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Oil dependency of the Russian economy: an econometric analysis

Abstract:
A macro econometric model of the Russian economy is developed, containing 13 estimated equations – covering major national account variables, government expenditures and revenues, interest rates, prices and the labour market. The model is tailored to analyze effects of changes in the oil price and economic policy variables. The model has good statistical properties and tracks history well over the estimation period, which runs from 1995Q1 to 2008Q1. Model simulations indicate that the Russian economy is vulnerable to large fluctuations in the oil price, but we also find evidence of significant economic growth capabilities in the absence of oil price growth.

Keywords: Russia, macro econometric model, oil price dependency, fiscal and monetary policy

JEL classification: C51, E17, E52, E63, Q43

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1. Introduction

The impact of higher oil prices on the Russian economy has some features that are similar to the effects in any oil consuming country. End user prices on energy increase, leading to substitution and income effects for non-oil producers and consumers. In general the macroeconomic impact is lower GDP and higher inflation. The magnitude of these effects depends on the policy response of the authorities including monetary and fiscal policy measures. However, in an oil and gas producing country such as Russia there will be additional positive income effects due to higher national income through positive terms of trade effects. One could also expect a direct effect of the oil price on investments in the domestic petroleum sector, with second round effects through demand for input directed towards other parts of the economy.

In earlier, model based analyses of the Russian economy, computable general equilibrium (CGE) models have often been applied. There is a number of studies that use CGE models of the Russian economy to assess impacts of trade policy options such as EU enlargement, Russia's WTO accession and the creation of the Common European Economic Space on Russian economy; see e.g. Jensen et al. (2004), Rutherford et al. (2005), Alekseev et al. (2003), Sulamaa and Widgren (2004). BOFIT (Bank of Finland, Institute for Economies in Transition) used a multiregional general equilibrium model GTAP (Global Trade Analysis Project modelling framework) to study impacts of Russian energy policy instruments on the Russian economy (Kerkelä 2004). The Central Bank of the Russian Federation (CBR) has a model framework closely related to the BOFIT models.

CGE models are handy when modelling economies for which time series data are scarce, and are thus often applied on developing economies. In such models, strong, theoretical assumptions replace historical evidence.

Empirical modelling constitutes a reality check on theory based assumptions. Data for macroeconomic variables are now available for a sufficient time period and of satisfactory quality to make possible the development of an empirical model of the Russian economy with desirable theoretical as well as statistical properties. In our view there remains a need for empirically based modelling of the Russian economy, of which we have found only a few attempts in the literature. BOFIT has developed a vector autoregressive (VAR) model for the Russian economy (see Rautava, 2004), which is used for forecasting. Suni (2007) utilises the global NiGEM model developed by the National Institute of Economic and Social Research which includes a simple representation of the Russian economy, to assess the oil price dependency of the Russian economy. Merlevede et al. (2009) estimate a somewhat more detailed macro econometric model of the Russian economy with the same purpose. Both papers find evidence for significant oil price dependency.

We develop a macro econometric model of the Russian economy, containing 13 estimated equations – covering major national account variables, prices, the exchange rate, the money market interest rate and the labour market – and a number of identities. The model includes important channels through which petroleum income affects the Russian economy. Direct effects are identified through oil exports, domestic inflation and government expenditure end revenue, and there are several indirect channels. Due to lack of sufficient data for petroleum investments, we have not been able to test the presence of a direct link from oil prices to petroleum investments explicitly in our model. Indirect effects of the oil price on petroleum investments are implicitly covered in the aggregate investment function. Furthermore, the model incorporates reaction functions for Russian fiscal and monetary policy. This provides us with the option of leaving economic policy endogenous, based on the estimated behaviour of fiscal and monetary authorities.

In the model, increasing oil prices lead to higher growth in government revenues than in government expenditure, introducing a stabilizing element to the economy, as well as means to be channelled into the Government controlled Reserve Fund and National Welfare Fund. In line with the Dutch disease hypothesis[1], an increase in the oil price yields a real appreciation of the rouble in the model, leading to reduced non-oil exports.

Although the CBR's main tool conducting monetary policy has been to provide the economy with sufficient liquidity with concern to inflation and the exchange rate, we find evidence for a "lean against the wind" interest rate equation, where interest rates increase in the face of higher inflation and lower unemployment. We find no direct effects of the interest rate on household consumption or private investments. However, the interest rate affects non-oil exports through the exchange rate in the model, reinforcing the Dutch disease effect: Increasing inflation is met by higher interest rates, leading to a stronger rouble. Thus, rising interest rates deal non-oil export industries a double blow, through increasing inflation and a stronger rouble.

[1] The Dutch disease hypothesis states that an increase in revenues from natural resources will lead to deindustrialisation by raising the exchange rate, and thus making the manufacturing sector less competitive. The term was introduced by The Economist in 1977 to illustrate the decline of the Dutch manufacturing sector following the discovery of large natural gas resources in the Netherlands in 1959. See for instance Wijnbergen (1984).

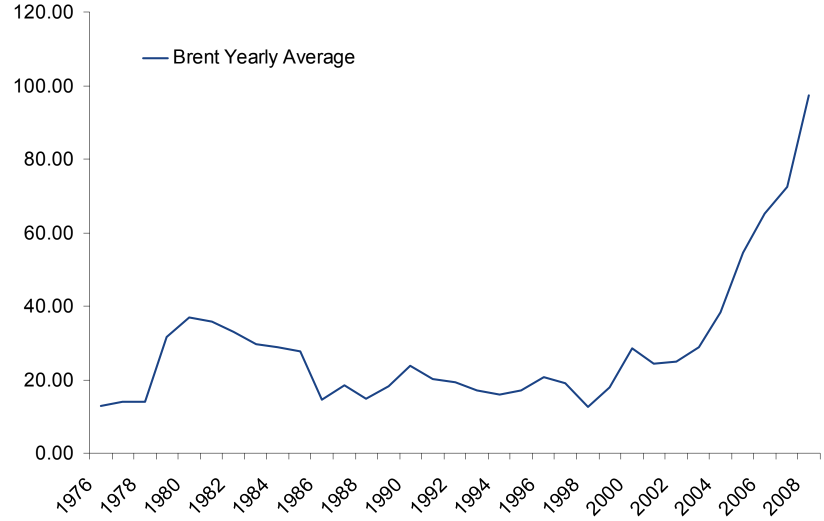
The estimation period runs from 1995Q1 to 2008Q1. The estimated equations are interpretable in accordance with economic theory, and satisfy standard statistical tests of residual properties and parameter stability. The model facilitates analyses of effects of changes in a number of central macro variables, such as economic policy variables, the exchange rate, international demand and prices – including the oil price. Model simulations suggest an important role for the oil price in the Russian economy and imply vulnerability to negative shocks in the oil price. However, we also find indications that the Russian economy exhibits significant growth capabilities in the absence of growth in the oil price.

The outline of the paper is as follows: There is a brief description of vital aspects of the oil market and its importance to the Russian economy in section 0. In section 0 there is a general introduction to the model, followed by a discussion of the econometric equations and central identities in section 0. Section 0 also presents data sources, explains estimation procedures and presents results of the empirical investigations. In section 0 there is an evaluation of overall model performance, while section 2 documents model simulations with two counterfactual scenarios for the oil price. Section 3 contains a discussion of possible extensions and modifications of the model, and concludes on the major findings of the analysis.

2. The Russian oil economy

Following the collapse of the Soviet Union, Russia engaged in an ambitious shock therapy privatization program under IMF guidance. Broken down supply chains, withdrawal of government demand and uncompetitive production led to widespread industrial insolvency and a collapse in government tax revenue. This, coupled with low oil prices and an IMF devised plan of pegging the rouble to counter inflation, led the government to accumulate large foreign loans in an attempt to offset capital outflows and cover the increasing budget deficit. The setup could not last and in 1998 the government defaulted on its foreign payments, floated the rouble and introduced capital restrictions. Departure from the artificially strong rouble gave Russian enterprises a chance to recover and in 1999 positive growth rates returned. For nine consecutive years, Russia stayed on a steady growth path, see Figure 2.2, until the global recession in 2009.

Figure 2.1: Brent Nominal USD/bbl. 1976-2009[2]



Source: EIA

The importance of oil exports to Russia's economic development is a matter of much discussion. The breakup of the Soviet Union was preceded by an abrupt fall in nominal crude prices in early 1986, from an average of USD 33 in the first half of the 1980s to hovering around USD 16 USD in the second half. Gaidar (2007), among others, claims that the drop in oil revenues was the prime trigger of the Soviet collapse. In more recent times, the economic boom of Putin's presidency with average annual GDP growth in excess of 7 per cent, has been accompanied by a substantial increase in oil prices. While the 2009 slump was preceded by a USD 100 drop in the oil price from July 2008 to January 2009, one should be careful to expect similar effects of oil price volatility today as those experienced by the Soviet Union. For the Soviet economy hard currency oil income was the main remedy against systemic flaws that were making the socialist economy increasingly infeasible.

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[2] The correct reference price for Russian exports would be the price of the Urals grade. However, since Urals time series are not readily available for the desired time period and at desired frequency we have chosen Brent as an acceptable proxy. Due to higher sulfur levels Urals is generally traded a couple of USD below Brent.

Figure 2.2: Russian Real GDP Growth and Inflation 1993-2009

Note: Numbers for 2009 are estimates of April 2009
Source: IMF WEO

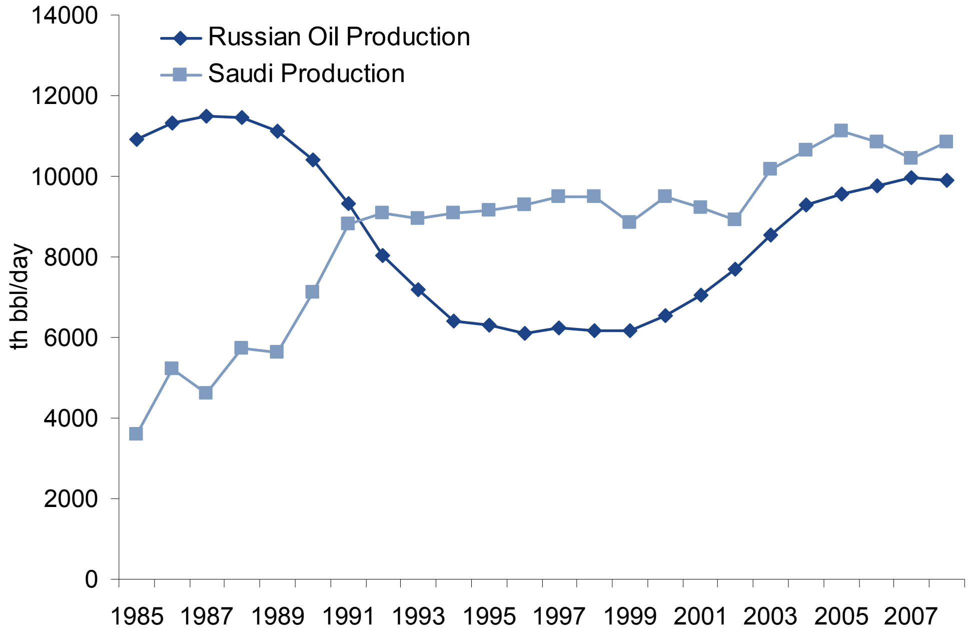
Russia ranks as the world's second largest oil producer, occasionally creeping up on Saudi Arabia in export volumes. The country's production reached a temporary post-communism peak in 2007, totalling almost 10 million bbl/day. It has been argued that mature Russian provinces are past their 'peak oil' production and that production from now on will steadily decline, or at best be maintained if new provinces are developed, cf. Jackson and Razak (2008).

In September 2009, however, Russia reached a new record level of oil production averaging 10 million bbl/day, surpassing Saudi Arabia as the world's largest oil producer.[3] In early 2009, Russian exports surpassed Saudi Arabia's 7 million bbl/day, reaching 7.4.

Russia's production decreased during the price hike of 2008 but reached new record levels under relatively modest prices in 2009. Rather than coordinating cuts with OPEC, Russia has eaten into OPEC market shares following OPEC cutbacks. Unless the OPEC capacity contracts sharply or OPEC–Russian relations develop significantly, Russia is best viewed as a price taker in today's oil markets.

[3] http://www.oilexp.ru/news/russian_rinok/rossiya-postavila-novyj-rekord-dobychi-nefti/29723/

Figure 2.3 Russian and Saudi Historic Oil Production



Source: BP, 2008

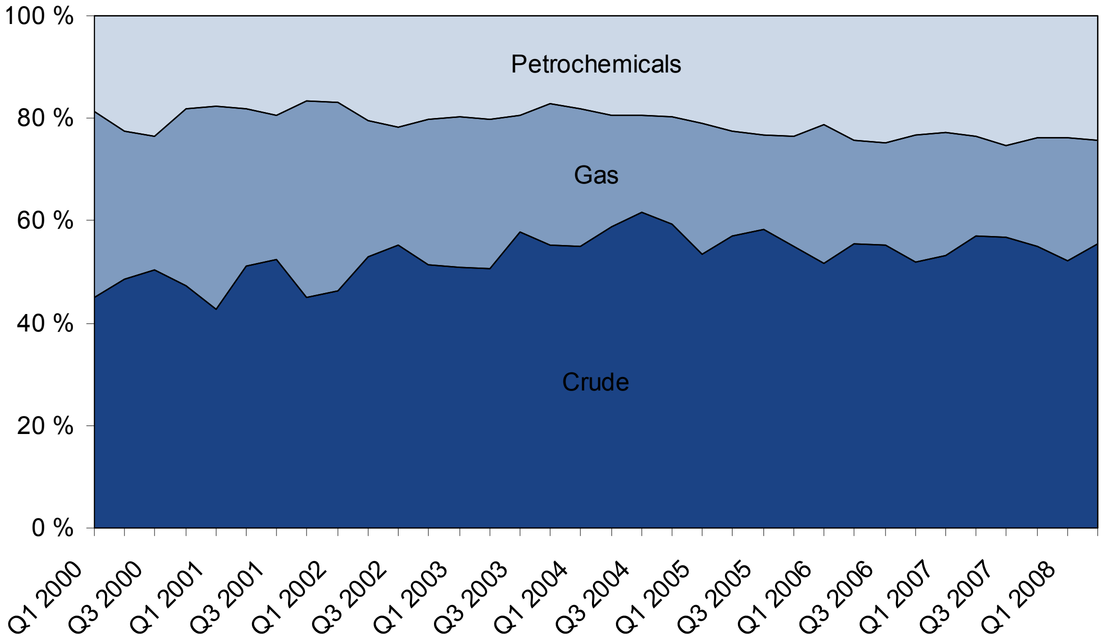
Russia exports a significant amount of natural gas as well as petrochemical products in addition to crude oil. The slight increase in petrochemicals' contribution to hydrocarbon export value seen in Figure 2.4 is a response to Russian policy of increased domestic processing. Gas has reduced its share compared to crude. This can be explained by the fact that gas production (and hence exports) remained relatively stable throughout the 90s and therefore has not seen the same rebound as crude production. With crude production at a perceived peak, one might expect the importance of gas to increase in the years to come. The impact from gas and petrochemical exports on the Russian economy is likely to be analogous to that of oil prices as gas and petrochemical prices remain indexed to oil prices.

Although global interest is mostly directed towards Russia's role as an energy exporter, Russia is also a significant consumer. Whereas Russia's gas market is characterized by low, regulated domestic prices, price formation in the oil market was liberalized in the 90s. Domestic oil prices therefore reflect changes in world prices despite distortions arising from regional monopolistic market structures.[4] Rising oil prices can therefore be expected to entail the usual negative effects on domestic consumption, non-oil output and more, as described in the introduction. Gas has been exempted from

[4] http://www.fas.gov.ru/competition/goods/analisys/a_226.shtml

international price volatility, but Russian policy makers are moving for a closer link between domestic and international prices.

Figure 2.4: Russia's Hydrocarbon Exports (Product Shares of Total By Value)



Source: CBR, Econ Pöyry Analysis

The importance of oil exports and hydrocarbon exports in general to the Russian economy arises along several channels. Income from crude has accounted for a significant share of Russian export revenues increasing from 25 per cent in 2000 to more than 35 per cent in 2008. Total hydrocarbon exports (inclusive natural gas and petrochemicals) accounted for 65 per cent of total export revenues in 2008. Fjærtoft (2008) found evidence that the price of crude is a key driving force behind Russia's trade flow driven exchange rate. This finding is supported in the present paper. Hydrocarbon exports generated 50 per cent of federal budget revenues in 2008 (EEG 2009) and the governments scope of manoeuvre is directly linked to the price of crude. On a larger scale the oil and gas sector is estimated to account for 20–25 per cent of GDP (Anker and Sonnerby 2008). The oil and gas sector also accounts for an important share of investment demand (World Bank 2008).

As an economy dominated by resource extraction and export, Russia faces the dangers of Dutch Disease, namely that an increase in revenues from natural resources will lead to deindustrialisation through an appreciating exchange rate. Westin (2004) found indications of Dutch disease in the Russian economy, later supported by Kalcheva and Oomes (2007). Similar results have also been found for other raw material exporting countries like Australia, Canada and New Zealand (cf. Issa et al. 2006) and Norway (cf. Bjørnstad and Jansen (2007). Jahan-Parvar and Hassan (2008) report similar results for a number of countries.

In recognition of the potentially detrimental long-run effects from instantly spending windfall profits and the benefits of saving for a rainy day (increasing future pension costs), the Russian government has repaid sovereign debt and, since 2004, accumulated reserves in the Stabilization fund, cf. Anker and Sonnerby (2008) for a review. The Stabilization Fund was transformed into a Reserve Fund and National Welfare Fund in 2008. Budget surpluses should be channelled into the second, once the first reaches 10 per cent of GDP. Apart from this, Russia does not practice a formalized rule for how much of oil and gas revenues that are to be spent.

Gurvich (2004) provides a comprehensive macro assessment of the Russian economy's oil price dependency. He argues that the influence of increased oil prices in the period 2000–2003 is lower than commonly claimed in the Russian discourse. Moreover, Gurvich (2004) estimates GDP growth with unchanged oil prices at 5 per cent compared to the actual 6.8 per cent annual average. However, it should be noted that the period of 2000–2003 displayed a modest level of oil prices compared to the subsequent years. The present paper also finds evidence that a substantial part of the Russian economic success during most of the 2000s is associated with the accompanying increase in the oil price.

3. Main features of the model

Our starting point is a relatively standard macroeconomic IS-LM framework, which includes macroeconomic relationships for the labour market, a fiscal block and a monetary policy rule captured in the interest rate equation. The model is presented in its entirety in Appendix A.

The model's IS-side consists of equations describing household consumption, private sector investment, public sector activity and net exports. The model includes an endogenous treatment of fiscal policy where government revenue and expenditure are directly affected by the oil price, inspired by the approach in Merlevede et al. (2009). This approach allows investigation of the effects of the Putin administration's provision to channel some of the windfall profits into debt repayments and wealth accumulation (Robinson 2003). Oil exports and non-oil exports are modelled separately in order to identify oil price effects on oil exports, and to allow for testing of Dutch Disease effects on non-oil exports.

The LM-side of the model includes equations for the exchange rate and inflation. We assume a direct effect of oil prices on the exchange rate along the lines of Spatafora and Stavrev (2003) and likewise for producer and consumer prices. We assume that although Russia is the second largest oil exporter in the world, Russia's market power is not sufficient to influence oil prices in the way OPEC attempts to do. Consequently, the oil price is treated as exogenous to the Russian economy.

Monetary policy is modelled according to a Taylor rule where unemployment and inflation are assumed to be the target variables (Taylor 1993 and 2001). Unemployment is assumed to depend on economic activity and real wages, and wages to depend positively on consumer prices and productivity and negatively on unemployment. Domestic prices are assumed to depend on wages, international prices - including the oil price - and the exchange rate.

Overall, the model is made up of 13 estimated equations and a number of identities. The model facilitates analyses of, among other things, effects on the economy of changes in interest rates, government expenditure, international demand and prices – including the oil price.

Data access limits the potential for detailed modelling of the Russian economy. The model is simple compared to large scale macro econometric models like for instance National Institute of Economic and Social Research's NiGEM model of the UK economy (Barrel et al 2001)[5], Fair's US model (Fair 2004) and Statistics Norway's model of the Norwegian economy, MODAG (Baug and Dyvi 2008), to mention a few. Simplicity makes the model more accessible and easier to understand and communicate. We argue that it contributes to a better understanding of core driving forces in the Russian economy. However, transparency and traceability comes at the expense of less details and realism. Weak spots and suggestions for expanding the model are discussed in the final section of the paper.

4. Data and estimation

4.1. Data

The model is estimated on quarterly data.[6] National accounts data are from IMF International Financial Statistics (IFS). Data for government expenditure and revenues are from the Russian

[5] See also http://www.niesr.ac.uk/research/research.php#1

[6] The software EViews6 is used for all estimation and simulation procedures.

Ministry of Finance, Economic Expert Group. Other data are from Reuters EcoWin. See appendix A for details. The estimation period is limited by data availability at the beginning of the sample and by the global financial crisis at the end of the sample, and runs from 1995Q1 to 2008Q1. The model lacks a sophisticated description of financial markets and is not capable of explaining the effects of the global financial crisis of 2008. Attempts to include four additional quarters produced large residuals, as could be expected in the face of an exogenous shock to the economy of this magnitude, originated in a part of the economy barely described by the model. When the world economy in general and the Russian economy in particular, return to "business as usual", the model may regain its relevance as a useful description of the Russian economy. This is a highly important topic for future research. Because of dynamics, simulation of the full model can start in 1996Q1.

Russian macroeconomic data has recently become more available due to increased and improved reporting, and are now available for a sufficient time period making empirical modelling feasible. Over the period for which we have obtained data, the Russian economy has gone through a gradual transition towards a market economy, and there has been some major changes along the way. The floating of the rouble in 1999 is handled by estimating the exchange rate and interest rate equations from 1999Q1. Furthermore, a step dummy in the household consumption equation is reflecting a change in consumer behaviour at the beginning of the millennium. Otherwise, recursive estimation indicates parameter stability, see appendix D. A comprehensive overview including definitions and sources is found in appendix A.

4.2. Modelling methodology

The modelling strategy is the general to specific approach (cf. Davidson et al. 1978), using ordinary least squares to estimate equilibrium correction models. Restrictions based on economic theory are applied if not rejected by statistical testing. It is emphasized that the final estimated equations should pass standard statistical tests for serial correlation, heteroscedasticity and normality in the residuals. Parameter stability is tested through recursive estimation. Statistical outliers are removed by impulse dummies if explainable and/or if substantial improvements in residual properties are achieved.

4.3. Estimation

In this section we present the estimated equations in the model. Lower case letters indicate logs. The delta (Δ) symbol represents change from the previous quarter. Delta terms correspond to short-run effects. The terms in brackets represent the equilibrium correction term, which in this setting is equivalent to the cointegrating vector. The cointegrating vector measures the long term effects of changes to the exogenous variables on the endogenous variable (see e.g. Engle and Granger 1987 and Hendry 1995). Standard errors are presented below the coefficient estimates. All included variables are statistically significant at the 5 per cent level, except for a few borderline cases, see appendix E for details. In all estimated equations the coefficient relating to the equilibrium correction term is significant with a negative sign, indicating a cointegrating relationship between the variables in the long run.

Standard diagnostic tests for normality, heteroscedasticity and serial correlation do not indicate serious signs of misspecification for any of the estimated equations, see Appendix C. This is further confirmed by recursive estimation, demonstrating reasonable constancy as reported in Appendix D. Impulse-, level- and seasonal dummy variables are omitted in this section for simplicity. Detailed estimation results are displayed in appendix E. Appendix F displays actual and fitted values of the dependent variable, including error bounds based on a simulation of the full model.

4.3.1. Consumption

Equation 1:

$$\Delta c_t = -\underset{(0.027)}{0.121} - \underset{(0.057)}{0.214}\{c - yd\}_{t-1} + \underset{(0.05)}{0.346}\Delta yd_t - \underset{0,006}{0.028} DSTEP01Q1$$

Real household consumption (c) depends on real disposable income (yd). The estimated equilibrium correction coefficient of –0.21 implies *ceteris paribus* a half-life of adjustment towards a new equilibrium of 3.5 quarters following a permanent shock to real disposable income. Consumption is homogenous of degree one in real disposable income in the long run, implying that a 1 per cent increase in real disposable income eventually will lead to a 1 per cent increase in household spending, all else equal. The homogeneity restriction is tested and not rejected. The positive estimated short-run elasticity of disposable income is close to 1/3 of its long-run counterpart, speeding up adjustment to a new equilibrium after a permanent change in real disposable income.

Data for household wealth was not available. Accumulated household wealth in Russia remains low compared to Western European countries, and Russians remain largely unable to properly smooth consumption in order to counter income shocks. Empirical research by Notten and Crombrugghe (2006) supports the notion that wealth does not have a significant influence on aggregate Russian consumption decisions.

The real interest rate was not found to be significant, and has therefore been left out. To some extent, this could be explained by the low level of Russian wealth accumulation, as the rouble interest rate is not perceived by Russians to be an opportunity cost of holding cash, implying that money to a large extent is spent or invested in foreign currency.

There is a step dummy (*DSTEP01Q1*) in the household consumption equation taking the value of 1 until 2000Q4 and 0 thereafter, reflecting a permanent change in consumer behaviour at the beginning of the millennium. Merlevede et al (2009) identifies a similar effect, and suggest increased confidence as an explanation, as economic and political risk were perceived to be reduced in the wake of Putin's take over at the onset of 2000.

4.3.2. Investment

Equation 2:

$$\Delta i_t = \underset{(0.148)}{-1.204} - \underset{(0.074)}{0.378}\{i - y\}_{t-1}$$

Investment (i) is homogenous of degree one in GDP in the long run, implying that over time investments in Russia tend to follow the overall economy. This restriction is tested and not rejected. We do not find support for a relationship between investments and real interest rates (RPY), which is a common result in international empirical investigations. In the case of Russia this can be attributable to the fact that bank financing accounts for just 10 per cent of corporate sector fixed investments, and that most investments are financed through internal sources, less dependent on interest rates.

Ideally, we would prefer to model oil investments separately, as this is an important sector in the Russian economy. Unfortunately, we have not been able to find adequate data for petroleum investments, and leave this for later research. If a direct relationship between the oil price and petroleum investments actually exists, this implies, ceteris paribus, that the effect of a change in the oil price is understated within our model framework. Indirect effects of the oil price, through income and demand effects are captured in the aggregated investment function.

4.3.3. Non-oil exports

Equation 3:

$$\Delta xexoil_t = \underset{(0.428)}{-1.828} - \underset{(0.081)}{0.355}\{xexoil - wimp + 0.245rex\}_{t-1} + \underset{(0.111)}{0.375}\Delta xexoil_{t-1}$$

Exports excluding oil (*xexoil*) depend in the long run on international demand (*wimp*) and the real exchange rate (*rex*); increasing in international demand, international prices (*pyusa*) and with a weaker rouble (*rubusd*), while decreasing in domestic prices (*py*). These findings are in line with the standard export model proposed by Armington (1969). Price homogeneity is tested and not rejected. An increase in the oil price affects non-oil exports through a real exchange rate appreciation in the overall model, thereby curbing exports from this sector. However, this effect is restrained by subsidized domestic energy supply, which curtails inflationary impulses from increased oil prices on domestic inflation.

4.3.4. Oil exports

Equation 4:

$$\Delta xoil_t = \underset{(0.194)}{0.561} - \underset{(0.033)}{0.098}\{xoil - 0.612(poilrub - \Delta py)\}_{t-1} - \underset{(0.156)}{0.323}\Delta py_{t-3}$$

Oil exports (*xoil*) depend positively on the oil price measured in roubles (*poilrub*) relative to domestic prices (*py*) in the long run. This result is consistent with: (1) that an increased oil price yields lower domestic demand leading to higher exports at a given level of production, and (2) that domestic production depends positively on the oil price, as higher oil prices make more sources for oil production economically viable. International demand is tested and rejected as an explanatory variable in the model. The estimated coefficient of the equilibrium correction term of – 0.1 implies relatively slow adjustment of oil exports in the event of a shock in the oil price. This reflects that the high volatility of the oil price and the magnitude of investments necessary to increase production foster conservative behaviour and correspondingly slow adjustment of production capacity in response to changing oil prices in the petroleum sector.

4.3.5. Imports

Equation 5:

$$\Delta z_t = -\underset{(0.166)}{0.384} - \underset{0.072}{0.292}\{z - 0.267(c + i + g + xexoil)\}_{t-1}$$

Imports (*z*) depend in the long run on domestic demand (*c* + *i* + *g*) and exports excluding oil, as non oil exports include a significant amount of imported input. Relative prices and the exchange rate was not found to be significant, indicating that growth in imports have mainly come as a result of increased economic growth. This is contrary to other studies; cf. Merlevede et al. (2009), who find support for the real exchange rate as an explanatory variable for imports.

4.3.6. Unemployment

Equation 6:

$$\Delta U_t = \underset{(0.039)}{0.199} - \underset{(0.05)}{0.243}\{U + 0.115y - 0.037(w - py)\}_{t-1}$$

The unemployment rate (*U*) depends negatively on GDP and positively on real wages (*w-py*) in the long run. Notice that the coefficient estimate of the unemployment rate is a semi-elasticity as *U* is defined as a rate variable with no logarithmic transformation. This implies that the estimated long-run coefficients are to be interpreted as the *percentage point* change in unemployment following a change of 1 per cent of GDP and real wage respectively.

4.3.7. Wages

Equation 7:

$$\Delta w_t = \underset{(0.155)}{0.679} - \underset{(0.042)}{0.267}\{w - pc + 4.26U - 0.79\,prod\}_{t-1} + \underset{(0.053)}{0.28}\,\Delta pc_{t-1}$$

Nominal wages (*w*) depend positively on consumer prices and productivity and negatively on the unemployment rate in the long run. Nominal wages are homogenous of degree one in consumer prices in the long run, implying that a 1 per cent increase in consumer prices eventually will lead to a 1 per cent increase in nominal wages, all else equal. This restriction is tested and not rejected. Additionally, there is a positive impact effect on wages of a change in consumer prices.

Wages increasing with lower unemployment is consistent with the implications of the wage curve. When unemployment is high, workers are more concerned with jobs than with wages, constraining wage claims. Also, a larger pool of employable workers allows employers to moderate their wage offers.

As in the unemployment equation, *U* is defined as a rate variable with no logarithmic transformation. Correspondingly, the estimated long-run coefficient of the unemployment rate should be interpreted as the percentage change in nominal wages following a change of 1 *percentage point* in the unemployment rate.

4.3.8. The GDP deflator

Equation 8:

$$\Delta py_t = -\underset{(0.118)}{1.121} - \underset{(0.042)}{0.416}\{py - 0.488w - 0.149(pceu + poilrub)\}_{t-1}$$
$$+\underset{(0.02)}{0.102}\Delta poilrub_t + \underset{(0.06)}{0.384}\Delta py_{t-1}$$

The GDP deflator (*py*) depends on wages, international prices (*pceu*), the rouble oil price and the exchange rate in the long run. International prices are proxied by the CPI for the euro area, as the euro area is the dominating trading partner. The effect of wages is relatively strong, indicating that an increase in domestic factor costs has a greater impact on inflation than an increase in international factor costs. The oil price effect lends weight to the argument that energy prices in Russia have a significant influence on product prices. Long-run homogeneity in wages, foreign prices and the oil price is not statistically significant and therefore not imposed by restriction. This is a common finding, and does not appear to pose any problems when simulating the model. The equation also includes a positive impact effect of a shock to the oil price and a positive autoregressive term (*Δpy*).

4.3.9. Consumer prices

Equation 9:

$$\Delta pc_t = -\underset{(0.195)}{1.112} - \underset{(0.055)}{0.313}\{pc - 0.387(w + pceu) - 0.086 poilrub\}_{t-1} + \underset{(0.036)}{0.505}\Delta pc_{t-1}$$

Consumer prices (*pc*) depend on wages, international prices, the exchange rate and the oil price measured in roubles in the long run. Notice that there is a smaller effect of the oil price and a larger effect of international prices compared to what is the case for the GDP deflator, reflecting a higher share of consumer goods in the CPI basket. This difference is illustrated in section 6 where the impact of changes to the oil price is greater on the GDP deflator than on consumer prices. Long-run homogeneity in wages, foreign prices and the oil price is rejected by data, as in the GDP deflator equation. The equation also contains a positive autoregressive term (*Δpc*).

4.3.10. Government expenditure

Equation 10:

$$\Delta ge_t = \underset{(0.318)}{0.215} - \underset{(0.054)}{0.132}\{ge - 0.288 poilrub\}_{t-1} + \underset{(0.096)}{0.26}\Delta g\exp_{t-3}$$

Government expenditure (*ge*) is determined by the rouble oil price in the long run. The estimated coefficient of the equilibrium correction term of –0.13 implies a relatively slow adjustment of government revenues in the event of a shock in the oil price. The equation also contains positive autoregressive effects from ge. Government consumption and investment (*G*) is determined as Government expenditures less transfers (*GT*).

4.3.11. Government revenue

Equation 11:

$$\Delta gr_t = \underset{(0.226)}{0.301} - \underset{(0.052)}{0.129}\{gr - 0.465\,poilrub\}_{t-1} + \underset{(0.154)}{0.657}\,\Delta y_t$$

Government revenue (*gr*) depends on the rouble oil price in the long run, with short-run effects of GDP. The estimated coefficient of the equilibrium correction term of –0.13 is similar to the corresponding coefficient in equation (10), and likewise implies relatively slow adjustment of government expenditure in the event of a shock in the oil price. A 1 per cent increase in the oil price yields an increase of almost 0.5 per cent in government revenues in the long run, indicating a firm success of the state capturing a large share of oil windfall profits. Furthermore, a raise in the oil price increases government revenues by more than it increases government expenditure, implying that rising oil prices yield a positive net effect on the fiscal budget. This is illustrated in section 6.

4.3.12. Interest rate

Equation 12:

$$\Delta R_t = \underset{(0.023)}{0.04} - \underset{(0.112)}{0.637}\{R - 0.286\Delta pc + 0.797U\}_{t-1} - \underset{(0.063)}{0.179}\,\Delta\Delta pc_{t-1}$$
$$-\underset{(0.025)}{0.078}\,\Delta\Delta pc_{t-2} - \underset{(0.592)}{1.5}\,\Delta U_t - \underset{(0.592)}{1.069}\,\Delta U_{t-3}$$

Equation 12[7] may be interpreted as a reaction function for the nominal interest rate, suggesting that the CBR is leaning against the wind by responding to higher inflation (*ΔPC*) and a lower unemployment rate by tightening monetary policy. Thus, higher oil prices induce the CBR to adjust interest rates in order to dampen inflationary pressures. The estimated coefficient of the equilibrium correction term is

[7] Bear in mind that all variables in this equation are defined as rates with no logarithmic transformation. Thus, the coefficient estimates of inflation and the nominal interest rate are interpreted as semi elasticities. A permanent one *percentage point* increase in the unemployment rate (inflation) leads to a 0.80 (0.29) *percentage point* reduction (increase) in the nominal interest rate in the long run.

0.64, implying rapid adjustment in the nominal interest rate to shocks in the unemployment rate and inflation.

There are estimated short-run effects of inflation and the unemployment rate. The short-run effect of the unemployment rate is substantially greater than the long-run counterpart. Accordingly, the nominal interest rate responds quickly and with overshooting to shocks in the unemployment rate. The estimated short-run effect of inflation is negative and will cause the interest rate to move in opposite directions in the short and the long run. These short run effects contribute to improve the statistical properties of the equation, but also make the adjustment process of the interest rate less smooth in the model after a shock in the explanatory variables.

4.3.13. Exchange rate

Equation 13:

$$\Delta rubusd_t = \underset{(0.161)}{1.251} - \underset{(0.04)}{0.311}\{rubusd + 0.186 poil\}_{t-1} - \underset{(0.03)}{0.065}\Delta poil_t - \underset{(0.087)}{0.269}\Delta R_t - \underset{(0.038)}{0.123}\Delta rubusd_{t-2}$$

In the long run, the rouble/USD exchange rate is a function of the oil price, where an increase in the oil price leads to a stronger rouble, in line with the Dutch disease hypothesis. We found no long term effects of domestic or international interest rates.

The estimated equation also includes an impact effect of the oil price about the size of the long run effect, implying that the rouble/USD gets close to the new long run level instantly after a permanent change in the oil price. There is also an estimated positive short-run effect of the domestic interest rate. Again, international interest rates were rejected by data. An autoregressive term is also included in the equation.

5. Fit

Model evaluation is often based on forecasting properties and ability to reproduce history. When comparing predicted future values of endogenous variables with actual outcomes, prediction errors are not only caused by the model but also by the exogenous variables, which are made ex ante. Furthermore, one has to wait for future data to enable comparison of predicted and realized values of endogenous variables. These problems can be avoided by making forecasts for a historical period. Then the “correct” exogenous variables are available, and only the model is to blame for forecast errors, not erroneous assumptions about the future paths of exogenous variables. A stringent evaluation is to test the model "out-of-sample". In this case the model is tested for a historical period, but after the estimation period. If the test is performed "in-sample" the estimated coefficients reflect information from the forecast period. However, when testing the model out of sample another problem occurs: giving up the last observations in the data set for evaluation purposes implies a loss to estimation. A limited period of viable data is available for the Russian economy. All available information is therefore utilized in the estimation, and we are left with an in sample evaluation as the best alternative available in practice. When simulated data is compared to historical data within the estimation period, it is rather a description of how the model tracks/fits historical data than a test of forecasting properties. However, it is hard to imagine a model having good forecasting properties if it is not able to reproduce history in a realistic manner.

To assess the model, we check its ability to track the actual development of the endogenous variables. Dynamic simulation starts in 1999Q1, after the 1998 crisis and within the estimation period of the exchange rate and interest rate equations. Dynamic simulation enables examination of model performance when used to forecast many periods into "the future". Forecasts from previous periods – and not actual historical data – are used when assigning values to the lagged endogenous variables in the model. The results illustrate model performance as if we in 1999 had used the model to forecast the next 9 years, assuming we had known the correct paths for the exogenous variables. Stochastic Monte Carlo simulation is used to provide a measure of uncertainty in the results, by adding error bounds of plus/minus two standard deviations to the predictions. Appendix F displays actual and fitted values of the dependent variable including error bounds. The simulation exercise reveals good tracking abilities for all variables, which indicate good overall model stability.

6. Changing the oil price

The model can be simulated under various assumptions for the exogenous variables. In this section we apply two counterfactual paths for the oil price, solving the model in a high and a low oil price scenario over the nine-year sample 1999 Q1 to 2008 Q1. These exercises shed light on the importance of the oil price to the Russian economy, and in particular to what extent the oil price increase of the 2000s has contributed to Russia's economic growth in this period. The alternative oil price scenarios also serve as illustrations of model properties, e.g. the different channels through which the oil price influences the Russian economy. The model is simulated with endogenous monetary and fiscal policy.[8]

[8] The model is simulated with historical residuals to ensure that the difference between the actual and the alternative scenario reflects only the effects of the change in the oil price, and not model errors.

Our analysis is partial in the sense that the USD oil price is the only exogenous variable that is changed. It is a common assumption that the oil price boom has been fuelled by fast-growing international demand, particularly in China. In our alternative scenarios international demand as well as international prices are treated exogenously and not changed from actual historical values. For instance, it would be perfectly reasonable to argue that a low oil price path would go hand in hand with low international demand and vice versa. However, with an alternative exogenous path for international demand we could not distinguish between the effects of the oil price and of international demand. The fact that monetary and fiscal policy, the exchange rate, and oil revenues and expenditure are endogenously determined in the model, based on historical behaviour, and thereby responds to changes in other model variables, contributes to realism in the results.

At the outset of the simulation period the oil price stood at a record low USD 11/bbl. The oil price gained USD 13 through 1999 and another USD 6 in 2000. Through the course of 2001–2002 prices hovered around USD 25–30. What is referred to as the oil price boom in this paper started in 2003 Q2, when prices climbed uninterrupted from USD 26 to USD 51 after two years and on to USD 97 in 2008 Q1. Beyond our sample the oil price grew another USD 25/bbl in 2008 Q2 before it fell to 55 in the second half of 2008, and recovered to 70-80 USD in the course of 2009.

6.1. Mean reversion oil price scenario

Going back to the outset of our simulation period, the oil price increases witnessed over the following decade were largely unexpected among analysts and policy makers. Pindyck (1999) argued in an influential article that oil prices exhibited reversion to a stochastically fluctuating trend that represents evolution of long-run marginal cost. According to his forecast the oil price in the period 2000–2010 should revert to a long-run level of $USD^{(1967)}$ 4.5/bbl or $USD^{(2000)}$ 23/bbl. Similar price expectations prevailed in Russia into the 2000s, cf. Gurvich (2004). Our first counterfactual oil price scenario involves solving the model under the assumption that such expectations were fulfilled, keeping the oil price at $USD^{(2000)}$ 23/bbl throughout the simulation period. This hypothetical development is illustrated against the actual oil price in Figure 6.1. Hypothetical and actual oil prices are quite similar up to 2003 Q2. For the sake of interpretability, we therefore allow the hypothetical and actual values to differ after this point only.

Model simulation along this oil price scenario sheds light on the question: How would the Russian economy have performed had it not been for the sustained oil price boom witnessed up until July 2008? Among Russia-focused researchers this is a question of much debate. Particularly because the debate is often coupled with an evaluation of President and Prime Minister Vladimir Putin's "semi-authoritarian" economic model as is the case in McFaul and Stoner-Weiss (2008).

Figure 6.1: Oil price, actual and mean reversion scenario

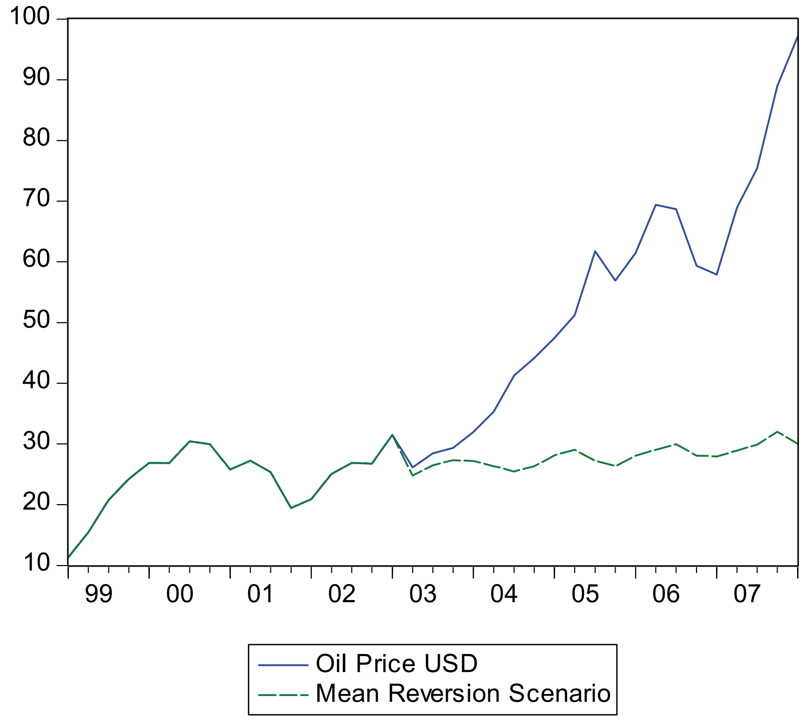
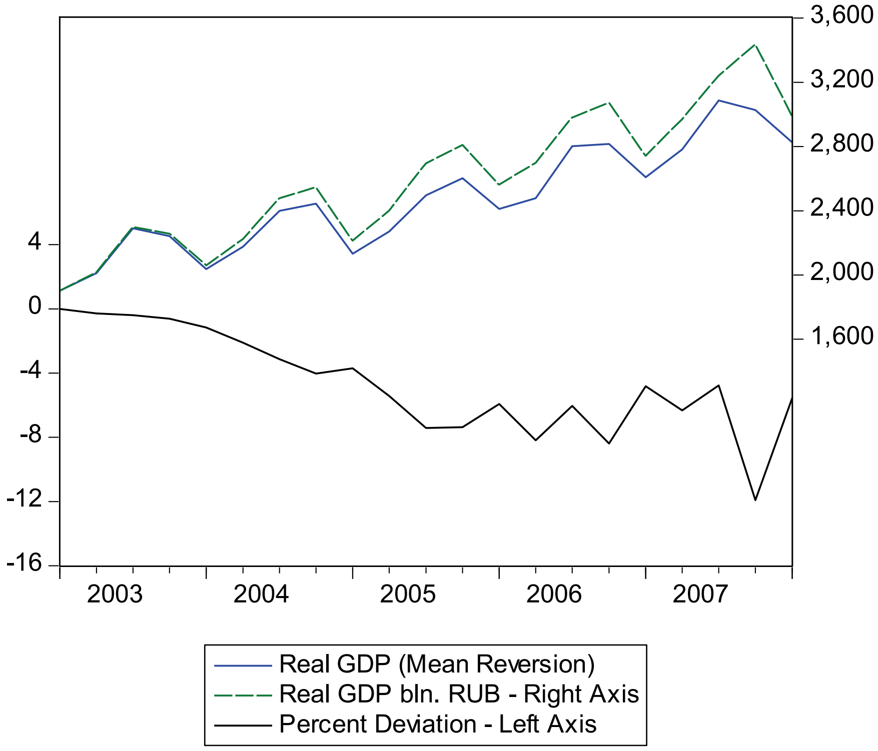


Figure 6.2 compares real GDP under the mean reversion scenario with the observed development of the same variable. Simulated GDP starts developing along a lower path immediately as hypothetical and actual oil prices diverge. The gap between actual and simulated GDP grows throughout the simulation period as oil price divergence increases. At the end of the simulation period, GDP is 6–7 per cent lower in the mean reversion oil price scenario.

Figure 6.2: GDP, actual and mean reversion scenario



Lower oil prices have a direct, negative effect on oil exports, government revenue and expenditure as well as consumer and producer prices, and cause the rouble to depreciate. Disposable income drops and curbs consumption. Investments are affected negatively through lower domestic demand.

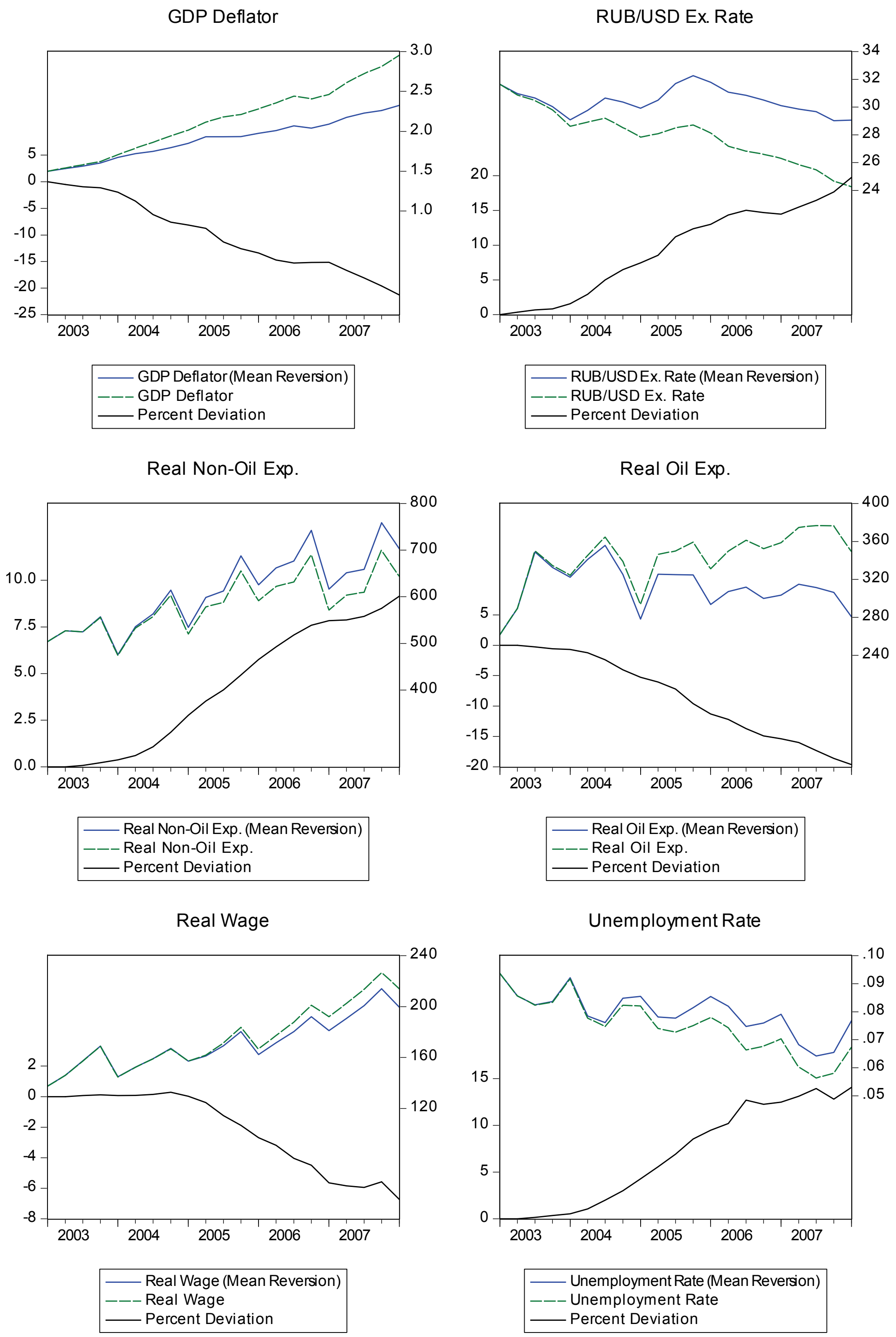
Inflation drops as a direct response to the lower oil price. This is reinforced through the wage channel as lower GDP increases unemployment and accordingly yields a negative effect on wage growth. A weaker rouble contributes ceteris paribus to higher inflation through pricier imports. At the end of the simulation period the simulated rouble is some 15 per cent weaker than actual observations.

The interest rate is lowered by approximately 2 percentage points as a response to increasing unemployment and lower inflation. Lower interest rates yield a rouble depreciation. Negative effects on GDP of lower oil prices are countered somewhat through the stabilizing properties of imports and non-oil exports. Imports are subdued through lower domestic demand, while non-oil exports experience a positive effect through depreciation of the rouble and lower domestic inflation.

Oil exports decrease from a peak in 2004, to end up 20 per cent lower than actual values. This may indicate that Russia's maintained level of oil production would not be viable if not for the substantial increase in the oil price actually observed. Our simulation thereby lends indicative support to the claim that Russian oil production has reached a peak and can be expected to decline in the future unless prices grow significantly.

Figure 6.3 contains the simulated and actual evolution of the GDP deflator, rouble–dollar exchange rate, non-oil and oil exports as well as money market rate and real wage. Appendix B contains graphic illustrations of all endogenous solutions in the mean reversion scenario.

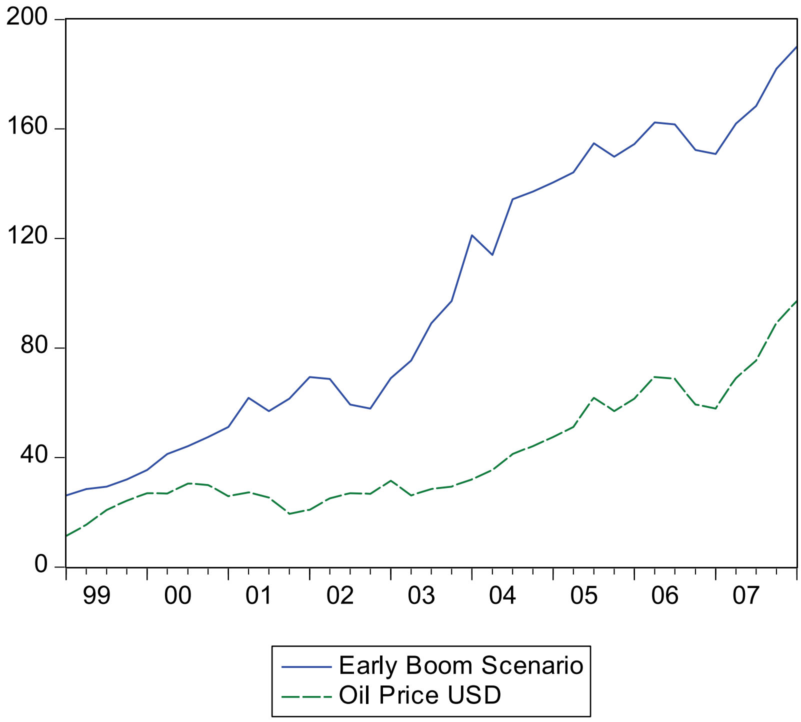
Figure 6.3: Mean reversion, selected variables



6.2. Early boom scenario

A different question is how the Russian economy would have performed should the oil price boom have occurred at the outset of our simulation period in 1999 rather than in 2003. Accordingly, we simulate the model applying a hypothetical oil price path, where the oil price observations for 2003 Q2 and onwards are shifted back to 1999 Q1. Thus the oil price boom starts 18 periods earlier and culminates in 2004 Q2 with the value observed in 2008 Q1. For the rest of the simulation period, we keep a constant difference between the hypothetical and the observed oil price, see Figure 6.4.

Figure 6.4: Oil Price, actual and early boom scenario



In the early boom scenario, GDP grows faster than actual observations until mid-sample when the gap between simulated and actual GDP starts to close, from 24 per cent to 12 per cent above actual observations at sample end, see Figure 6.5.

At first, a higher oil price path leads to higher oil exports and -income, increasing public consumption and investment as well as household consumption. Higher demand leads to increased private investment and higher imports. Lower unemployment generates higher wage growth, contributing to higher inflation, although inflation is dampened somewhat by lower imported price impulses due to a stronger rouble. Non-oil exports are curbed by the rouble and higher domestic inflation, and are 12 per cent lower after 5 years.

The oil price gap increases until mid-sample only, remaining constant thereafter. Thus the scenario oil price is growing in parallel with the actual oil price from 2004 Q2, providing no additional stimulus to the economy from this point. From here on, the development is reversed somewhat for all variables.

Growth in government expenditure drops and lower growth in real disposable income brings down growth in household consumption. Private investments are hampered by weaker overall economic development. Lower inflation and higher unemployment cause lower interest rates, resulting in a weaker rouble which reduces petroleum income measured in roubles, curbing domestic demand further. Nevertheless, at the end of the simulation period the rouble is still 14 per cent stronger than the observed counterpart. Non-oil exports gains somewhat on the observed value over the last 4 years thanks to the weaker rouble, but is still 10 per cent below at the end of the simulation period.

Figure 6.6 illustrates the evolution of selected variables under the early boom scenario. For reference, the solutions for all endogenous variables are provided in Appendix B.

Figure 6.5: GDP, actual and early boom scenario

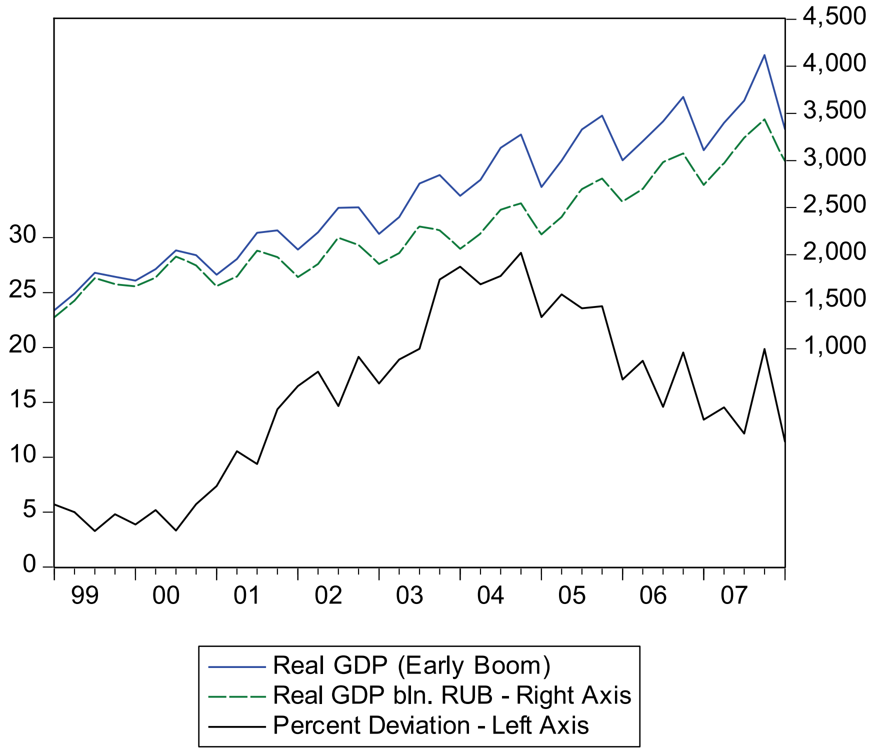


Figure 6.6: Early boom scenario, selected variables

7. Conclusion

Russia is occasionally surpassing Saudi Arabia as the world's number one oil producer and exporter. Oil revenues make a significant share of Russia's exports and foreign trade turnover as well as government earnings. The demise of the Soviet Union and Russia's recovery in the 2000's have been linked to falling and rising oil prices respectively. Prior to the 2008 economic crisis Russia's average GDP growth since 2001 has been in excess of 7 per cent and thus among the strongest in the world. At the same time Russia has seen an increased role of the state while market institutions remain underdeveloped. This has lead critics of the Russian regime, and in part the current President Medvedev to claim that Russia's boom has largely been facilitated by unprecedented oil price growth.

To shed light on these issues we have estimated a macro econometric model of the Russian economy. The Russian society as well as the economy, including fiscal and monetary policy, has been in constant development throughout the data period. This makes identifying stable relationships a challenging task. One important example is the change in exchange rate regime following the 1998 default, allowing us to model the exchange rate and interest rate from 1999 only. Another example is the household consumption equation, where a change in consumer behaviour is identified at the beginning of the millennium, controlled for by introducing a step dummy variable. Nevertheless, we estimate a model with good statistical properties that explains history well.

We assess the degree of oil price dependency of the Russian economy through two counterfactual shifts in the historical oil price. We analyse how the economy, according to the model, responds to these alternative paths. Under the first scenario the real oil price does not increase after 2003, in contrast to the soaring oil prices actually observed. Under the second scenario the 2003 oil price boom commences in 1999 rather than in 2003. The simulations indicate that the oil price has been of considerable importance to the Russian economy over the last decade. However, the results indicate that the Russian economy exhibits significant growth capabilities also in the absence of growth in the oil price. Furthermore, an increase in the oil price yields a real appreciation of the rouble, leading to reduced non-oil exports in line with the Dutch Disease hypothesis.

The alternative scenarios were chosen to provide grounds for a discussion of how the Russian economy actually would have performed should oil prices have evolved in a different way. The scenarios are chosen with an eye to realism in the sense that they should be easy to relate to the actual development of the oil price. The two alternative paths for the oil price are not symmetric, which complicates scenario comparison. Nevertheless, we argue that our choice is justified as we shed light on issues that are of direct concern to many Russia analysts. For the interested reader Appendix B contains model solutions for a 100 per cent permanent increase in the oil price as well as a permanent halving of the oil price. These more stylized simulations forego some realism in order to make the results more easily interpretable.

Notwithstanding the advances in this paper, several issues are left in need of further research. The CBR has operated a money targeting program aimed at providing the economy with sufficient liquidity subject to constraining inflation and concerns for rapid rouble appreciation. Our knowledge of how money supply affects interest rates and accompanying transmission effects into inflation is limited.[9] Nevertheless, we find empirical evidence for modelling monetary policy as the CBR "leaning against the wind", tightening monetary policy – represented by the money market interest rate – in the face of increasing inflation and falling unemployment. Keeping in mind these uncertainties and the omission of one of the target variables of the Russian monetary policy (money supply), more detailed modelling of Russian monetary policy might provide important insights and add precision to model forecasts.

An additional interesting implication of the model is that the non-oil export industries are left alone taking a double beating from higher oil prices, as the channel from interest rates to the economy goes through the exchange rate. Higher inflation is met by higher interest rates, leading to a stronger rouble. Thus, when the oil price increases, the non-oil export industries are not only hit by high domestic inflation, but also by a strong rouble.

With reference to the discussion above, a prime goal for Russian monetary authorities is a western style transfer to free float of the rouble and inflation targeting using the interest rate. When it comes to fiscal policy, our model does not include a specific spending rule for petroleum revenues. Rather, government expenditure is modelled based on observed behaviour over the estimation sample. Model simulation illustrates how government spending increases slower than government revenues following a positive shift in the oil price, allowing significant amounts to be transferred to the Reserve and National Wealth Funds.

[9] We found no empirical evidence for a link between money supply and interest rates nor inflation in the Russian economy.

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Appendix A

Variable list (data sources in parentheses)

C = Household consumption (IMF International Financial Statistics (IFS))

I = Private investments (IFS)

G = Government consumption and investment (IFS)

GT = Government transfers (see definition)

XOIL = Oil exports (IFS)

XEXOIL = Non oil exports (IFS)

Z = Imports (IFS)

Y = GDP (IFS)

YD = Disposable income (see definition)

GE = Government expenditure (Ministry of Finance, Economic Expert Group)

GR = Government revenue (Ministry of Finance, Economic Expert Group)

PC = Consumer price index (OECD MEI)

PY = GDP deflator (OECD MEI)

DPC = Consumer price inflation (see definition)

DPY = GDP deflator inflation (see definition)

R = 3 month money market interest rate (IFS)

RPC = real interest rate (see definition)

RPY = real interest rate (see definition)

REX = real exchange rate (see definition)

W = Wage per employed (IFS)

U = Unemployment rate (Ecowin)

E = Number of employed (Ecowin)

L = Labour force (Ecowin)

PROD = Productivity (see definition)

POIL = Oil price (Brent Blend) denoted in USD (Norges Bank)

POILRUB = Oil price (Brent blend) in roubles (see definition)

Estimated equations (identical to equations 1-13 in section 4))

$$\Delta c_t = -\underset{(0.027)}{0.121} - \underset{(0.057)}{0.214}\{c - yd\}_{t-1} + \underset{(0.05)}{0.346}\Delta yd_t - \underset{0,006}{0.028} DSTEP01Q1$$

$$\Delta i_t = -\underset{(0.148)}{1.204} - \underset{(0.074)}{0.378}\{i - y\}_{t-1}$$

$$\Delta xexoil_t = -\underset{(0.428)}{1.828} - \underset{(0.081)}{0.355}\{xexoil - wimp + 0.245 rex\}_{t-1} + \underset{(0.111)}{0.375}\Delta xexoil_{t-1}$$

$$\Delta xoil_t = \underset{(0.194)}{0.561} - \underset{(0.033)}{0.098}\{xoil - 0.612(poilrub - \Delta py)\}_{t-1} - \underset{(0.156)}{0.323}\Delta py_{t-3}$$

$$\Delta z_t = -\underset{(0.166)}{0.384} - \underset{0.072}{0.292}\{z - 0.267(c + i + g + xexoil)\}_{t-1}$$

$$\Delta U_t = \underset{(0.039)}{0.199} - \underset{(0.05)}{0.243}\{U + 0.115y - 0.037(w - py)\}_{t-1}$$

$$\Delta w_t = \underset{(0.155)}{0.679} - \underset{(0.042)}{0.267}\{w - pc + 4.26U - 0.79 prod\}_{t-1} + \underset{(0.053)}{0.28}\Delta pc_{t-1}$$

$$\Delta py_t = -\underset{(0.118)}{1.121} - \underset{(0.042)}{0.416}\{py - 0.488w - 0.149(pceu + poilrub)\}_{t-1}$$
$$+\underset{(0.02)}{0.102}\Delta poilrub_t + \underset{(0.06)}{0.384}\Delta py_{t-1}$$

$$\Delta pc_t = -\underset{(0.195)}{1.112} - \underset{(0.055)}{0.313}\{pc - 0.387(w + pceu) - 0.086 poilrub\}_{t-1} + \underset{(0.036)}{0.505}\Delta pc_{t-1}$$

$$\Delta ge_t = \underset{(0.318)}{0.215} - \underset{(0.054)}{0.132}\{ge - 0.288 poilrub\}_{t-1} + \underset{(0.096)}{0.26}\Delta g\exp_{t-3}$$

$$\Delta gr_t = \underset{(0.226)}{0.301} - \underset{(0.052)}{0.129}\{gr - 0.465 poilrub\}_{t-1} + \underset{(0.154)}{0.657}\Delta y_t$$

$$\Delta R_t = \underset{(0.023)}{0.04} - \underset{(0.112)}{0.637}\{R - 0.286\Delta pc + 0.797U\}_{t-1} - \underset{(0.063)}{0.179}\Delta\Delta pc_{t-1}$$
$$-\underset{(0.025)}{0.078}\Delta\Delta pc_{t-2} - \underset{(0.592)}{1.5}\Delta U_t - \underset{(0.592)}{1.069}\Delta U_{t-3}$$

$$\Delta rubusd_t = \underset{(0.161)}{1.251} - \underset{(0.04)}{0.311}\{rubusd + 0.186 poil\}_{t-1} - \underset{(0.03)}{0.065}\Delta poil_t - \underset{(0.087)}{0.269}\Delta R_t - \underset{(0.038)}{0.123}\Delta rubusd_{t-2}$$

Definitions

$c_t = \log(CONS_t / PC_t)$

$yd_t = \log(YD_t / PC_t)$

$y_t = \log(Y_t / PY_t)$

$i_t = \log(I_t / PY_t)$

$xexoil_t = \log(XEXOIL_t / PY_t)$

$rex_t = \log(PY_t /(PYUSA_t * RUBUSD_t))$

$xoil_t = \log(XOIL_t /(POIL_t * RUBUSD_t))$

$z_t = \log(Z_t / PY_t)$

$g_t = \log(G_t / PY_t)$

$pceu_t = \log(PCEU_t * RUBEUR_t)$

$ge_t = \log(GE_t / PY_t)$

$gr_t = \log(GR_t / PY_t)$

$polirub_t = \log(POIL_t * RUBUSD_t)$

Identities

(14) E = L * (1 - (U))

(15) PROD = (Y / PY) / E

(16) DPY = (PY / PY(-1))^4 - 1

(17) DPC = (pPC / PC(-1))^4 - 1

(18) RPY = R - DPY

(19) RPC = R - DPC

(20) YD = Y - GR + GT

(21) G = GE - GT

(22) Y = G + CONS + I + XEXOIL + XOIL - Z + SD

In equation (14), employment (E) follows from labour supply (L) and the unemployment rate (U). Productivity is defined in (15) as real GDP per employed. Equation (16) and (17) defines inflation in the GDP deflator and CPI, respectively, as growth in prices from the previous quarter at annualised rates. Corresponding real interest rates are defined in (18) and (19). Private sector disposable income (YD) is defined in (20) by what is left to the private sector after the public sector has taken its share (GR) less transfers to the private sector (GT). Public consumption (G) equals government expenditure (GE) less transfers to the private sector, as seen in equation (21). GDP (Y) follows in (22) as the sum of public consumption and investments (G), household consumption (CONS), private sector investments (I), exports excluding oil (XEXOIL), oil exports (XOIL) less imports (Z) and adding a term covering statistical discrepancies (SD).

Figure 7 Mean reversion scenario

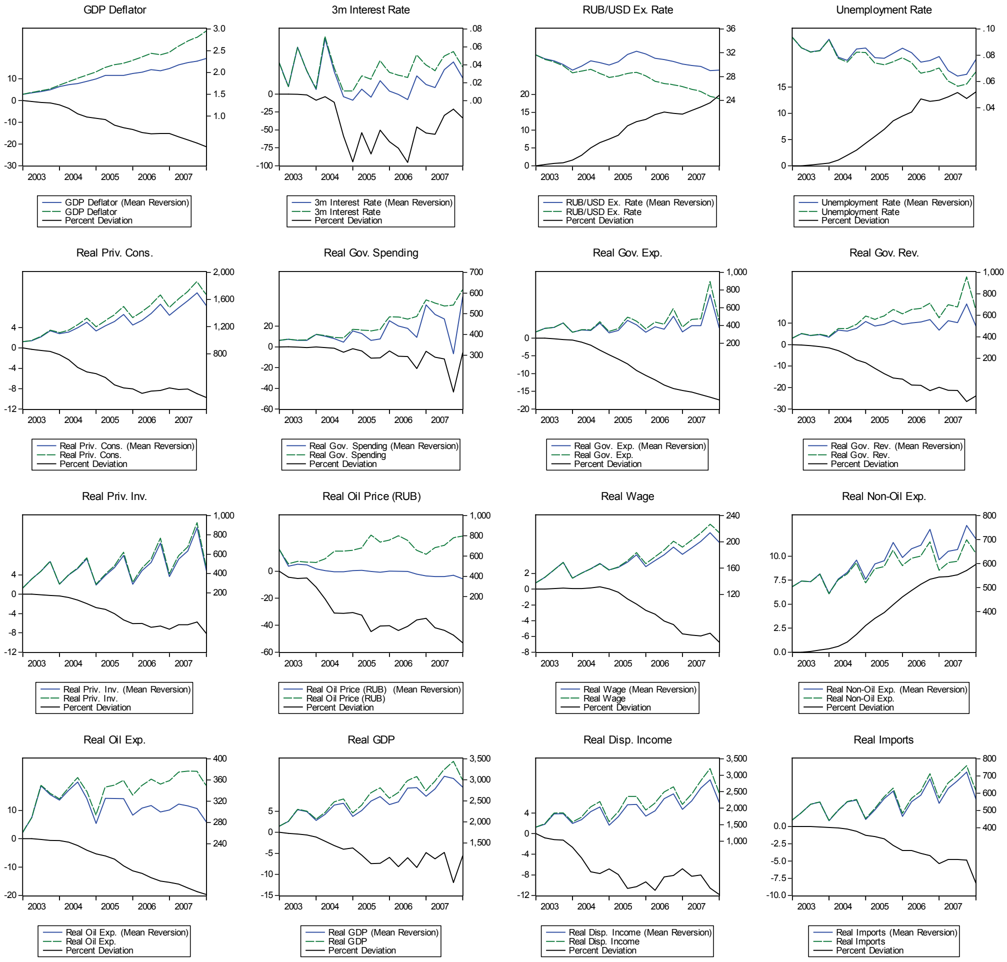


Figure 8 Early boom scenario

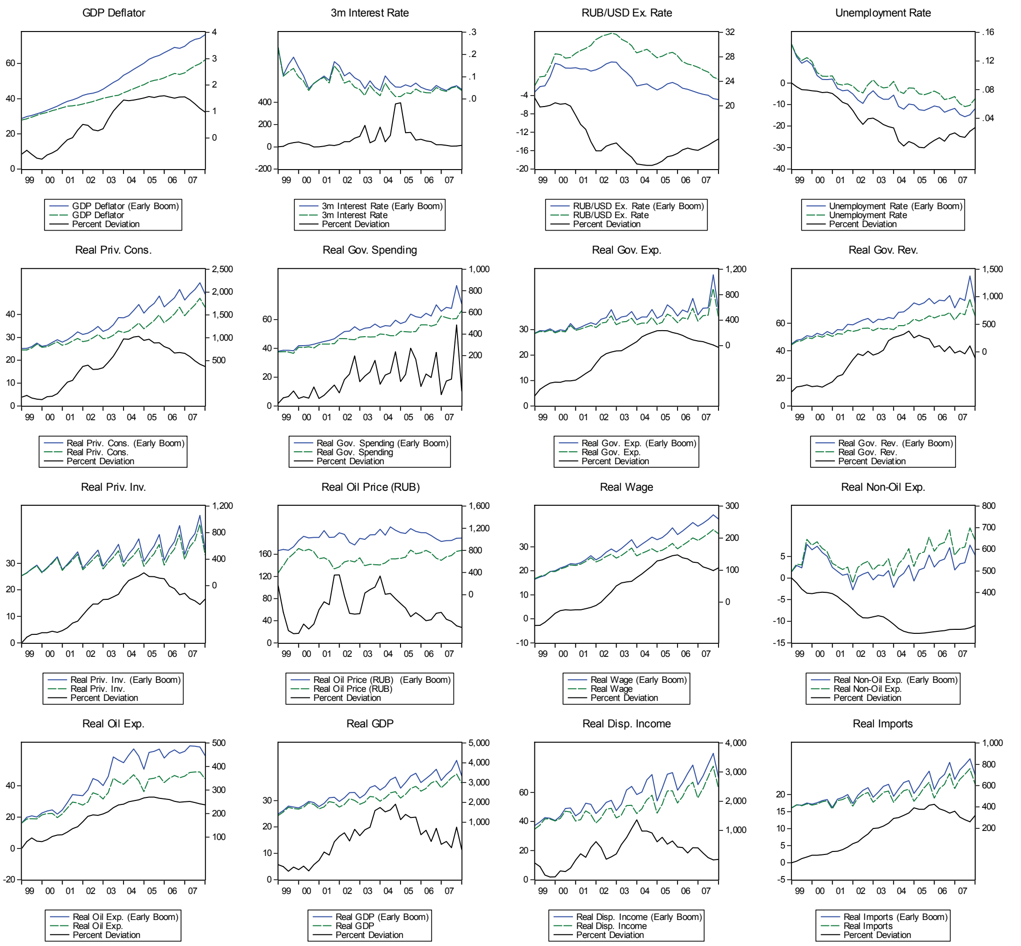


Figure 9 100 % sustained oil price increase

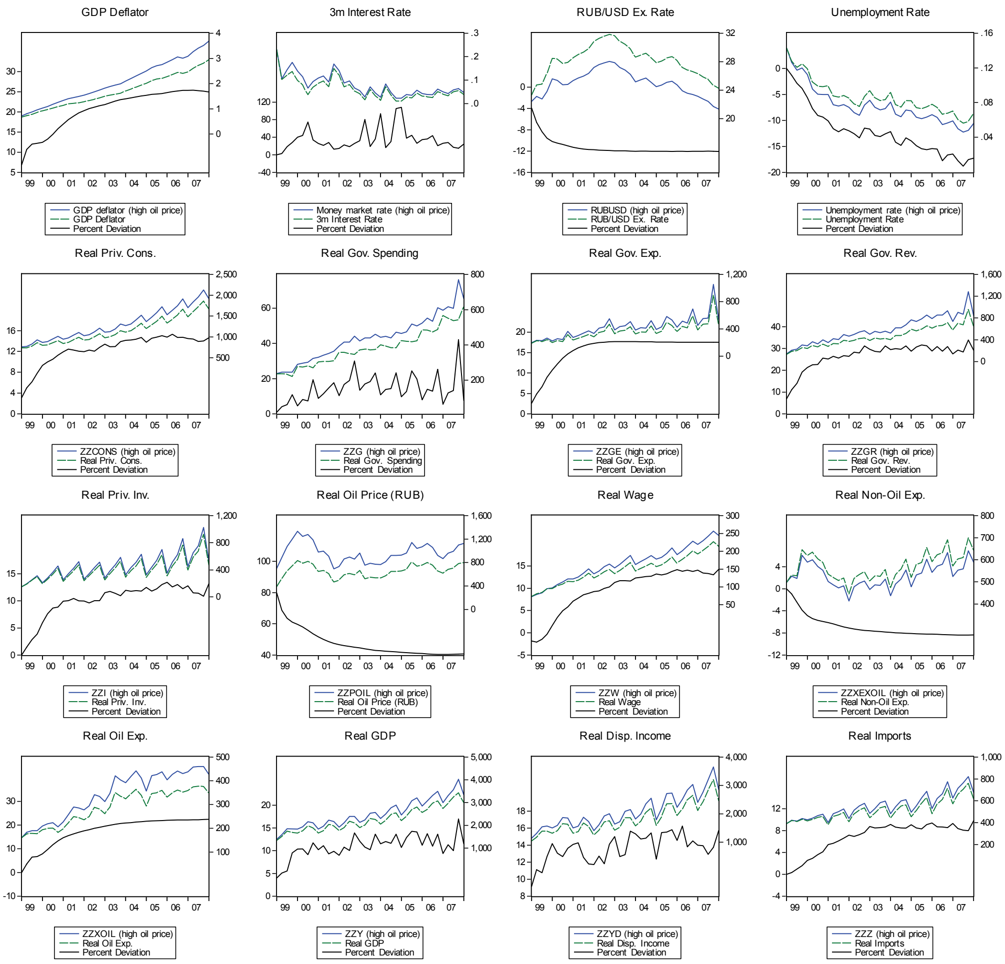
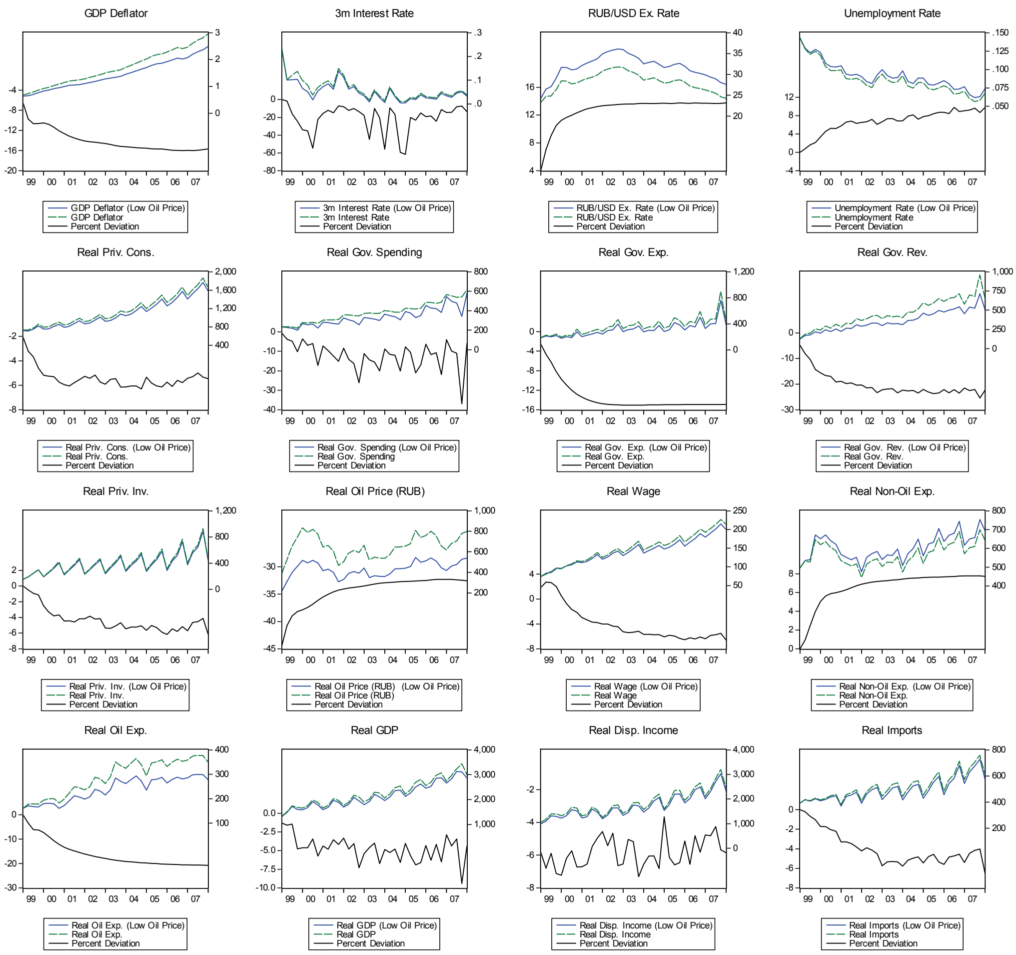


Figure 10 50% sustained oil price decrease



Appendix C

Residual misspecification tests

The null hypothesis of *normal distribution* of the residuals is not rejected for any of the equations at the five per cent level. The Jarque-Bera statistic for each equation is reported in the table below.

If the error term is *serially correlated*, the estimated OLS standard errors are invalid and the estimated coefficients will be biased and inconsistent due to the presence of a lagged dependent variable on the right-hand side. The Breusch-Godfrey LM-test does not reject the null hypothesis of no serial correlation up to order four for any of the equations at the five per cent level.

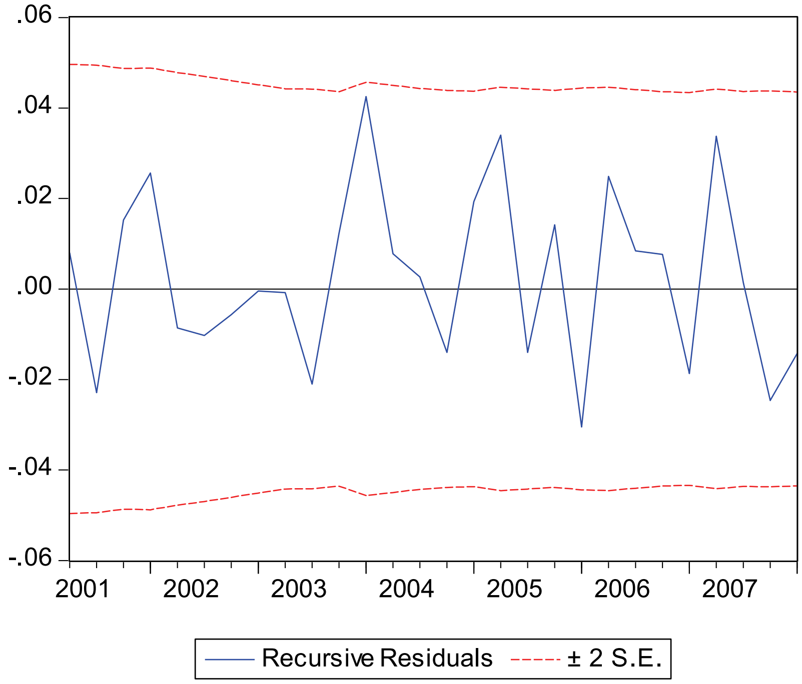
The ARCH test for *heteroskedasticity* in the residual regress the squared residuals on lagged squared residuals and a constant. In the presence of heteroskedasticity, ordinary least squares estimates are still consistent, but the conventional computed standard errors are no longer valid. Heteroscedasticity does not appear to pose a problem in any of the equations.

Equation	Normality Jarque Bera		Serial Correlation Breusch-Godfrey		Heteroskedasticity ARCH	
	Jarque-Bera	Prob.	Obs*R-squared	Prob. Chi-Square(2)	Obs*R-squared	Prob. Chi-Square(1)
CONS	1.483	0.476	5.771	0.056	0.582	0.446
I	1.423	0.491	3.129	0.209	0.147	0.701
XEXOIL	7.095	0.029	1.350	0.509	3.738	0.053
XOIL	0.122	0.941	7.065	0.029	0.803	0.370
Z	0.362	0.835	4.425	0.109	0.0003	0.985
U	3.375	0.184	2.358	0.308	0.593	0.441
W	0.106	0.948	4.027	0.134	0.867	0.352
PY	2.069	0.355	0.787	0.675	0.150	0.699
PC	2.000	0.368	3.320	0.190	0.245	0.621
GE	0.637	0.727	1.459	0.482	0.398	0.528
GR	0.786	0.674	1.548	0.461	3.271	0.071
R	1.613	0.446	1.978	0.372	0.062	0.803
RUBUSD	0.302	0.859	4.815	0.090	1.838	0.175

Stability tests, recursive residuals[10]

In this appendix we display plots of *recursive residuals* for each equation. Plus/minus two standard errors are shown at each point. Residuals outside the standard error bands would suggest instability in the equation parameters. At the 5 per cent level, 5 observations out of 100 outside the error band are acceptable. This test does not give strong indications of instability for any of the equations.

Figure 11 (1) C



[10] EViews only allows for recursive estimation after the last dummy varible, reducing the estimation period for recursive residuals for some equations

Figure 12 (2) I

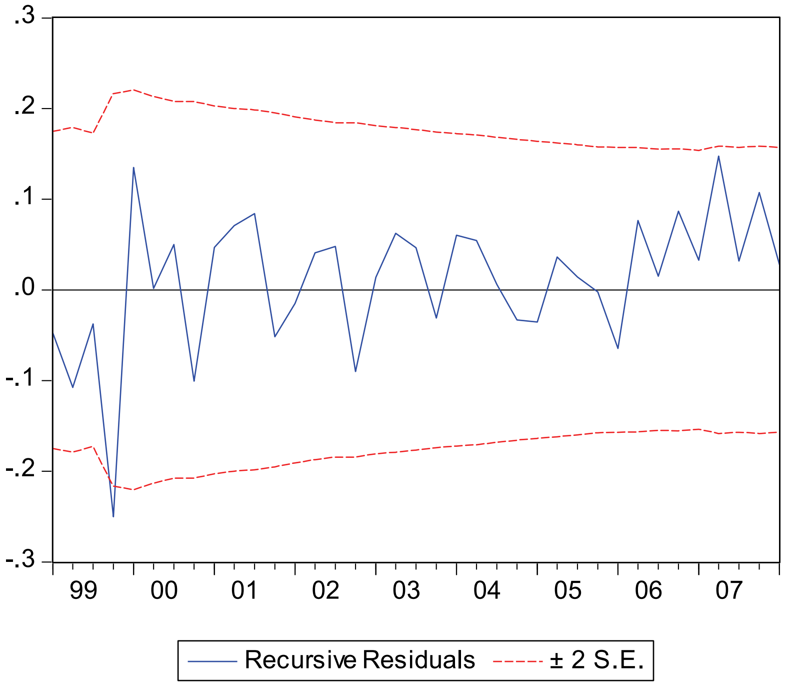


Figure 13 ***(3) XEXOIL***

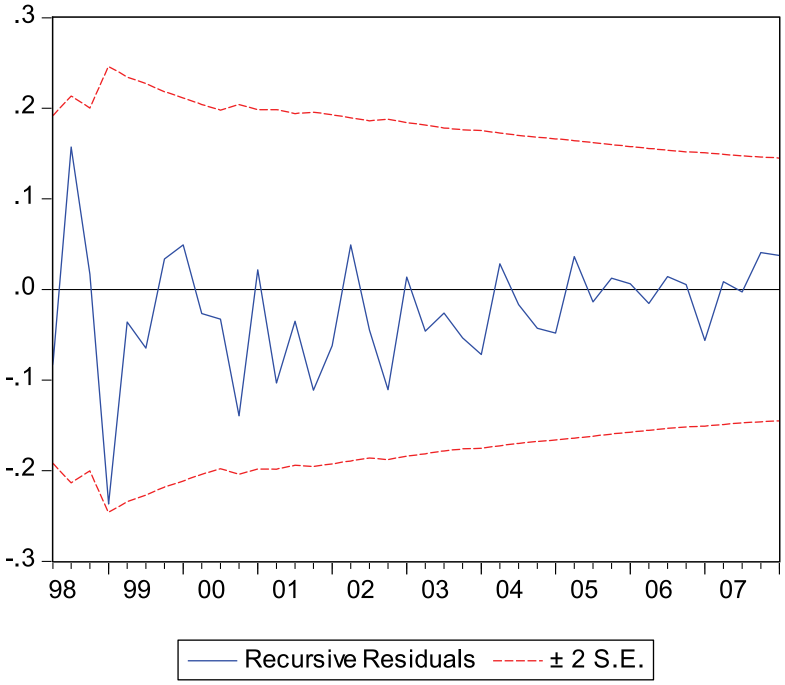


Figure 14 (4) XOIL

Figure 15 (5) Z

Figure 16 (6) U

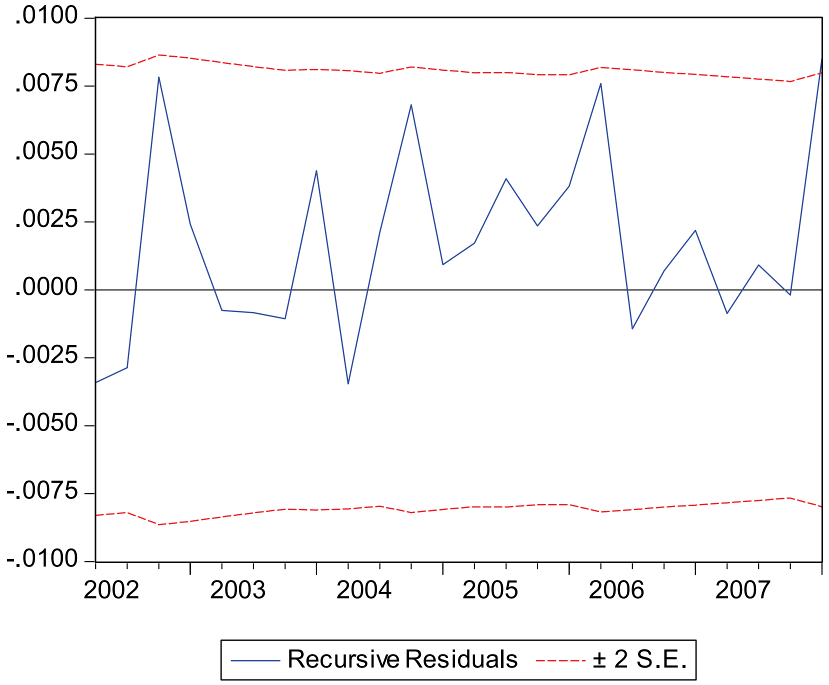


Figure 17 (7) W

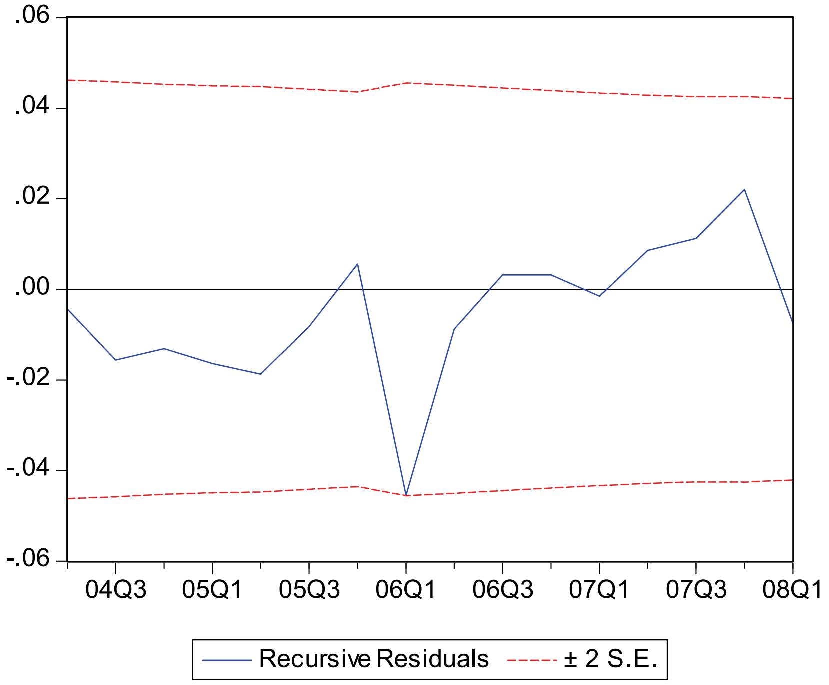


Figure 18 (8) PY

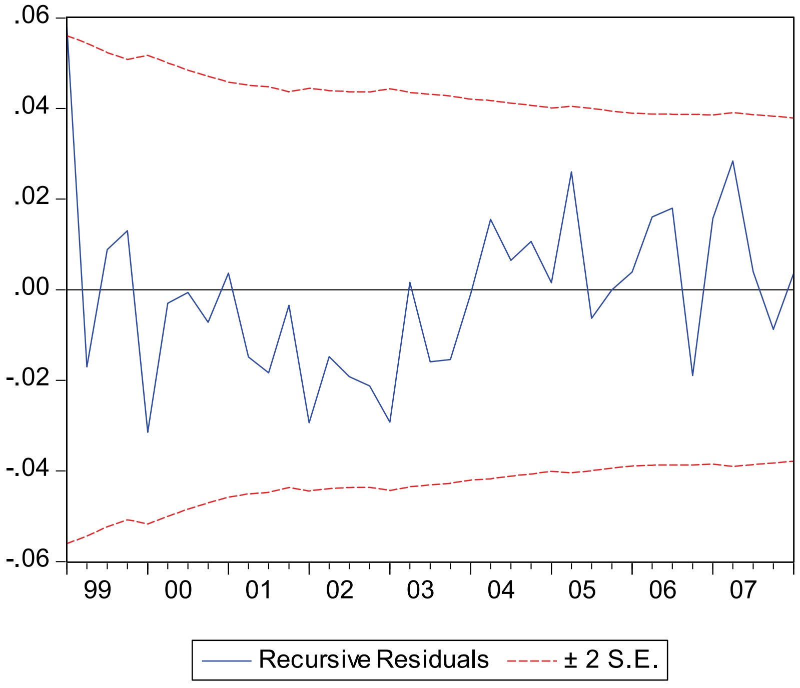


Figure 19 (9) PC

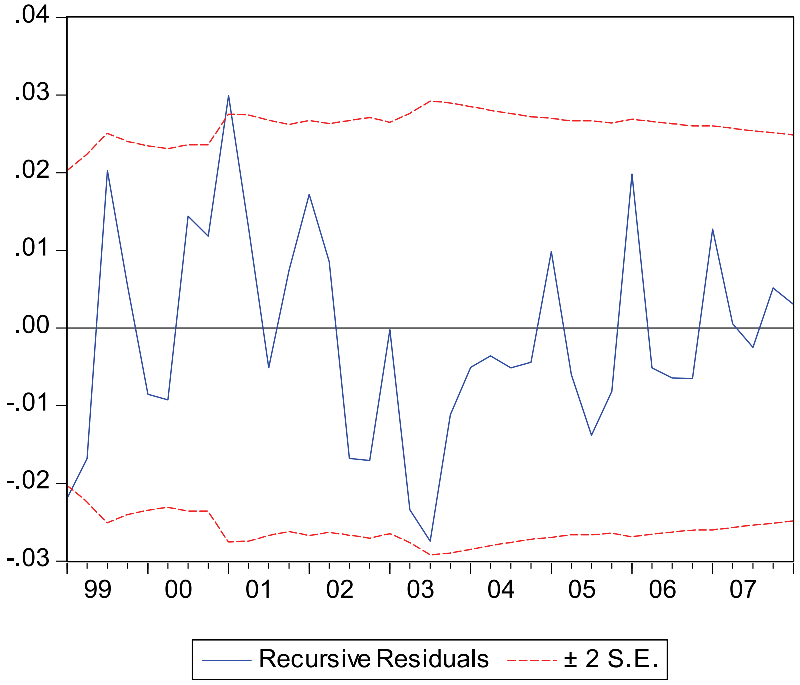


Figure 20 (10) GE

(Not available due to late dummy variable (08Q1)

Figure 21 (11) GR

Figure 22 (12) R

Figure 23 (13) RUBUSD

Appendix E

Detailed estimation results

The R-squared (R^2) statistic measures the success of the regression in predicting the values of the dependent variable within the sample. The statistic will equal one if the regression fits perfectly, and zero if it fits no better than the simple mean of the dependent variable. The adjusted R^2 penalizes the R^2 for the addition of regressors which do not contribute to the explanatory power of the model.

The standard error (S.E.) of the regression is a summary measure based on the estimated variance of the residuals.

The Durbin-Watson (DW) is a test for first order serial correlation in the residuals. As a rule of thumb, if the DW is less than 2, there is evidence of positive serial correlation. If there are lagged dependent variables on the right-hand side of the regression, the DW test is no longer valid. Additional testing of serial correlation is reported in appendix D.

The Akaike-, Schwarz- and Hannan-Quinn information criteria provide measures of information that strikes a balance goodness of fit and parsimonious specification of the model, and are used as a guide in model selection.

The F-statistic reported in the regression output is from a test of the hypothesis that *all* of the slope coefficients (excluding the constant, or intercept) in a regression are zero.

The Prob (F-statistic) shows the probability of drawing a t-statistic (or a z-statistic) as extreme as the one actually observed, under the assumption that the errors are normally distributed, or that the estimated coefficients are asymptotically normally distributed.
The table also shows the mean and the standard deviation of the endogenous (dependent variables.

(1) Consumption:

=========================

Dependent Variable: D(LOG(CONS/PC))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.120871	0.025899	-4.666944	0.0000
LOG(CONS(-1)/PC(-1))-LOG(YD(-1)/PC(-1))	-0.214604	0.057018	-3.763763	0.0005
S2	0.046111	0.016405	2.810829	0.0073
S3	0.043474	0.019195	2.264915	0.0284
S4	0.074759	0.014685	5.091035	0.0000
DSTEP01Q1	-0.028192	0.006278	-4.490578	0.0000
D97Q1	0.085422	0.022954	3.721491	0.0005
D(LOG(YD/PC))	0.346299	0.050087	6.913959	0.0000

R-squared	0.922493	Mean dependent var	0.009489
Adjusted R-squared	0.910437	S.D. dependent var	0.072662
S.E. of regression	0.021746	Akaike info criterion	-4.680548
Sum squared resid	0.021279	Schwarz criterion	-4.383146
Log likelihood	132.0345	Hannan-Quinn criter.	-4.566181
F-statistic	76.51346	Durbin-Watson stat	2.417535
Prob(F-statistic)	0.000000		

(2) Investment:

=========================

Dependent Variable: D(LOG(I/PY))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.204714	0.148918	-8.089785	0.0000
LOG(I(-1)/PY(-1))-LOG(Y(-1)/PY(-1))	-0.378270	0.100879	-3.749723	0.0005
S2	0.724264	0.064083	11.30200	0.0000
S3	0.713019	0.046111	15.46318	0.0000
S4	0.825476	0.040730	20.26723	0.0000
D98Q4	-0.324942	0.081942	-3.965512	0.0003

R-squared	0.965666	Mean dependent var	0.016583
Adjusted R-squared	0.961934	S.D. dependent var	0.402684
S.E. of regression	0.078565	Akaike info criterion	-2.141604
Sum squared resid	0.283936	Schwarz criterion	-1.916460
Log likelihood	61.68170	Hannan-Quinn criter.	-2.055289
F-statistic	258.7577	Durbin-Watson stat	2.321732
Prob(F-statistic)	0.000000		

(3) Non-oil exports:

=========================

Dependent Variable: D(LOG(XEXOIL/PY))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.828396	0.428233	4.269630	0.0001
LOG(XEXOIL(-1)/PY(-1))-LOG(WIMP(-1))	-0.355108	0.081150	-4.375952	0.0001
LOG(PY(-1))-LOG(PYUSA(-1)*RUBUSD(-1))	-0.087683	0.045792	-1.914800	0.0619
S2	0.212675	0.040840	5.207508	0.0000
S3	0.111594	0.030113	3.705792	0.0006
S4	0.215660	0.030916	6.975732	0.0000
D98Q1	-0.239598	0.076137	-3.146906	0.0029
D(LOG(XEXOIL(-1)/PY(-1)))	0.375989	0.110604	3.399412	0.0014

R-squared	0.732149	Mean dependent var	0.002792
Adjusted R-squared	0.690484	S.D. dependent var	0.130267
S.E. of regression	0.072473	Akaike info criterion	-2.272951
Sum squared resid	0.236354	Schwarz criterion	-1.975549
Log likelihood	68.23321	Hannan-Quinn criter.	-2.158584
F-statistic	17.57200	Durbin-Watson stat	1.845679
Prob(F-statistic)	0.000000		

(4) Oil Exports:

=========================

Dependent Variable: D(LOG(XOIL/POILRUB))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.561516	0.193880	2.896196	0.0062
LOG((XOIL(-1)/POILRUB(-1)))	-0.098376	0.033011	-2.980097	0.0050
LOG((POILRUB(-1)/PY(-1)))	0.059965	0.023583	2.542734	0.0152
D98Q4	-0.153863	0.048519	-3.171163	0.0030
D00Q4	-0.113925	0.048184	-2.364374	0.0233
D05Q1	-0.104472	0.046224	-2.260126	0.0296
D03Q3	0.145130	0.046906	3.094068	0.0037
S2	0.093972	0.016430	5.719507	0.0000
S3	0.079233	0.016754	4.729076	0.0000
D(LOG(PY(-3)))	-0.323048	0.156158	-2.068727	0.0454

R-squared	0.745209	Mean dependent var	0.015381
Adjusted R-squared	0.684864	S.D. dependent var	0.079638
S.E. of regression	0.044707	Akaike info criterion	-3.194337
Sum squared resid	0.075950	Schwarz criterion	-2.804504
Log likelihood	86.66410	Hannan-Quinn criter.	-3.047019
F-statistic	12.34910	Durbin-Watson stat	2.367842
Prob(F-statistic)	0.000000		

(5) Imports:

========================

Dependent Variable: D(LOG(Z/PY))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.384194	0.165874	-2.316180	0.0253
LOG(Z(-1)/PY(-1))	-0.292049	0.072803	-4.011495	0.0002
LOG(CONS(-1)/PC(-1))+LOG(I(-1)/PY(-1))+LOG(G(-1)/PY(-1))+LOG(XEXOIL(-1)/PY(-1))	0.078760	0.016876	4.667018	0.0000
S2	0.324207	0.017044	19.02138	0.0000
S3	0.291994	0.016596	17.59469	0.0000
S4	0.269016	0.015949	16.86766	0.0000
D95Q3	-0.199719	0.040101	-4.980410	0.0000
D99Q1	0.212880	0.040251	5.288848	0.0000
D00Q1	0.205820	0.040503	5.081556	0.0000

R-squared	0.921690	Mean dependent var	0.001451
Adjusted R-squared	0.907452	S.D. dependent var	0.124809
S.E. of regression	0.037969	Akaike info criterion	-3.550576
Sum squared resid	0.063432	Schwarz criterion	-3.215998
Log likelihood	103.0903	Hannan-Quinn criter.	-3.421914
F-statistic	64.73387	Durbin-Watson stat	2.112284
Prob(F-statistic)	0.000000		

(6) Unemployment:

Dependent Variable: D(U)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.198772	0.038910	5.108514	0.0000
U(-1)	-0.243674	0.050797	-4.797051	0.0000
LOG(Y(-1)/PY(-1))	-0.028316	0.007164	-3.952348	0.0003
S2	-0.012241	0.001552	-7.884774	0.0000
S3	-0.008213	0.001481	-5.544345	0.0000
LOG(W(-1)/PY(-1))	0.008918	0.005809	1.535208	0.1317
D99Q1	0.012710	0.004264	2.980743	0.0046
D02Q1	-0.010002	0.004207	-2.377218	0.0218

R-squared	0.682786	Mean dependent var	-0.000145
Adjusted R-squared	0.633442	S.D. dependent var	0.006600
S.E. of regression	0.003996	Akaike info criterion	-8.068888
Sum squared resid	0.000718	Schwarz criterion	-7.771485
Log likelihood	221.8255	Hannan-Quinn criter.	-7.954521
F-statistic	13.83718	Durbin-Watson stat	1.743767
Prob(F-statistic)	0.000000		

(7) Wages:

========================

Dependent Variable: D(LOG(W))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.678678	0.154673	4.387832	0.0001
LOG(W(-1))-LOG(PC(-1))	-0.267254	0.042086	-6.350246	0.0000
U(-1)	-1.136862	0.310776	-3.658145	0.0007
LOG(PROD(-1))	0.211739	0.040898	5.177198	0.0000
S2	0.086405	0.008895	9.713780	0.0000
S4	0.077974	0.008839	8.821658	0.0000
S3	0.076445	0.008888	8.600623	0.0000
D04Q1	-0.080752	0.022445	-3.597741	0.0008
D(LOG(PC(-1)))	0.280352	0.053182	5.271572	0.0000

R-squared	0.913491	Mean dependent var	0.073885
Adjusted R-squared	0.897762	S.D. dependent var	0.065873
S.E. of regression	0.021063	Akaike info criterion	-4.729114
Sum squared resid	0.019520	Schwarz criterion	-4.394536
Log likelihood	134.3215	Hannan-Quinn criter.	-4.600451
F-statistic	58.07698	Durbin-Watson stat	2.490735
Prob(F-statistic)	0.000000		

(8) GDP Deflator:

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Dependent Variable: D(LOG(PY)) ======

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Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.121735	0.117741	-9.527172	0.0000
LOG(PY(-1))	-0.415577	0.042377	-9.806562	0.0000
LOG(W(-1))	0.202693	0.021926	9.244413	0.0000
LOG(PCEU(-1)*RUBEUR(-1))+LOG(POILRUB(-1))	0.061878	0.008830	7.007376	0.0000
D(LOG(POILRUB))	0.101800	0.020539	4.956377	0.0000
D(LOG(PY(-1)))	0.383897	0.055803	6.879550	0.0000
D98Q4	0.164627	0.023458	7.017857	0.0000

R-squared	0.946159	Mean dependent var	0.064091
Adjusted R-squared	0.939137	S.D. dependent var	0.076752
S.E. of regression	0.018935	Akaike info criterion	-4.973099
Sum squared resid	0.016493	Schwarz criterion	-4.712872
Log likelihood	138.7871	Hannan-Quinn criter.	-4.873028
F-statistic	134.7290	Durbin-Watson stat	2.014737
Prob(F-statistic)	0.000000		

(9) CPI:

=========================

Dependent Variable: D(LOG(PC))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.111547	0.194940	-5.701990	0.0000
LOG(PC(-1))	-0.313133	0.054622	-5.732768	0.0000
LOG(W(-1))+LOG(PCEU(-1)*RUBEUR(-1))	0.120833	0.022999	5.253882	0.0000
LOG(POIL(-1)*RUBUSD(-1))	0.026761	0.009497	2.817987	0.0073
D95Q1	0.065247	0.028220	2.312079	0.0256
D95Q2	-0.067428	0.021886	-3.080953	0.0036
D95Q3	-0.047170	0.018267	-2.582284	0.0133
D98Q4	0.268382	0.013968	19.21437	0.0000
D98Q3	0.144525	0.013967	10.34745	0.0000
D(LOG(PC(-1)))	0.505479	0.035639	14.18329	0.0000

R-squared	0.979181	Mean dependent var	0.061510
Adjusted R-squared	0.974823	S.D. dependent var	0.078329
S.E. of regression	0.012429	Akaike info criterion	-5.769353
Sum squared resid	0.006642	Schwarz criterion	-5.397600
Log likelihood	162.8879	Hannan-Quinn criter.	-5.626395
F-statistic	224.7090	Durbin-Watson stat	1.662099
Prob(F-statistic)	0.000000		

(10)Government Expenditure:

========================

Dependent Variable: D(LOG(GE/PY))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.214844	0.317956	0.675705	0.5030
LOG(GE(-1)/PY(-1))	-0.131642	0.053691	-2.451830	0.0186
S2	0.433663	0.039040	11.10828	0.0000
S3	0.270033	0.035624	7.580015	0.0000
S4	0.541357	0.051523	10.50707	0.0000
LOG(POIL(-1)*RUBUSD(-1))	0.037635	0.011499	3.272969	0.0022
D05Q3	0.259043	0.088624	2.922930	0.0056
D05Q4	-0.243054	0.092321	-2.632694	0.0119
D96Q1	0.491896	0.091955	5.349316	0.0000
D07Q4	0.515132	0.094485	5.452008	0.0000
D08Q1	-0.347472	0.097995	-3.545827	0.0010
D(LOG(GE(-3)/PY(-3)))	0.260095	0.096245	2.702428	0.0100

R-squared	0.907185	Mean dependent var	-0.004731
Adjusted R-squared	0.882283	S.D. dependent var	0.244449
S.E. of regression	0.083870	Akaike info criterion	-1.922981
Sum squared resid	0.288403	Schwarz criterion	-1.476877
Log likelihood	62.95900	Hannan-Quinn criter.	-1.751431
F-statistic	36.43064	Durbin-Watson stat	2.247138
Prob(F-statistic)	0.000000		

(11) Government Revenue:

========================

Dependent Variable: D(LOG(GR/PY))

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.301172	0.226087	1.332108	0.1895
LOG(GR(-1)/PY(-1))	-0.129020	0.051704	-2.495352	0.0163
LOG(POIL(-1)*RUBUSD(-1))	0.059846	0.019867	3.012332	0.0042
S2	0.159549	0.036424	4.380319	0.0001
S4	0.166698	0.034823	4.787028	0.0000
D(LOG(Y/PY))	0.656659	0.153510	4.277641	0.0001
D96Q1	0.546122	0.107700	5.070779	0.0000
D05Q1	0.310960	0.106129	2.930029	0.0053

R-squared	0.698075	Mean dependent var	0.012244
Adjusted R-squared	0.651109	S.D. dependent var	0.170825
S.E. of regression	0.100901	Akaike info criterion	-1.611097
Sum squared resid	0.458145	Schwarz criterion	-1.313695
Log likelihood	50.69407	Hannan-Quinn criter.	-1.496730
F-statistic	14.86337	Durbin-Watson stat	2.187674
Prob(F-statistic)	0.000000		

(12) Money market rate:

=========================

Dependent Variable: D(R)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.040272	0.022668	1.776621	0.0873
R(-1)	-0.637271	0.111815	-5.699358	0.0000
DPC(-1)	0.182308	0.062240	2.929127	0.0070
U(-1)	-0.507527	0.346651	-1.464089	0.1552
D99Q2	-0.323859	0.141256	-2.292704	0.0302
D99Q3	-0.239645	0.075238	-3.185165	0.0037
D01Q4	0.081950	0.019018	4.308998	0.0002
D(DPC(-1))	-0.179025	0.062266	-2.875156	0.0080
D(DPC(-2))	-0.077936	0.025368	-3.072157	0.0049
D(U)	-1.502241	0.592493	-2.535457	0.0176
D(U(-3))	-1.069032	0.592035	-1.805689	0.0826

R-squared	0.923789	Mean dependent var	-0.012432
Adjusted R-squared	0.894477	S.D. dependent var	0.055268
S.E. of regression	0.017954	Akaike info criterion	-4.960284
Sum squared resid	0.008381	Schwarz criterion	-4.481362
Log likelihood	102.7653	Hannan-Quinn criter.	-4.791442
F-statistic	31.51570	Durbin-Watson stat	2.391560
Prob(F-statistic)	0.000000		

(13) RUBUSD:

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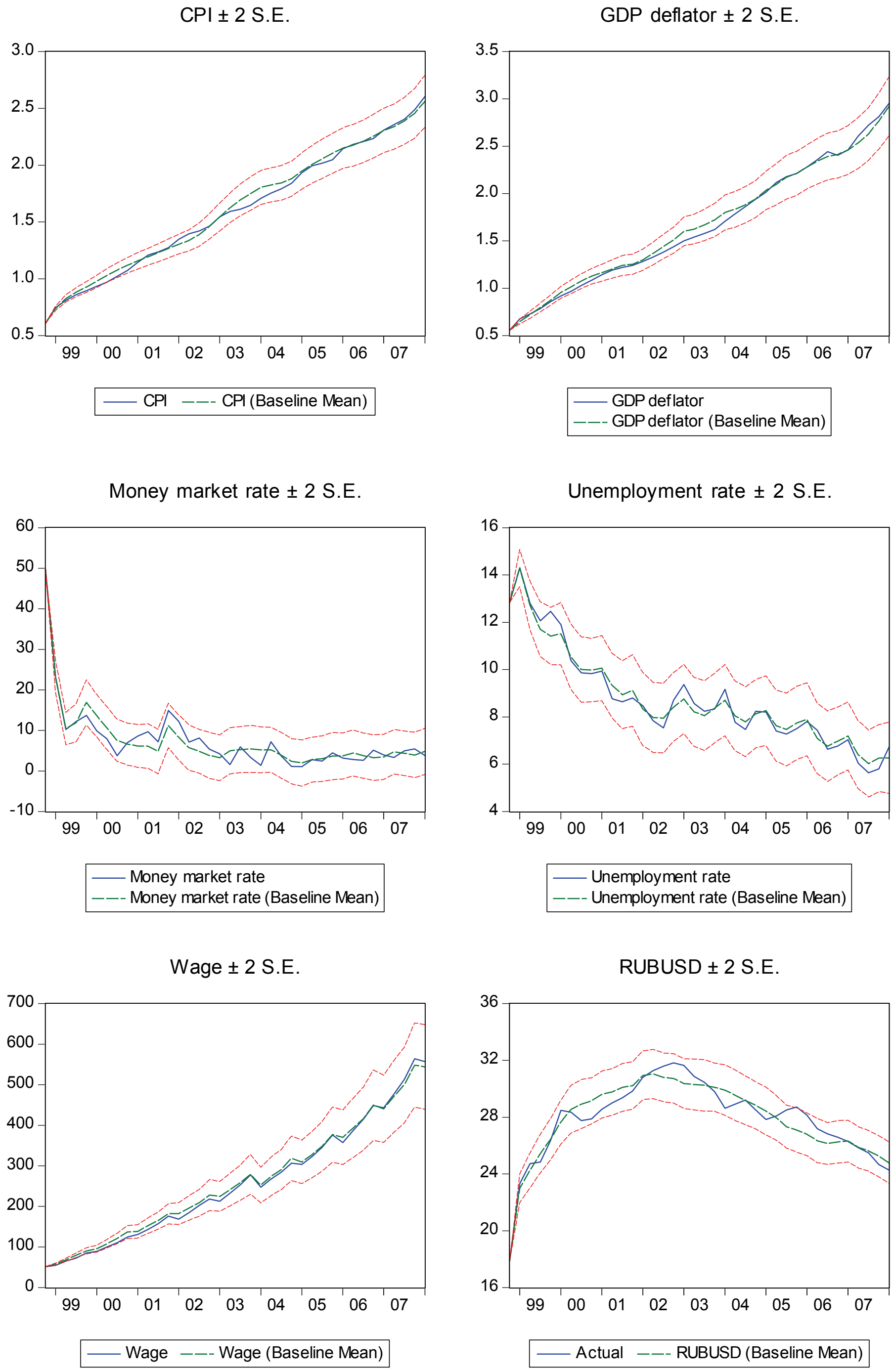
Dependent Variable: D(LOG(RUBUSD))

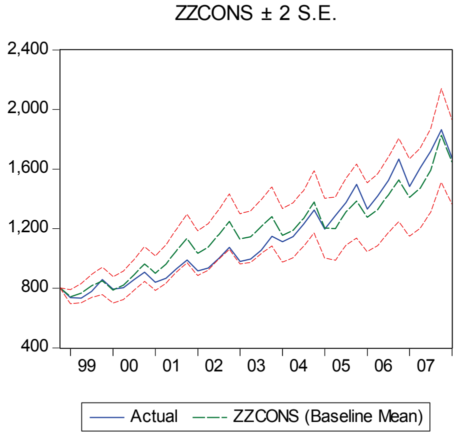
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.251254	0.161952	7.726055	0.0000
LOG(RUBUSD(-1))	-0.311048	0.044275	-7.025404	0.0000
LOG(POIL(-1))	-0.057695	0.008822	-6.539799	0.0000
D(LOG(POIL))	-0.065333	0.030495	-2.142393	0.0401
D(R)	-0.268828	0.087294	-3.079569	0.0043
D(LOG(RUBUSD(-2)))	-0.122892	0.036785	-3.340781	0.0022

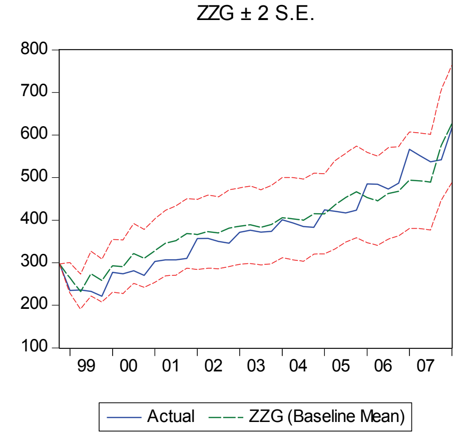
R-squared	0.860749	Mean dependent var	0.008278
Adjusted R-squared	0.838290	S.D. dependent var	0.050834
S.E. of regression	0.020442	Akaike info criterion	-4.795065
Sum squared resid	0.012954	Schwarz criterion	-4.533835
Log likelihood	94.70871	Hannan-Quinn criter.	-4.702969
F-statistic	38.32406	Durbin-Watson stat	1.455416
Prob(F-statistic)	0.000000		

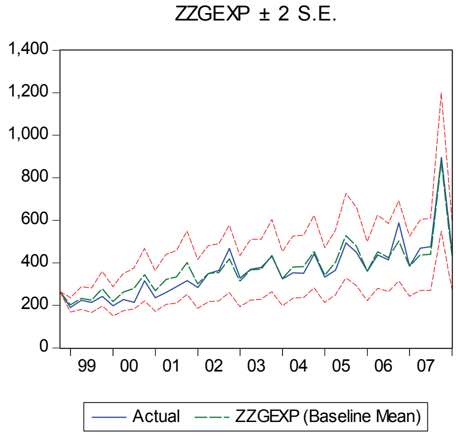
In-sample dynamic simulation

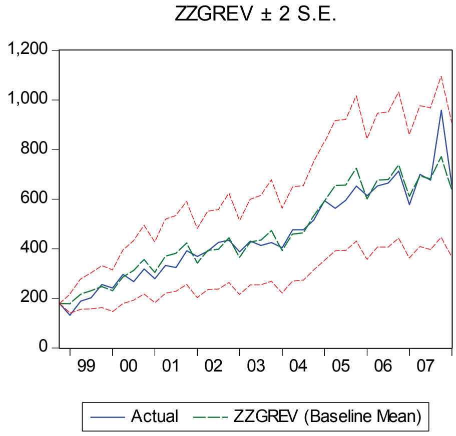
Actual and fitted values of the dependent variable including error bounds (+/-2*std.e.).

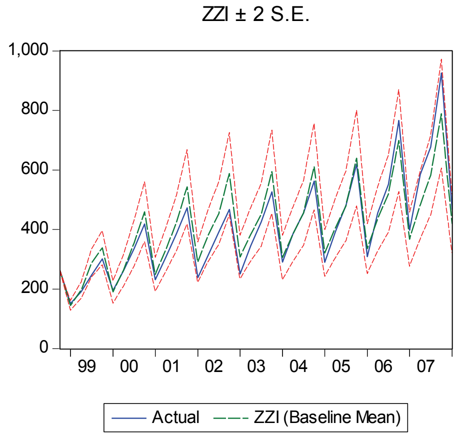


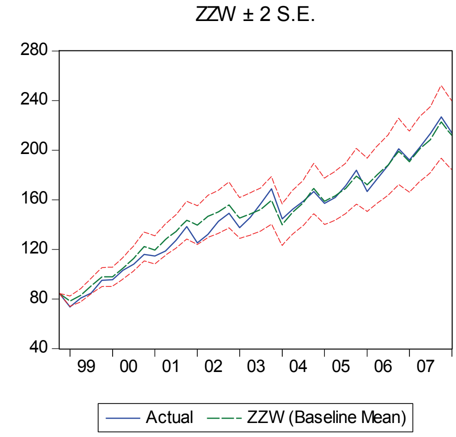

ZZCONS ± 2 S.E.
2,400
2,000
1,600
1,200
800
400
99 00 01 02 03 04 05 06 07
Actual
ZZCONS (Baseline Mean)

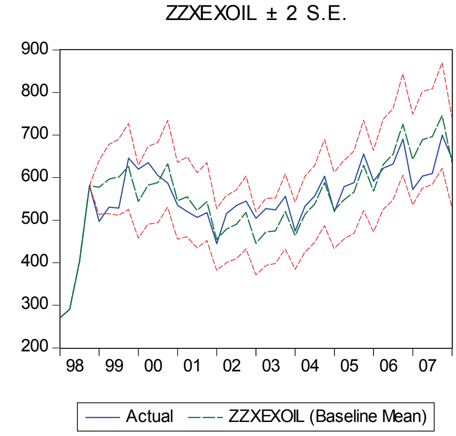

ZZG ± 2 S.E.
800
700
600
500
400
300
200
100
99 00 01 02 03 04 05 06 07
Actual
ZZG (Baseline Mean)

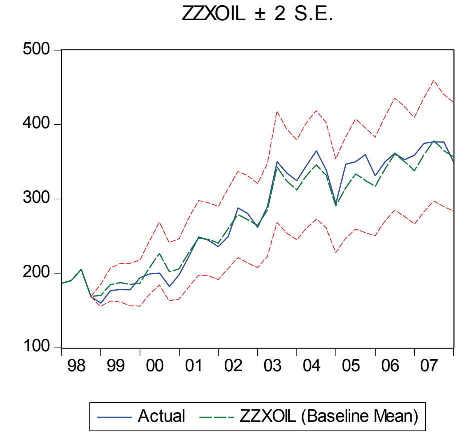

ZZGEXP ± 2 S.E.
1,400
1,200
1,000
800
600
400
200
0
99 00 01 02 03 04 05 06 07
Actual
ZZGEXP (Baseline Mean)

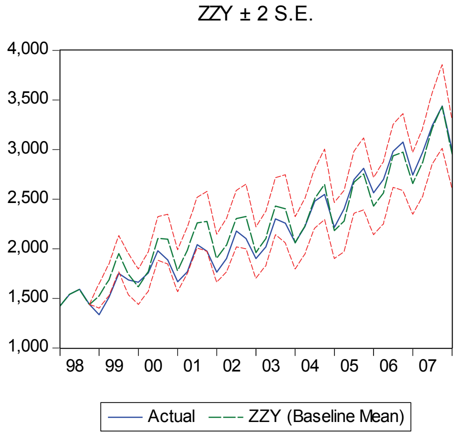

ZZGREV ± 2 S.E.
1,200
1,000
800
600
400
200
0
99 00 01 02 03 04 05 06 07
Actual
ZZGREV (Baseline Mean)

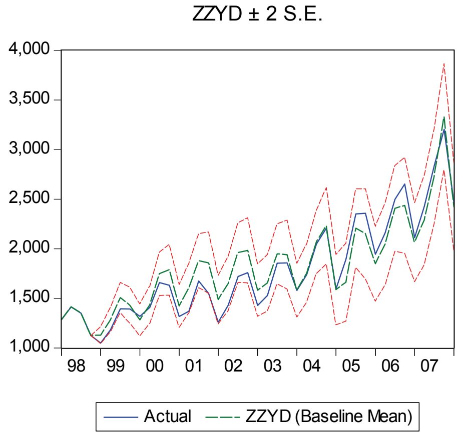

ZZI ± 2 S.E.
1,000
800
600
400
200
0
99 00 01 02 03 04 05 06 07
Actual
ZZI (Baseline Mean)

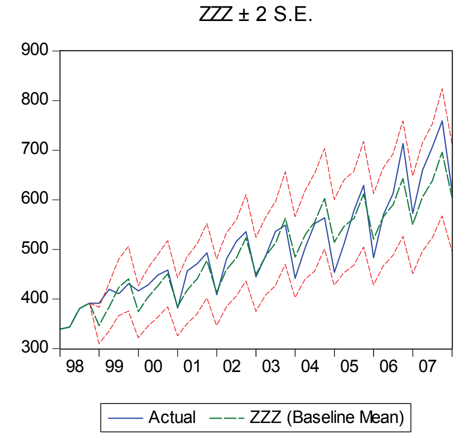

ZZW ± 2 S.E.
280
240
200
160
120
80
40
99 00 01 02 03 04 05 06 07
Actual
ZZW (Baseline Mean)


ZZXEXOIL ± 2 S.E.
900
800
700
600
500
400
300
200
98 99 00 01 02 03 04 05 06 07
Actual
ZZXEXOIL (Baseline Mean)


ZZXOIL ± 2 S.E.
500
400
300
200
100
98 99 00 01 02 03 04 05 06 07
Actual
ZZXOIL (Baseline Mean)


ZZY ± 2 S.E.
4,000
3,500
3,000
2,500
2,000
1,500
1,000
98 99 00 01 02 03 04 05 06 07
Actual
ZZY (Baseline Mean)


ZZYD ± 2 S.E.
4,000
3,500
3,000
2,500
2,000
1,500
1,000
98 99 00 01 02 03 04 05 06 07
Actual
ZZYD (Baseline Mean)


ZZZ ± 2 S.E.
900
800
700
600
500
400
300
98 99 00 01 02 03 04 05 06 07
Actual
ZZZ (Baseline Mean)