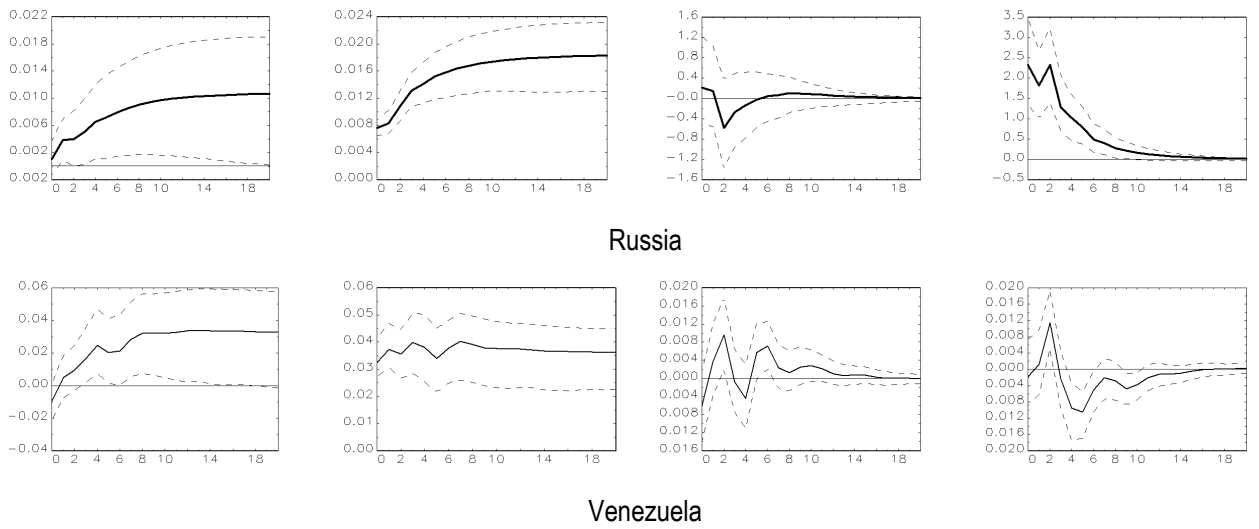


Figure A.3. Effects of structural shocks on GDP

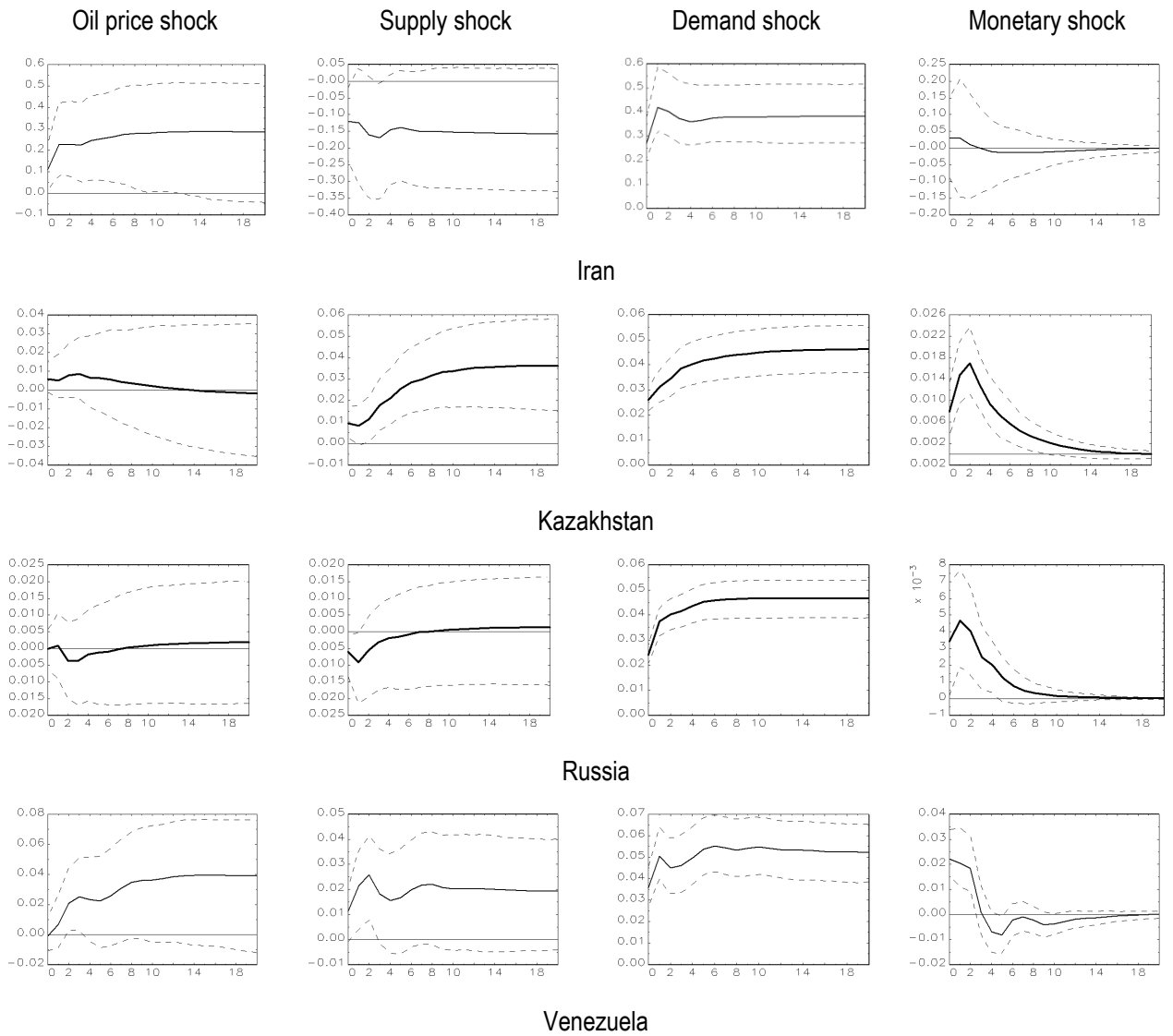


Figure A.4 Effects of structural shocks on real exchange rate

p-values of linearity tests

Kazakhstan			
Transition variable			
Hypothesis	Δoil_{t-1}	Δoil_{t-2}	Δoil_{t-3}
H ₀	0.18	0.10	0.80
H ₀₄	0.29	0.13	0.87
H ₀₃	0.77	0.10	0.67
H ₀₂	0.02	0.64	0.26

Russia			
Transition variable			
Hypothesis	Δoil_{t-1}	Δoil_{t-2}	Δoil_{t-3}
H ₀	0.51	0.41	0.82
H ₀₄	0.45	0.24	0.93
H ₀₃	0.81	0.57	0.49
H ₀₂	0.16	0.58	0.36

Venezuela			
Transition variable			
Hypothesis	Δoil_{t-1}	Δoil_{t-2}	Δoil_{t-3}
H ₀	0.00	0.03	0.26
H ₀₄	0.01	0.34	0.20
H ₀₃	0.00	0.01	0.48
H ₀₂	0.00	0.14	0.37

Iran			
Transition variable			
Hypothesis	Δoil_{t-1}	Δoil_{t-2}	Δoil_{t-3}
H ₀	0.30	0.96	0.67
H ₀₄	0.19	0.74	0.53
H ₀₃	0.33	0.74	0.80
H ₀₂	0.65	0.95	0.33

Note: see Teräsvirta (2004) for details of the testing sequence. Values in bold indicate that the null hypothesis of linearity can be rejected.

Table A.1 Importance of structural shocks for real exchange rate, omitting oil price

Horizon	Iran		
	Supply	Demand	Monetary
1	0.29	0.61	0.11
5	0.42	0.49	0.10
10	0.43	0.48	0.10
20	0.43	0.48	0.10
Kazakhstan			
	Kazakhstan		
	Supply	Demand	Monetary
1	0.11	0.83	0.06
5	0.15	0.73	0.12
10	0.17	0.70	0.13
20	0.17	0.70	0.13
Russia			
	Russia		
	Supply	Demand	Monetary
1	0.09	0.87	0.04
5	0.08	0.88	0.04
10	0.08	0.88	0.04
20	0.08	0.88	0.04
Venezuela			
	Venezuela		
	Supply	Demand	Monetary
1	0.10	0.49	0.41
5	0.14	0.39	0.47
10	0.15	0.38	0.47
20	0.15	0.38	0.47

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Bank of Finland
BOFIT – Institute for Economies in Transition
PO Box 160
FIN-00101 Helsinki

 + 358 10 831 2268

bofit@bof.fi

<http://www.bof.fi/bofit>