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Monetary policy in an oil-dependent economy in the presence of multiple shocks

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Abstract
Russian monetary policy has been challenged by large and continuous private capital outflows and a sharp drop in oil prices during 2014. Both contributed to significant depreciation pressures on the ruble and led the central bank to give up its exchange rate management strategy. Against this background, this work estimates a small open economy model for Russia, featuring an oil price sector and extended by a specification of the foreign exchange market to correctly account for systematic central bank interventions. We find that shocks to the oil price and private capital flows substantially affect domestic variables such as inflation and output. Simulations for the estimated actual strategy and alternative regimes suggest that the vulnerability of the Russian economy to external shocks can substantially be lowered by adopting some form of inflation targeting. Strategies to target the nominal exchange rate or the ruble price of oil prove to be inferior.

Keywords Monetary policy · Exchange rate interventions · Oil price · Capital flows

JEL Classification E52 · F31 · F41 · G15

1 Introduction

After Russian GDP growth already slowed down in 2013, increased political uncertainty and sanctions related to the annexation of the Crimean peninsula have amplified capital outflows and the economic downturn in 2014. In addition, the sharp fall in oil prices in the second half of the year reduced capital inflows and output growth even further. In order to prevent a sharp depreciation of the ruble and an increase in domestic inflation as a result thereof, the central bank raised its key policy rate in six steps by 1150 basis points during 2014. In addition, it directly intervened in the foreign exchange (FX) market by selling parts of its currency reserves until it officially

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allowed the ruble to freely float. Whereas a strong devaluation could not have been prevented and the exchange rate management has been eventually given up, raised interest rates might have posed an additional obstacle for the already weak economy. Against this background, this work aims at analyzing and assessing the monetary policy of the Russian central bank in the presence of simultaneously occurring shocks to the oil price and capital outflows. To correctly account for specific features of the Russian economy, the oil sector as well as a mirco-founded foreign exchange market are introduced into a small open economy DSGE model estimated for Russia. Simulations are conducted for different alternative policy strategies that are subsequently assessed on the basis of the effects they have on particular variables of interest.

The importance of the fuel sector for the Russian economy is huge. According to data from the Bank of Russia, exports of oil, oil products and natural gas constituted on average more than 60 percent of total goods exports from 2001 until 2015. Their share in total output averaged 16 percent over the same period. The high correlation of 0.88 (0.94 when expressed in ruble terms) between changes in the price of oil and GDP growth suggests that fluctuations in the revenues from fuel exports that are caused by price dynamics have a substantial impact on the domestic economic activity. By the same token, the Russian trade balance is strongly affected by the oil price leading to appreciation (depreciation) pressures on the ruble in the wake of rising (falling) oil prices. In order to smooth their impact on the domestic economy, the Bank of Russia (CBR) has implemented a managed floating exchange rate regime in 1999 under which it conducted operations on the foreign exchange market. Over the following years, the CBR's exchange rate policy underwent gradual changes. Most importantly, the operational target for the dollar/euro dual-currency basket has been changed from a fixed to a floating band. In general, the exchange rate management to limit ruble exchange rate fluctuations via interventions remained officially in place until November 2014 after not being able to counteract the ongoing large capital outflows. However, it still engaged in FX interventions during 2015.

This study analyzes the managed floating exchange rate regime within a framework that considers relevant aspects for the Russian economy and its monetary policy in particular. In doing so, we add to the literature on the optimal reaction of monetary policy in the presence of commodity price shocks and the implementation of foreign exchange interventions into dynamic stochastic general equilibrium (DSGE) models. Bernanke et al. (1997) and Gertler et al. (1999) argue that an insufficient monetary policy reaction to oil price shocks amplifies the negative influences of the shock. Their conclusion stems from the empirical evidence of the 1970s when the Federal Reserve raised interest rates too little to curb the impact of the oil price shocks on inflation and inflation expectations. On the other hand, the policy tightening was too strong that it led to adverse implications for the real economy. While these conclusions can be applied to other oil-importing economies, implications on the effects of commodity price shocks and optimal monetary policy would differ for exporting countries such as Russia. In an estimated DSGE model for Canada, Dib (2008) finds that commodity price shocks significantly contribute to real business cycle dynamics. In that context, flexible exchange rates can offset some of the negative effects from external shocks. Sosunov and Zamulin (2007) and Semko (2013) employ DSGE models calibrated as well as estimated for the Russian economy to conclude that a monetary policy reaction to oil price shocks is redundant if oil revenues can be saved in some stabilization fund. Sosunov and Zamulin (2007) find consumer price inflation (CPI) targeting to be the optimal monetary policy in the case of Russia. Herz et al. (2015) calibrate the model by Ratto et al. (2009) to the Russian economy to conclude that CPI targeting is superior to the alternative of targeting the ruble price of oil, a strategy following the idea proposed by Frankel (2005) to target the price of the most important export commodity expressed in local currency.

The most recent and detailed work on the Russian economy within a DSGE framework is the one by Malakhovskaya and Minabutdinov (2014). They find evidence for commodity export shocks affecting domestic production in the short-run as well as the long-term. However, although the authors account for many important features of the Russian economy, they assume a completely floating exchange rate and by that ignore the implications that exchange rate management might has on the transmission of shocks. To address this deficiency, the framework of this study is designed to explicitly account for the exchange rate policy of the CBR that has been described as a strategy to smooth the behavior of the ruble's exchange rate against the US dollar and later a dual-currency basket consisting of the dollar and the euro.

Whereas the inclusion of the nominal exchange rate in the policy rate reaction function is a common feature of small open economy (SOE) models, little work has been done so far to take into account direct central bank interventions on the foreign exchange market that are characteristic for most of the economies targeting the dynamics of their nominal exchange rate. Benes et al. (2015) built on a financial sector following Edwards and Vegh (1997) and construct a model in which sterilized central bank interventions stabilize the exchange rate but also change the portfolio composition of domestic commercial banks that entail further macroeconomic consequences via changes in the domestic credit rates. Herrera et al. (2013) extend their framework by considering an oil-exporting sector and calibrate the model parameters to the Colombian economy to argue that foreign exchange intervention increases the volatility of credit supply and consumption compared to the alternative policy strategy of inflation targeting via an interest rate rule. Another approach to account for foreign exchange interventions has been proposed by Montoro and Ortiz (2016) who built on Bacchetta and Van Wincoop (2006) to incorporate market microstructure of exchange rate determination into a SOE model. In particular, they assume that the foreign exchange market is operated by risk-averse dealers that process sale and purchase orders for foreign securities in exchange for domestic bonds from foreign investors and the domestic central bank. Interventions of the latter will cause the ratio of domestic to foreign assets held by the dealers and their demanded risk premium to change causing immediate movements in the nominal exchange rate. Based on their calibrated model, they argue that intervention can shelter the domestic economy from external shocks, in particular if they are rule-based. Malovana (2015) conducts a similar analysis for the Czech Republic. However, she excludes rule-based interventions from the estimated model specifications and analyzes their implication for the transmission of shocks in calibrated simulations only.

We build on the idea proposed by Montoro and Ortiz (2016) and further expand their model by an oil-exporting sector as well as productive capital. The resulting framework exhibits all necessary features of the Russian economy in general and the monetary policy in particular and enables the analysis of the effects that shocks to the oil price and capital flows, two key external disturbances, have on domestic variables in the presence of different monetary policy strategies.

The remainder of the paper is structured as follows: Sect. 2 presents the derivation of the model equations. Details on the estimation are outlined in Sect. 3.2. Estimation results and an analysis of the vulnerability of the domestic economy based on the estimated parameters and shocks are presented in Sect. 4, whereas Sect. 5 analyzes alternative policy strategies to cope with external shocks based on the estimated model parameters and the policy strategy in place. Section 6 concludes.

2 Model

The model used for estimation and simulation in the following sections is built on the standard small open economy (SOE) model in the spirit of Galí and Monacelli (2005), Monacelli (2005) and Justiniano and Preston (2010), featuring several kinds of rigidities like Calvo (1983)-pricing, partial indexation, habit formation and deviations from the law of one price for internationally-traded goods. However, it is extended in several ways to exhibit important characteristics of the Russian economy. In particular, we include an oil sector whose export revenues generate income for domestic households. For an appropriate representation of the monetary policy, we follow Montoro and Ortiz (2016) in incorporating a foreign exchange market on which the central bank can influence its currency's exchange rate via sales and purchases of foreign securities. Finally, contrary to standard SOE models that abstract from investment, we allow for the formation of productive capital to gauge the effects that monetary policy has on its dynamics via the interest rate channel. The remainder of this section derives the model equations from the optimal behavior of the different agents and sectors in the economy that are non-standard and the consequential equilibrium conditions for particular markets and dynamics of individual variables.[1] The full set of log-linearized model equations used for estimation and simulations is laid out in online Appendix B.

2.1 Global economy and oil price

Based on the small open economy assumption, the behavior of foreign economy variables is assumed to be exogenous to the development of domestic variables. We follow Justiniano and Preston (2010) in specifying the dynamics of the rest of the world output, inflation and interest rate as an VAR(2) in logs. Similar to Bjørnland et al. (2018), we also include the oil price in the VAR to account for the mutual dynamics of world economic activity and the oil price, such that:

[1] For the derivation of behavioral equations of particular sectors that are standard in the DSGE literature the reader is referred to online Appendix A.

$$A_0 \begin{bmatrix} y_t^* \\ \pi_t^* \\ p_{o,t} \\ r_t^* \end{bmatrix} = \begin{bmatrix} \rho_{11}^* & \rho_{12}^* & \cdots & \rho_{16}^* \\ \rho_{21}^* & \rho_{22}^* & \cdots & \rho_{26}^* \\ \rho_{31}^* & \rho_{32}^* & \cdots & \rho_{36}^* \\ \rho_{41}^* & \rho_{42}^* & \cdots & \rho_{46}^* \end{bmatrix} \begin{bmatrix} y_{t-1}^* \\ y_{t-2}^* \\ \pi_{t-1}^* \\ \cdots \\ r_{t-2}^* \end{bmatrix} + \begin{bmatrix} \eta_t^{y^*} \\ \eta_t^{\pi^*} \\ \eta_t^{o} \\ \eta_t^{r^*} \end{bmatrix}, \tag{1}$$

where $\eta_t^{y^*}$, $\eta_t^{\pi^*}$, η_t^o and $\eta_t^{r^*}$ are i.i.d. normal shocks with zero mean and standard deviations $\sigma_{\eta^{y^*}}$, $\sigma_{\eta^{\pi^*}}$, σ_{η^o} and $\sigma_{\eta^{r^*}}$, whereas A_0 is a lower triangular matrix of coefficients. The latter specification is based on Kilian (2009) and implies that shocks to economic activity have an immediate impact on the oil price, while shocks to the latter affect the global economy only with a lag.

2.2 Oil-exporting sector

The economy is endowed with an infinite amount of oil that is exported at the world market price in foreign currency, $P_{o,t}$. In every period, revenues of the oil sector in local currency units are then given by:

$$Y_{o,t} = \tilde{e}_t P_{o,t} O_t, \tag{2}$$

where O_t is the exported volume, that is assumed to be a constant fraction of total world oil demand, with the latter being a function of world economic activity. This simplifying assumption is motivated by data from BP (2021) according to which Russia's share in world oil exports is more or less constant over the time period considered in this analysis.[2] Russia's oil export volume can hence be specified as an ad-hoc function (in logs):

$$o_t = \rho_{oild} o_{t-1} + \left(1 - \rho_{oild}\right)\left(\phi_{y^*} y^*\right) + \eta_t^{oild}, \tag{3}$$

where ρ_{oild} is a smoothing parameter and η_t^{oild} is an i.i.d. shock term with zero mean and variance $\sigma^2_{\eta^{oild}}$.

We are aware of the overall simplistic modeling of the oil-exporting sector, in particular the abstraction from any supply-side determinants of output. However, since we are interested in the analysis of how the monetary policy's reaction to oil price shocks affects economic activity in the short-term and, moreover, we use time series for all foreign variables as well as world oil demand, we are able to account for all relevant dynamics without putting too much attention on potential supply-side effects that might unveil in the longer term and that are clearly beyond the focus of this paper. In addition, data from BP (2021) shows that, both, Russia's oil exports (in barrels) and real GDP grew by comparable average rates over the period of analysis, suggesting that the oil sector has not experienced an exceptional development in terms of factor inputs and productivity that should be investigated in more detail.

[2] Between 2005 and 2015, the share of Russia's oil exports in total world exports fluctuated in a narrow range between 12.4 and 13.6 percent.

2.3 Foreign exchange dealers

Following Montoro and Ortiz (2016), we extend the otherwise standard model by a continuum of risk-averse dealers d on the unit interval that operate the secondary bond market by executing orders they receive from households, foreign investors and the domestic central bank. Whereas households and foreign investors hold only domestic and foreign bonds, respectively, the central bank engages in both types of securities. It is assumed to exchange the domestic bonds it issues for foreign securities. Each of the dealers receives purchase or sale orders for domestic bonds from households and the central bank, $\omega_t(d)$ and $\omega_{CB,t}(d)$, as wells as purchase or sale orders for foreign bonds from foreign investors and the central bank, $\omega_t^*(d)$ and $\omega_{CB,t}^*(d)$. All dealers receive the same amounts of orders, that are exchanged among each other. At the end of every period, the holdings of domestic and foreign bonds of each dealer, $B_t(d)$ and $B_t^*(d)$, are given by:

$$B_t(d) + \tilde{e}_t B_t^*(d) = \omega_t(d) - \omega_{CB,t}(d) + \tilde{e}_t\Big(\omega_t^*(d) + \omega_{CB,t}^*(d)\Big). \tag{4}$$

All dealers' profits are transferred to the households.

Dealers are assumed to be risk-averse and short-sighted. They maximize their expected end-of-period utility which is given by the following constant absolute risk aversion function:

$$-E_t(d)e^{-\gamma\Omega_{t+1}(d)}, \tag{5}$$

where γ is the coefficient of absolute risk aversion and $\Omega_{t+1}(d)$ is total investment after returns of dealer d, given by:

$$\Omega_{t+1}(d) = \big(1 + r_t\big)B_t(d) + \big(1 + r_t^*\big)E_t(d)\tilde{e}_{t+1}B_t^*. \tag{6}$$

Substituting for the dealer's resource constraint and log-linearizing the excess return on foreign bonds, with $e_t = \ln \tilde{e}_t$, leads to:

$$\Omega_{t+1}(d) \approx \big(1 + r_t\big)\Big[\omega_t(d) - \omega_{CB,t}(d) + \tilde{e}_t\Big(\omega_t^*(d) + \omega_{CB,t}^*(d)\Big)\Big] \tag{7}$$

$$+ \big(r_t^* - r_t + E_t(d)e_{t+1} - e_t\big)B_t^*(d). \tag{8}$$

Maximization of the utility function with respect to end-of-period foreign bond holdings results in the following first order condition:

$$-\gamma\big(r_t^* - r_t + E_t(d)e_{t+1} - e_t\big) + \gamma^2 B_t^*(d)\sigma_{\Delta e}^2, \tag{9}$$

with $\sigma_{\Delta e}^2$ being the unconditional variance of the rate of nominal exchange rate depreciation. This last term results from assumptions about the exchange rate in period $t + 1$, the only non-predetermined variable in the optimization problem. From (9) it follows for the demand for foreign bonds of each dealer d:

$$B_t^*(d) = \frac{r_t^* - r_t + E_t(d)e_{t+1} - e_t}{\gamma \sigma_{\Delta e}^2}. \tag{10}$$

Thus, demand for foreign bonds is positively affected by an interest rate differential to domestic bonds, an expected appreciation of the foreign currency, lower risk aversion and lower exchange rate volatility.

2.4 Central bank

The monetary authority sets the short-term interest rate according to a Taylor (1993)-type monetary policy rule. As in Semko (2013) and Malakhovskaya and Minabutdinov (2014), it is assumed to react to deviations of the consumer price inflation from its target and to output fluctuations. In line with its objectives to "limit excessive dual-currency basket value fluctuations" and to "smooth[ed] excess volatility of the ruble exchange rate", the central bank also reacts to dynamics of the nominal exchange rate. The lagged value of the policy rate is considered to account for its rather smooth dynamics. We assume that (in log-linear representation):

$$r_t = \rho_r r_{t-1} + \left(1 - \rho_r\right)\left(\phi_\pi \pi_t + \phi_{gdp} gdp_t + \phi_{\Delta e} \Delta e_t\right) + \eta_t^r, \tag{11}$$

where ρ_i is the degree of interest rate smoothing, ϕ_π and $\phi_{\Delta e}$ are the reaction coefficients to movements of the inflation rate and the degree of exchange rate depreciation, and η_t^r is an i.i.d. normal error with zero mean and variance $\sigma_{\eta^r}^2$, capturing non-systematic interest setting behavior.

In addition to the interest rate as a standard monetary policy operating target, the central bank uses interventions on the foreign exchange market as an instrument to stabilize the behavior of the nominal exchange rate. The monetary authority finances the acquisition of foreign exchange reserve by the issuance of its own securities B_t. Following Montoro and Ortiz (2016), we assume that the central bank is capable to fully sterilize its interventions so that it is able to control the interest rate paid on its bonds, regardless of the volume of securities issued or bought.[3] As outlined in the previous section, securities in the foreign exchange market are traded via risk-averse dealers which execute the orders they receive from households, foreign investors and the domestic central bank. In contrast to the capital flows generated by foreign investors, purchases and sales of international reserves by the central bank are assumed to be carried out systematically. In particular, a monetary authority intended to mitigate exchange rate fluctuations is expected to counter appreciation (depreciation) pressures on its currency resulting from the excess demand for (supply of) domestic assets and thus to purchase (sell) foreign bonds in exchange for domestic ones.

[3] In practice, as outlined by Montoro and Ortiz (2016), the ability of central banks to fully sterilize their interventions is limited by the amount of FX reserves and the demand for domestic bonds. Given the stock of reserves held by the CBR as well as the absence of investment alternatives for government bonds for the domestic financial sector, it is reasonable to disregard both of these aspects in the case of Russia.

Following the standard approach for interest rate rules, the foreign bond sale orders from the central bank are expressed (in log-linear representation) as:

$$\omega^*_{CB,t} = \phi_{\Delta e,int} \Delta e_t + \eta^{int}_t, \tag{12}$$

with $\phi_{\Delta e,int}$ being the reaction coefficient to movements of the degree of exchange rate depreciation, and η^{int}_t an i.i.d. normal error term with zero mean and variance $\sigma^2_{\eta^{int}}$, capturing non-systematic foreign exchange interventions. Different from the dynamic behavior of the policy rate, the volume of interventions does not exhibit persistence over time but rather strongly depends on current economic conditions the central bank is reacting to. Thus, it is reasonable to not consider a smoothing parameter in the intervention equation.

2.5 Aggregation and market clearing

Goods and factor markets Domestic goods market clearing requires non-oil goods production, net of utilization adjustment costs, to be equal to the demand for consumption, investment, non-oil exports and imports $M_t = C_{F,t} + I_{F,t}$:

$$Y_t = C_t + I_t + X_t - M_t + G_t + \omega(u_t)K_{t-1}, \tag{13}$$

where G_t captures government spending. Under the assumption that fiscal policy is pro-cyclical with respect to the oil price, we characterize the dynamics of public expenditures as a fiscal rule in the spirit of Leeper et al. (2010), among others, such that (in logs):

$$g_t = \rho_g g_{t-1} + (1 - \rho_g)(e_t + p_{o,t}) + \eta^g_t, \tag{14}$$

where η^g_t is an i.i.d normal error term with zero mean and variance $\sigma^2_{\eta^g}$. Total real GDP is then defined as the sum of non-oil GDP and oil revenues:

$$GDP_t = \frac{\tilde{e}_t P_{o,t} O_t + P_{H,t} Y_t}{P_{Y,t}}, \tag{15}$$

where $P_{Y,t}$ is the GDP deflator. The capital market clears when the capital supplied by domestic households equals the demand from domestic producers at the market rate for rented capital $\tilde{r}_{k,t}$. The market for labor is in equilibrium when the labor supplied by domestic households equals the labor demand from domestic producers at the aggregate wage.

Prices By definition, the GDP deflator equals the weighted average of the individual price levels of its components:

$$P_{Y,t} = (\phi_c + \phi_i)P_t + \phi_o(\tilde{e}_t P_{o,t}) + \phi_x \tilde{e}_t P_{X,t} - \phi_m P_{M,t}, \tag{16}$$

with ϕ_c, ϕ_i, ϕ_o, ϕ_x and ϕ_m being the shares of consumption, investment, oil revenues, non-oil exports and imports to GDP, respectively. The real exchange rate is defined as:

$$Q_t = \frac{\tilde{e}_t P_t^*}{P_t}. \tag{17}$$

Foreign exchange market As outlined in Montoro and Ortiz (2016), market clearing in the domestic market for foreign bonds requires the aggregate demand of foreign investors and the central bank to equal the end-of-period holdings of foreign bonds by all dealers:

$$\int_0^1 B_t^*(d)\mathrm{d}d = \int_0^1 \left(\omega_t^*(d) + \omega_{CB,t}^*(d)\right)\mathrm{d}d = \omega_t^* + \omega_{CB,t}^*. \tag{18}$$

Aggregating (10) over the continuum of dealers and substituting total demand by (18), the following modified uncovered interest rate parity (UIP) condition is obtained:

$$E_t e_{t+1} - e_t = r_t - r_t^* + \gamma\sigma_{\Delta e}^2\left(\omega_t^* + \omega_{CB,t}^*\right). \tag{19}$$

The expression explicitly assumes that there is information homogeneity across all dealers so that the average expectation of the future nominal exchange rate is the same for all of them.

Risk aversion and short-sightedness of foreign exchange dealers results in an augmentation of the standard UIP condition by a time-variant risk premium that depends on foreign capital flows and central bank interventions. According to (19), the latter affect the nominal exchange rate through two mechanisms: the portfolio balance channel and the expectations channel. The former is defined by the last part of the UIP condition. Central bank interventions change the composition of domestic and foreign assets in the dealers' portfolios that have been chosen optimally based on their assessment of the respective returns and risks. A holding of a higher share of either security in their portfolio has thus to be compensated by a higher relative risk-adjusted return. Purchases (sales) of foreign bonds by the central bank increase (reduce) the relative share of foreign bonds in the dealers' portfolios. This will lead them to ask for a lower (higher) risk premium to be compensated for a relatively lower (higher) quantity of domestic currency they hold, resulting in a nominal appreciation (depreciation). The effect of central bank interventions on the exchange rate is the higher, the larger the risk premium factor $\gamma\sigma_{\Delta e}^2$, i.e. the more risk-averse dealers are or the higher the risk (uncertainty) in terms of the expected exchange rate volatility. The expectations channel is captured by the expected next period exchange rate. Rule-based interventions affect agents' beliefs about the future interventions and thus the dynamics of the exchange rate. All other variables kept equal, this will result in respective dynamics of the exchange rate already today.

Foreign capital flows are assumed to be non-fundamental in the sense that they are not explained by any other model variable. In particular, we do not directly link them to oil price dynamics. Although large drops in the oil price seem to trigger capital outflows as the prospects for the Russian economy worsen, the opposite does not hold true for rising oil prices. Also, the continuous capital outflows since the outbreak of the Global Financial Crisis suggest that they are rather driven by structural or political factors that are not explicitly modeled. We thus treat foreign capital flows as exogenous and describe their dynamics by the following equation (in logs):

$$\omega_t^* = \rho_{\omega^*} \omega_{t-1}^* + \eta_t^{\omega^*}, \tag{20}$$

where $\eta_t^{\omega^*}$ is an i.i.d. normal shock with zero mean and variance $\sigma^2_{\eta^{\omega^*}}$.

Flow budget constraint The aggregation of the households budget constraint, the oil export revenues, profits of the foreign exchange dealers, firms and retail sectors as well as the equilibrium in the domestic bond market leads to the following flow budget constraint of the domestic economy:

$$B_t = \left(1 + \tilde{r}_{t-1}\right) B_{t-1} + \tilde{e}_t P_{o,t} O_t + \tilde{e}_t P_{X,t} X_t - P_{M,t} M_t - \frac{\psi}{2}\left(B_t - \bar{B}\right)^2. \tag{21}$$

3 Estimation

3.1 Data

For estimation 13 quarterly time series from 2001 until 2015 are used. These include GDP, consumption, investment, the consumer price index, wages, the real exchange rate, the three-month interbank rate, capital flows, the oil price, world oil demand as well as series for foreign output, inflation and interest rates. Data for GDP, its aggregates and wages is taken from the Federal State Statistics Service (Rosstat). They are seasonally adjusted and transformed to real variables with the GDP deflator from the CBR. Finally, they are divided by the active labor force series from the OECD to obtain per capita values.

For consumer prices, we seasonally adjust the respective index obtained from Rosstat and take the first log-differences to calculate the respective inflation rates. We take period averages of the 3-month MIBOR rate from the Bank of Russia and divide them by 400 to obtain the quarterly interest rate series. For the capital flows, data on private sector capital flows by the CBR is used and divided by nominal GDP in US dollars.

All foreign variables as well as the oil prices and the real exchange rate are expressed in terms of the dual-currency basket, that has been used as an exchange rate benchmark by the Bank of Russia since 2005. The weights of the US dollar and the euro have been adjusted five times. Since 2007 the basket weights of the dollar and the euro have been 0.55 and 0.45, respectively. We use this ratio for the whole sample under consideration. As has been argued by Malakhovskaya and Minabutdinov (2014), this simplification can be justified by the share of Russian exports to the euro area and Switzerland relative to the exports to its 15 main trade partners being around the same number. Foreign GDP, inflation and interest rate are thus weighted averages of the respective US and euro area time series, that are processed in the same way as the domestic variables described above. The real exchange rate is calculated by equating the changes in the nominal exchange rate index constructed from the bi-lateral ruble exchange rates against the dollar and the euro and the inflation differential between Russia and the weighted foreign average. For world oil demand we use a linearly de-trended series obtained from the OECD. Finally, the quarter-average spot price of Brent oil is converted to be expressed in terms of the currency basket and divided by the weighted average foreign consumer price index to obtain the respective real series.

Prior to estimation, all observable series are demeaned.

3.2 Priors and calibration

Most of the prior choices are motivated by Justiniano and Preston (2010). These include the ones for the consumption utility σ set to 1.20 with a standard deviation of 0.40, the inverse Frisch elasticity φ with mean 1.50 and standard deviation 0.75, and the habit parameter h centered around 0.50 with a standard deviation of 0.25. The priors for the elasticities of substitution between domestic and foreign goods are set for, both, the home country and the rest of the world to a mean of 1.50 and a standard deviation of 0.75. Priors for all Calvo parameters are set to a mean of 0.5 and a standard deviation of 0.10, whereas the priors for the degrees of indexation are set to the same mean but a standard deviation of 0.25. Choices for the priors for the fix cost parameter as well as the investment adjustment and capital utilization adjustment costs are set according to Smets and Wouters (2003). Priors for the central bank's reaction functions are standard in the literature. The prior of the inflation reaction coefficient is set to 1.50 with a standard deviation of 0.50, whereas the priors for the exchange rate reaction parameters are centered around 0.25 with a standard deviation of 0.15 in both rules. The prior for the interest rate smoothing parameter is set to 0.80 and a standard deviation of 0.10. We fit an AR(1) process for the actual data on capital flows and oil demand to define the prior for the respective AR(1) parameter at a mean of 0.40 and standard deviations of 0.15, respectively. For all remaining AR(1) parameters, the respective priors are centered around 0.80 with a standard deviation of 0.10. For most of the standard deviations of model shocks, the prior means are chosen to be 0.01 with a standard deviation of 2. The choices for the shocks to capital flows, the oil price and central bank interventions are motivated by estimates of respective AR(1) processes. The complete set of prior choices is presented in online Table A.2.

The remaining parameters and steady-state values are calibrated, since they are either difficult to estimate or there exist strong evidence for a particular value in the data. Standard choices are made for the discount parameter ($\beta = 0.99$), implying a steady-state real interest rate of 4 percent, the share of capital in the production function ($\psi = 1/3$), the rate of depreciation of private capital ($\delta = 0.025$), i.e. an annual depreciation of 10 percent, and the net wage markup ($\lambda^w = 0.15$). The shares of consumption, investment, non-oil exports and imports to total output are calibrated to their average value over the sample period. In a similar way, the share of foreign goods in consumption and investment is fixed at 0.23. Matching the ratio of central bank reserves to GDP, the respective model equivalent, the ratio of domestic bonds to output is set to 0.9. Analogously, the proportion of oil exports to GDP is set to 0.17, the average of oil, oil products and gas. We choose this rather broad definition of commodity exports to properly account for the significance they have for the Russian economy. The close co-movements of crude oil and natural gas prices do not raise objections to treat the two commodities as one. As for the parameters of the UIP condition, the variance of the nominal exchange rate depreciation is calibrated to its sample period average of 0.0065, whereas the degree of risk aversion is set to 200. With the latter we deviate from the respective value in Bacchetta and Van Wincoop (2006) and Montoro and Ortiz (2016). Our choice is motivated by an estimate of the UIP equation using actual data on the exchange rate, the interest rate differential, private capital flows and central bank interventions. Following Justiniano and Preston (2010), we use coefficient estimates of a VAR(2) for the interaction of the three foreign variables and the oil price in the model.

The complete set of calibrated parameters is presented in online Table A.1.

We use the MATLAB preprocessor Dynare (see Adjemian et al. 2011) to solve and subsequently estimate the model using Bayesian techniques. Chris Sims' optimization routine CSMINWEL is used to obtain an initial estimate of the posterior mode, based on prior distributions and observable time series for endogenous model variables. The Kalman filter is used to infer latent variables, e.g. central bank interventions. To approximate the distribution of the parameters, we run one Markov chain with 3,000,000 draws, dropping the first 50%. 5000 subdraws were used to compute posterior distributions of various objects.

4 Results

4.1 Parameter estimates and model fit

The posterior means and probability intervals of the estimated parameters and the standard deviations of the model disturbances are presented in online Table A.3. All of them fall into a plausible range. Remarkably, prices for domestic and exported goods exhibit both, a higher frequency of prices changes (indicated by respectively lower Calvo parameters) and a higher degree of indexation when compared to imported goods, possibly as a result of less stable input prices at home. Another remarkable difference is estimated for the elasticity of substitution between home and foreign goods from the domestic and the foreign perspective. In contrast to the demand for Russian goods abroad, demand for foreign goods in Russia is by less than a half influenced by relative price movements, pointing at a higher substitutability of Russian goods. Monetary policy is estimated to react rather strongly to variations in the inflation rate and modesty to exchange rate fluctuations, with the respective reaction coefficients being 1.80 and 0.14, while strongly smoothing the dynamics of the policy rate, with the AR(1) parameter estimated to be 0.84. The reaction coefficient for exchange rate movements in the intervention rule is estimated to be 1.22. Since there is no benchmark in the literature to assess the plausibility of this value, we compare the smoothed series for central bank interventions that has been employed in the estimation process to actual data that is available from the CBR from mid-2008. Figure 1 plots the smoothed series for central bank

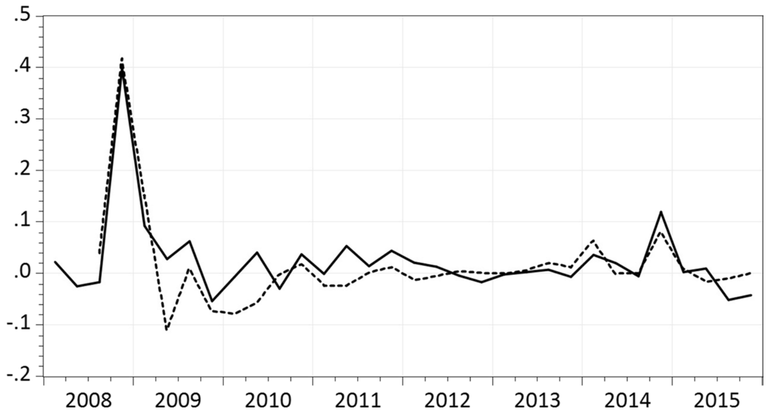

Fig. 1 Smoothed central bank interventions (dashed) and actual demeaned interventions (solid) in relation to nominal GDP

interventions against the actual interventions, demeaned over the respective sample, in relation to nominal GDP. The correlation of both series is 0.87 and the smoothed series in particular tracks the spikes of the actual data very well. We consider this finding as an important performance benchmark of the model used to characterize the Russian monetary policy and thus regard the setup capable of analyzing the actual and alternative policy strategies.

4.2 Historical decomposition

Figures 2, 3 and 4 show the historical decompositions of the real exchange rate, real GDP and the consumer price inflation rate. From 2004 on, oil prices have put an appreciation pressure on the real ruble rate. In periods of high or rising oil prices, the central bank actively counters these dynamics by direct interventions or, to a lesser extent, policy rate cuts. In crises times, there are mainly shocks to foreign capital flows affecting the value of the ruble. From the beginning of 2008 until 2009 and also, but to a lesser extent, at the turn of the years 2014 and 2015, capital outflows curbed the ruble's exchange rate. Whereas during the global financial crisis the CBR could soften the depreciation pressure via direct interventions, the most recent Russian crisis episode is characterized by a non-sufficient policy response to keep the currency's value stable. This finding does not come as a surprise. After all, the ruble's depreciation at the end of 2014 has been much stronger than at the start of 2009. In addition, the CBR announced to let its currency freely float during the latest episode of depreciation. At least concerning its direct interventions, there is evidence in the historical decomposition for the monetary authority to have complied with its announcement.

Fluctuations in total real GDP are primarily caused by shocks to technology (domestic supply) and domestic demand. Negative shocks to domestic supply have been the main driver of the most recent downturn that has started to unfold already at the end of 2012. The sharp drop in the oil price has negatively affected

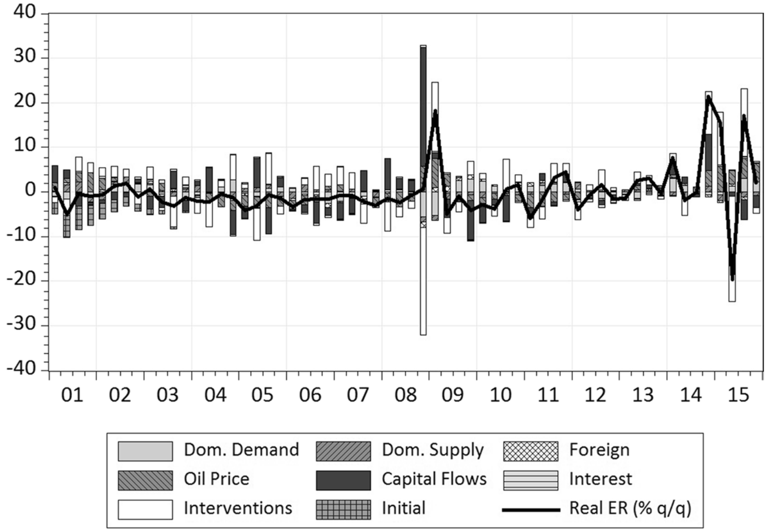

Fig. 2 Historical decomposition of the demeaned quarterly real exchange rate depreciation

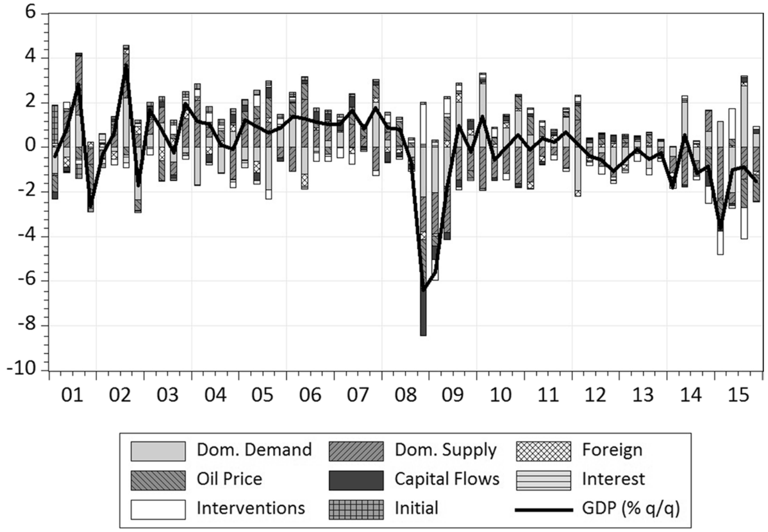

Fig. 3 Historical decomposition of demeaned quarterly real GDP growth

total Russian output in at the end of 2008 and from the end of 2014 until the end of the estimation sample. The impact of the central bank's foreign exchange interventions is, however, different for both crises episodes. While the efforts of the central bank to stabilize the ruble and to fend off negative effects on the domestic

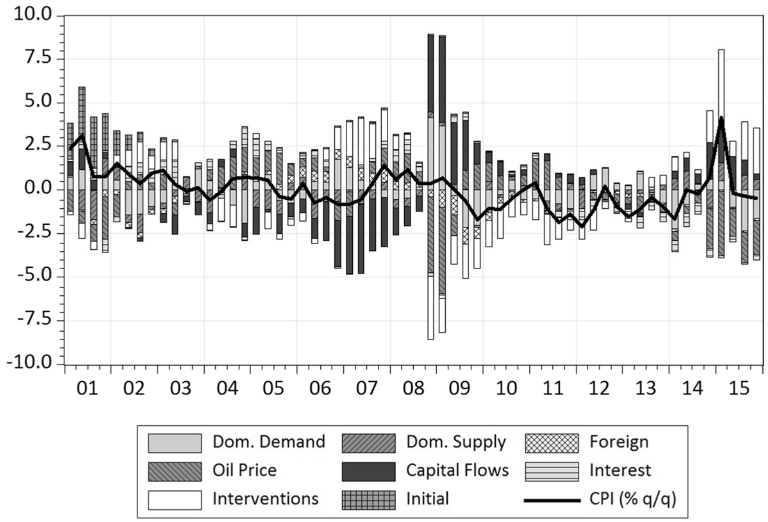

Fig. 4 Historical decomposition of demeaned consumer price inflation

economy proved to more successful during the Great Recession, the insufficient amount of central bank interventions in the wake of falling oil prices and capital outflows had a negative impact on GDP growth at the end of 2014 and the beginning of 2015.

As concerns inflation, there does not appear to be a particular pattern of shocks influencing its rate in normal times, primarily owed to a relatively stable exchange rate. When large capital outflows put depreciation pressure on the ruble, however, the extent to which the central bank is able to offset their impact is crucial for the dynamics of the price level. During the global financial crisis, the CBR could keep the ruble relatively stable and lower the inflation rate in an environment of low economic activity. At the end of 2014, on the contrary, the insufficient and later scrapped strategy of preventing a depreciation dramatically increased the prices of imported goods and consequently also total inflation.

4.3 Forecast error variance decomposition

The forecast error variance decompositions for selected time horizons and variables based on the estimates of the model are presented in Table 1.[4] Around one third of the short-term variations of domestic GDP can be explained by domestic demand shocks. Most of it go back to investment shocks and their effect on deviations of the productive capital stock from its steady state. Domestic supply shocks, mainly to

[4] Unless otherwise noted, all simulation results and reported variances in this work are based on simulations with the model parameters and standard deviations of shocks being calibrated to their respective estimated posterior means.

Table 1 Forecast error variance decomposition at different horizons

1 Quarter	η^m	η^{int}	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	0.0	4.3	2.6	31.5	6.5	0.8	0.2	23.0	12.1	18.8	0.3
Consumption	1.1	0.0	0.0	31.4	2.0	0.0	50.4	0.2	1.1	13.7	0.0
Investment	0.0	0.1	0.1	6.9	1.0	0.0	9.3	0.0	77.9	4.6	0.1
Exports	0.1	18.6	11.4	6.9	14.8	0.0	12.7	0.2	0.0	5.5	29.8
Imports	1.6	1.4	1.0	3.4	44.2	0.0	41.5	0.2	2.6	4.0	0.2
Real wages	2.1	5.7	4.6	14.0	12.1	0.0	40.4	0.0	0.6	20.2	0.3
Inflation	2.9	19.8	16.7	11.4	17.6	0.0	21.0	0.2	0.1	9.0	1.3
Dom. prices	2.5	14.9	12.5	12.9	22.0	0.0	23.6	0.3	0.1	10.2	1.0
Real ER	0.0	58.4	31.5	1.6	3.6	0.0	3.0	0.0	0.0	1.3	0.5
4 Quarters	η^m	η^{int}	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	0.1	1.9	1.7	39.4	5.6	0.1	6.7	5.0	15.4	24.0	0.2
Consumption	0.4	0.4	0.5	49.5	1.4	0.0	24.7	0.2	1.5	21.2	0.2
Investment	0.0	0.1	0.1	12.9	2.5	0.0	12.7	0.0	64.4	7.0	0.2
Exports	0.3	14.0	11.9	6.2	43.2	0.0	10.5	0.1	0.1	6.4	7.3
Imports	0.4	2.7	1.8	1.1	75.0	0.1	14.6	0.1	1.6	2.6	0.2
Real wages	1.0	4.2	3.4	47.1	11.1	0.0	19.3	0.1	0.9	12.7	0.2
Inflation	2.5	23.7	21.0	7.4	17.8	0.0	17.8	0.2	0.1	7.3	2.2
Dom. prices	2.1	18.5	16.2	8.6	23.7	0.0	20.5	0.2	0.1	8.4	1.6
Real ER	0.3	36.3	26.7	3.6	22.6	0.0	6.1	0.1	0.1	3.8	0.4
8 Quarters	η^m	η^{int}	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	0.1	1.4	1.3	45.2	9.3	0.1	5.0	2.8	15.7	18.9	0.4
Consumption	0.5	0.5	0.5	57.2	4.4	0.0	17.2	0.2	1.3	18.1	0.3
Investment	0.2	0.2	0.1	21.3	6.7	0.0	13.2	0.0	49.7	8.2	0.3
Exports	1.1	8.4	7.3	5.1	63.4	0.0	6.1	0.1	0.4	4.1	4.2
Imports	0.6	3.4	2.6	0.5	83.8	0.0	7.0	0.0	0.8	1.2	0.1
Real wages	0.7	3.3	2.7	60.2	10.2	0.0	13.2	0.1	0.7	8.8	0.2
Inflation	2.5	22.2	19.8	7.1	18.6	0.0	19.1	0.2	0.2	7.7	2.7
Dom. prices	2.0	17.3	15.3	8.2	23.7	0.0	22.1	0.2	0.2	9.0	2.0
Real ER	1.1	26.0	19.4	3.7	41.5	0.0	4.5	0.0	0.3	3.0	0.5
∞	η^m	η^{int}	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	0.0	0.9	0.8	58.6	12.5	0.0	3.3	1.6	10.2	11.6	0.4
Consumption	0.3	0.9	0.8	70.1	6.4	0.0	9.0	0.1	2.6	9.7	0.1
Investment	0.3	1.1	1.0	37.8	11.3	0.0	10.5	0.0	30.6	7.0	0.3
Exports	1.2	7.7	6.8	4.9	67.1	0.0	5.0	0.0	0.6	3.1	3.5
Imports	0.7	4.6	4.0	0.9	82.4	0.0	5.4	0.0	0.6	1.2	0.4
Real wages	0.4	1.8	1.5	74.1	8.0	0.0	7.2	0.0	2.3	4.7	0.1
Inflation	2.5	21.6	19.3	6.9	20.7	0.0	18.5	0.2	0.2	7.4	2.8
Dom. prices	2.1	16.9	14.9	7.9	26.0	0.0	21.2	0.2	0.2	8.6	2.1
Real ER	1.3	22.2	16.8	3.8	48.3	0.0	4.1	0.0	0.5	2.5	0.5

technology, account for around one half of domestic output variations in the short-run and more than two-thirds over the medium-term. This finding corresponds to the historical decomposition of output according to which domestic supply shocks contributed most to GDP growth fluctuations in the past. Capital flows and central bank interventions strongly affect GDP only in the very short term and rather weakly. Finally, oil price shocks account for less than one-tenth of output fluctuations in the very short-run and slightly more over the longer-term.

Fluctuations of the rate of consumer price inflation are primarily driven by monetary shocks, oil price shocks, non-fundamental capital flows and domestic demand shocks, with their respective relative importance being almost constant over time. Prices for domestically produced goods are stronger affected by preference shocks and oil price disturbances, with the latter having a strong impact on households' utilities and hence their wage setting, affecting domestic producers' costs and consequently prices. Dynamics of prices for imported goods are to larger extent driven by shocks to capital flows and non-systematic interventions, since they, both, directly influence the behavior of the nominal exchange rate. Non-oil exports and imports are strongly affected by fluctuations of the oil price, with the impact of the latter influencing the real exchange rate strongest in the long-run, creating a channel to weigh on trade via relative price variances.

Based on the findings that nearly all domestic variables are substantially influenced by shocks to oil prices and/or capital flows at all horizons, the following sections focus on the effects that the two disturbances have on the Russian economy, given the estimated monetary policy in place. Starting with an isolated consideration of either shock, a situation is analyzed in which both disturbances hit the economy simultaneously. While the narrative considers the effects of positive shocks, the derived conclusions hold true in opposite direction also for the respective negative disturbances. Their effects in absolute terms, however, will tend to be somewhat lower given the possibly asymmetric nature of oil price shocks for commodity exporters. While the model framework employed in this analysis does not allow for non-linear dynamics that would adequately capture these possibly asymmetric responses, it does not qualitatively alter the conclusions presented in the remainder of the paper. This holds in particular true for the comparison of policy alternatives.

4.4 Effects of oil price shocks

Following a positive oil price shock (Fig. A.1), household incomes rise on impact, leading to higher consumption expenditures. As a consequence, the marginal rate of substitution between consumption and labor increases, resulting in higher wages and consequently rising marginal costs and higher prices for domestically produced goods and total consumer prices. The consequent decline in real interest rates further stimulates household spending. These effects are very short-term, however. With their positive impact on the balance of payments, higher oil prices lead to a nominal and real exchange rate appreciation that is only in part offset by central bank interventions. The resulting relatively lower prices for foreign goods lead to an increase in imports and a decline in total consumer prices. On the other hand, foreign demand for domestically produced goods decreases sharply and persistently in the wake of the local currency's appreciation. The decline is, however, overcompensated by the increase in domestic demand due to higher incomes from oil exports, despite the fact that their rise is weaker when expressed in local currency units. Consequently, non-oil GDP is affected positively by the higher commodity prices, in particular also due to an increased capital stock as a result of risen investment spending.

In absolute terms, oil price shocks have the largest long-run effects on the real exchange rate, investment, non-oil exports, and imports. These findings largely correspond to the ones in Malakhovskaya and Minabutdinov (2014).

4.5 Effects of capital flow shocks

According to the model specification, a capital inflow shock (Fig. A.2) increases the relative share of dealers' assets denominated in domestic currency, leading to an immediate appreciation of the latter. Its magnitude is weakened by the central bank's cutting of the domestic interest rate as well as direct interventions on the foreign exchange market. With constant world market prices, the nominal appreciation reduces the oil export revenues expressed in local currency units. Import prices decrease sharply in light of a stronger domestic currency. Due to lower interest rates and consequently lower capital costs, prices for domestically produced goods also drop, leading to a decline in total consumer prices. Consumption and investment spending is increased as a consequence of the unexpectedly risen ex-post real interest rate on savings. Nevertheless, in consequence of the sharp increase in its nominal value, the domestic currency also appreciates in real terms. Foreign demand for domestic non-oil goods drops. Imports, however, do not increase since the price for imported goods drops less sharply than for domestically produced ones. The gradual reduction of capital inflows in combination with lower domestic interest rates cause the exchange rate to depreciate again after two quarters. In consequence of the low persistence of capital flow shocks, their direct effects dissolve already after one year. The expansive monetary policy in reaction to the initial currency appreciation, however, remains in place given that inflation is still below its steady state. This leads to reverse dynamics of the nominal exchange, overshooting its steady state level. With the inflation rate returning to its trend, this results in a real depreciation of the domestic currency, with the real exchange rate persistently exceeding its steady state level from the sixth quarter onwards. Dynamics of the GDP aggregates reverse in the light of this turnaround of relative prices. Exports of non-oil goods increase. Domestic demand that has been initially stimulated by the capital inflows decreases in light of gradually increasing real interest rates. The reaction of total GDP follows a similar pattern.

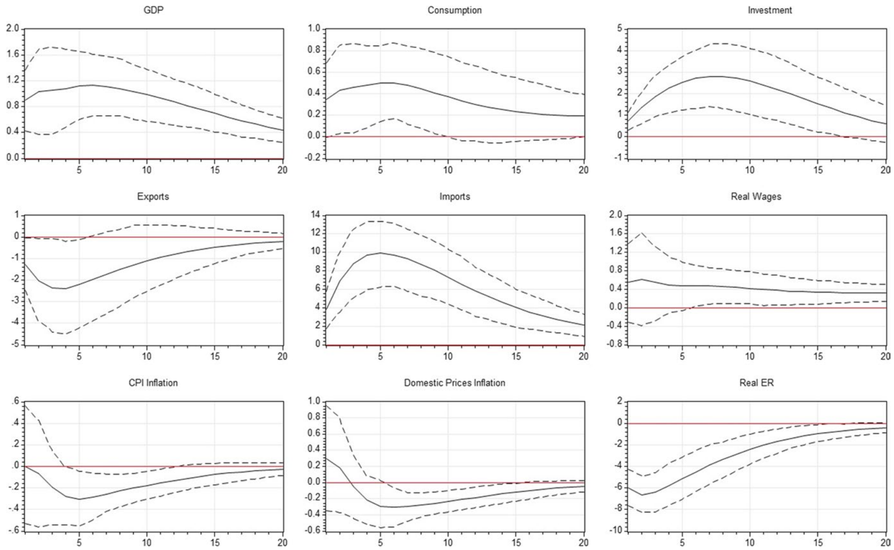

Fig. 5 Impulse response functions following a simultaneous 1 s.d. shock to the oil price and capital flows in percentage deviations from the steady state. Dashed lines indicate the upper and lower bounds of the 90% HPDI

In absolute terms, capital flow shocks have the largest long-run effects on the real exchange rate, the rate of nominal exchange rate appreciation, the domestic currency price of oil as well as investment, non-oil exports, and imports. The reaction of the central bank is not sufficient to counter the shock and to prevent it from having an impact on the domestic economy. On the contrary, due to their persistence, its measures affect real variables long after capital flows have returned to their steady state. For all real variables the unconditional variance is remarkably higher compared to the conditional variance up to the sixth quarter, when the shock dissolves completely.

4.6 Effects of simultaneous oil price and capital flow shocks

In addition to the analysis of the effects of oil price and capital flow shocks hitting the economy independently from each other, we also examine the case in which both disturbances occur simultaneously. The rationale is twofold: on the one hand, it appears to be reasonable that flows of foreign capital into or out of an oil-dependent economy are closely linked to the revenue prospects of the commodity sector. Whereas oil exporting firms profit directly from higher oil prices, the rest of the economy benefits from higher incomes and other second round effects. Public finances, on their part, are strongly influenced by revenues from commodity exports so that oil price dynamics have a notable impact on the attractiveness of sovereign bonds. On the other hand, capital flows are also driven by structural and political factors that are not explicitly modeled. Such a scenario of large capital outflows and falling oil prices features two main shocks the Russian economy has been confronted with during the year 2014. To analyze the effects that these two disturbances have on the domestic economy given the monetary policy strategy in place, the oil price is again shocked with the estimated intensity. In addition, the correlation of the capital flow shock to the oil price disturbance is calibrated to 0.4815, the correlation of the two respective smoothed shocks' series in the estimation.

The effects of a positive oil price shock on real domestic variables are amplified in the presence of a concurrent capital inflow shock (Fig. 5). The nominal exchange rate appreciates more strongly, despite increased central bank interventions and a lowered policy rate. As a consequence, prices for imported goods drop sharply in comparison to the separately occurring oil price shock. Although wages increase as in the former case, lower capital costs curb the increase in prices for domestically produced goods. Total consumer prices rise only marginally on impact. Hence, there is no tradeoff for the monetary authority to stabilize either inflation or the exchange rate. The dimension of its nominal appreciation outweighs the reduction in the price level, so that the domestic currency appreciates in real terms, curbing non-oil exports and stimulating imports. As in the single-shock scenarios, domestic demand increases as a consequence of, both, higher commodity export revenues and ex-post real returns on bonds. The absolute effects on non-oil GDP, consumption, investment, non-oil exports and imports peak after three to five quarters and decrease gradually afterwards.

In absolute terms, simultaneously occurring shocks to oil prices and capital flows have the largest long-run effects on the real exchange rate, non-oil exports and imports as well as investment. Whereas both trade aggregates are affected to a comparable extent as in the single oil shock scenario, the impact on investment is lower. Due to a stronger nominal appreciation on impact and a faster return to the initial level in the quarters thereafter, the total effect on the commodity price in local currency units is smaller and less persistent than without a concurrent capital flow shock.

5 Alternative monetary policy strategies

Based on the findings in the previous section, we analyze to which extent alternative monetary policy strategies could possibly limit the impact of external shocks, in particular to oil prices and capital flows, on the domestic economy. The variances of model variables following an oil price shock, a capital flow shock and both shocks occurring simultaneously, relative to the policy strategy in place, are presented in Table 2 as well as online Tables A.4 and A.5.

5.1 Inflation targeting

As a first policy alternative, a strategy is considered according to which the central bank adjusts its policy rate only in reaction to deviations of the inflation rate from its

Table 2 Variances following simultaneous shocks to oil prices and capital flows under inflation targeting (IT), strict inflation targeting (SIT), hybrid inflation targeting (HIT), a fixed exchange rate (FIX) and ruble price of oil targeting (ROIL), relative to current policy

1 Quarter	IT	SIT	HIT	FIX	ROIL
Real GDP	1.74	2.45	3.00	0.46	2.59
Consumption	0.04	0.98	0.03	4.00	1.11
Investment	0.03	0.15	0.45	0.72	0.43
Exports	2.45	2.28	2.97	0.49	3.08
Imports	0.80	0.66	0.44	2.11	0.02
Real Wages	0.83	0.30	0.20	8.93	6.08
Inflation	2.85	0.00	5.94	33.34	47.34
Dom. Prices	1.71	0.20	0.55	11.77	9.34
Real ER	5.49	5.16	7.86	0.10	6.90
4 Quarters	IT	SIT	HIT	FIX	ROIL
Real GDP	0.58	1.13	1.77	0.35	2.41
Consumption	0.01	0.21	0.71	1.45	0.64
Investment	0.03	0.09	0.72	0.42	0.84
Exports	0.98	0.95	1.21	0.46	2.52
Imports	0.75	0.50	0.53	1.51	0.25
Real Wages	1.10	0.22	0.14	5.89	2.96
Inflation	4.84	0.00	5.83	26.49	40.22
Dom. Prices	2.91	0.20	0.71	12.28	9.84
Real ER	1.55	1.57	2.28	0.24	4.14
8 Quarters	IT	SIT	HIT	FIX	ROIL
Real GDP	0.48	0.89	1.57	0.55	1.63
Consumption	0.03	0.14	0.93	0.93	0.52
Investment	0.07	0.13	0.86	0.42	0.79
Exports	0.82	0.83	1.04	0.45	2.25
Imports	0.79	0.58	0.67	1.20	0.53
Real Wages	1.21	0.39	0.27	4.42	2.42
Inflation	2.08	0.00	3.37	11.05	16.20
Dom. Prices	2.06	0.14	0.91	8.74	6.77
Real ER	1.21	1.26	1.78	0.28	3.45
∞	IT	SIT	HIT	FIX	ROIL
Real GDP	0.39	0.62	1.47	0.73	1.00
Consumption	0.38	0.55	1.53	1.12	0.19
Investment	0.32	0.43	1.45	0.65	0.55
Exports	0.91	1.03	1.13	0.58	1.98
Imports	0.99	0.90	0.90	1.06	0.60
Real Wages	1.01	0.76	0.88	1.69	0.96
Inflation	0.59	0.00	1.08	1.91	2.82
Dom. Prices	0.70	0.04	0.70	2.10	1.61

Table 2 (continued)

∞	IT	SIT	HIT	FIX	ROIL
Real ER	1.25	1.33	1.74	0.39	2.91

trend. The respective parameter ϕ_{π} is calibrated to its estimated value, whereas the output and exchange rate coefficients ϕ_{gdp} and $\phi_{\Delta e}$ are set to zero. The central bank does not engage in any direct interventions on the foreign exchange market. Since its ability to control the exchange rate via the policy rate only is rather limited, the central bank takes lower (higher) import prices due to an appreciation (depreciation) as given and loosens (tightens) monetary policy to fuel (curb) domestic inflation to keep the overall price level rather stable.

Following an oil price shock, the central bank increases its policy rate by more than under the actual strategy, since the stronger appreciation of the domestic currency leads to even greater balance sheet effects and thus higher wages, domestic as well as total inflation. The impact on domestic real variables is smaller and less persistent, though, since the higher interest rate curbs the increase in demand. Over the medium and long-term horizon, most domestic variables are less affected by the shock than under the estimated policy in place. The effect on non-oil exports is slightly larger due to the stronger appreciation.

In the presence of a capital inflow shock, the central bank cuts the interest rate by less than under the actual policy to limit deflationary pressures on domestic prices, leading to an even stronger appreciation and weaker exports in the very short-term. In contrast to the policy in place, the weaker policy reaction results in a less strong and persistent deviation from its steady-state so that the appreciation pressure on the domestic currency is remarkably lower in the course of the fast expiring shock. Consequently, the exchange rate overshoots its long-run trend by less with respectively weaker effects on the other variables. The total impact of the capital flow shock on the domestic economy under an inflation targeting strategy is remarkably lower compared to the actual policy. The higher variance of the real exchange rate stems almost fully from the response on impact.

In the case of simultaneously occurring shocks to oil prices and capital flows, the central bank raises its policy rate in response to the upcoming pressures on domestic prices and wages. In light of the reduction of the initial shock impulses, the domestic currency appreciation quickly reverses, causing the central bank to further increase its interest rate, as higher import prices increase total inflation. Its high persistence keeps the interest rate above its steady state and the exchange rate overvalued in real terms, with a negative impact on exports and a stimulus for imports. The relative variance of all GDP components is nonetheless smaller under inflation targeting compared to the estimated policy in place. Wages and prices are slightly stronger affected under the alternative strategy even over the two-year horizon, in particular because of their strong reaction on impact.

5.2 Strict inflation targeting

Similar to the first policy alternative, we assume a strategy according to which the central bank reacts only to movements in the inflation rate. Contrary to the former alternative, however, we assume that the reaction is very strong. To capture this, the respective parameter is set to $\phi_\pi = \infty$. All other monetary policy parameters do not change compared to the moderate inflation targeting strategy.

By definition, the domestic inflation rate does not deviate from its trend, since the central bank adjusts its policy rate to whatever extent it takes to counter any shocks, with the respective effects on other domestic variables. Following an oil price shock that leads to an initial increase in the price level of domestically produced goods due to higher wages, the domestic interest rate increases by more, fueling a stronger appreciation of the domestic currency and a larger impact on exports. Higher interest rates almost entirely offset the positive effects on domestic demand, leading to an only slight increase in imports. Lower import prices, however, compensate for the moderate increase in the domestic price level to stabilize total inflation. Except for the free floating exchange rate and exports, the home economy is affected less strongly by oil price shocks compared to the policy in place.

In reaction to a capital inflow shock, the central bank lowers the policy rate to curb the effects of a stronger appreciation on prices. Consumption increases due to a decreased real interest rate, as do wages in light of a higher marginal rate of substitution between consumption and labor and consequently domestic prices. As under the current policy, the effects are not persistent and revert after less than one year. With capital flows returning to its trend, an enduringly lower interest rate and zero inflation cause the real exchange rate to overshoot its long-term level by even more than under the policy strategy in place. On the two-year horizon, consumption and investment are more affected under strict inflation targeting. The larger imbalance leads, however, to a faster return to the steady state. In the longer-run, however, all domestic variables except for the exchange rate exhibit a lower degree of impact.

Following the simultaneous disturbances to oil prices and capital flows, the central bank lowers it policy rate even more strongly to curb the effect of the strong appreciation on import prices and the total price level. As a result, domestic prices increase only modestly, as lower capital costs more than outweigh the rise in wages. Consumption and investment expenditures increase by less than under the baseline monetary policy strategy. Exports, on the other hand, decrease more strongly. In the medium and long-run, the volatility in most of the domestic variables is lower as compared to the actual policy strategy. However, only prices are less volatile in comparison to the moderate inflation targeting alternative.

5.3 Hybrid inflation targeting

As a third policy alternative, we analyze a strategy according to which the central bank focuses primarily on movements of the inflation rate but also on deviations of output from its trend. The strategy follows Taylor (1993) who proposed reaction coefficients of 1.5 and 0.5, respectively. We set the output reaction parameter to 0.38, given that the model is indeterminate for values greater than our choice.

In the presence of an oil price shock, the central bank raises the interest rate only modestly to allow for a stronger appreciation of the domestic currency. This in turn has several positive effects on the authority's targeted variables: oil price revenues in domestic currency units increase by less than under the actual strategy, curbing the rise in domestic demand, wages and thus the domestic goods inflation. In addition, prices for imported goods fall more sharply, limiting the increase in total inflation. On the other hand, the stronger currency appreciation holds true also in real terms, translating to a higher volatility of non-fuel exports.

The reaction of the monetary policy to a capital inflow shock under hybrid inflation targeting is similar to the ordinary inflation targeting case, with the effects on most of the variables being almost identical. Simultaneously occurring shocks to the oil price and capital flows lead to a fall in the rate of total inflation, as import prices fall more sharply in light of a strongly appreciating currency, whereas domestic prices decrease due to declining. As under the inflation targeting strategy, the fast reduction in capital flows and the return of the oil price to its pre-shock level, put depreciation pressure on the domestic currency in the subsequent quarters. The initial effects on prices reverse quickly leading to an increase in the real interest rate and consequently higher domestic demand. Over the medium and long-term, the strategy of hybrid inflation targeting does not outperform the previous two alternatives, neither does it appear to be superior to the policy in place.

5.4 Fixed exchange rate

This alternative policy is characterized by the central bank's strategy to fix its currency's exchange rate by conducting unlimited direct interventions on the foreign exchange market. Consequently, the reaction coefficient in the intervention rule is set to $\phi_{\Delta e,int} = \infty$. The interest rate is not used as a policy instrument, as in reality it cannot be set independently of the foreign exchange market operations. Since in the model specification it is assumed that the central bank is capable to fully sterilize its interventions, the latter does not have any effects on the former so that it remains at its steady state level.

Foreign capital shocks are completely offset by the monetary policy serving excess demand for and demanding excess supply of foreign currency via sales and purchase of its reserves. Domestic variables remain unaffected.

Shocks to the oil price, however, translate one-to-one to higher revenues quoted in domestic currency, stimulating consumption and total output. Wages increase more strongly pushing domestic prices and total inflation. Imports soar against the background of higher demand. Exports are affected less, since the impact of the disturbance on the real exchange rate is relatively modest. Absent this channel and with the oil price gradually returning to its pre-shock level, the effects of its initial increase on income and spending gradually decline. Even over the longer-term, however, consumption and investment are more volatile compared to most inflation targeting alternatives. Also, with the exchange rate and thus prices of imported goods held constant, consumer prices are stronger affected by the higher volatility of the domestic price level.

Since shocks to foreign capital flows can be fully neutralized by central bank interventions, the effects of the disturbance in combination with a simultaneous oil price shock correspond exactly to the latter occurring independently. Relative to the outcome under alternative strategies, in which import prices drop following an even stronger appreciation to curb the total price level, consumer price inflation is even more affected under the peg regime, as higher wages push the domestic price level and monetary policy cannot be tightened to counter these dynamics.

5.5 Ruble price of oil targeting

Finally, we analyze the alternative strategy of the CBR targeting the ruble price of oil, so that it intervenes to match the rate of exchange rate appreciation (depreciation) to the change in the price of oil on the world market. This policy alternative is motivated by Frankel (2005), who argues that countries that are specialized in exporting one particular commodity should fix its price in terms of the local currency since this would automatically accommodate shocks to the terms of trade. The strategy should provide a credible nominal anchor to monetary policy and be based on reliable 'now data', reducing problems associated with time-inconsistency. We implement the policy strategy by including the domestic currency price of oil in the intervention rule and setting the respective reaction coefficient to infinity.

As in the case of an exchange rate peg, foreign capital shocks are completely offset by the monetary policy, so that domestic variables remain unaffected.

Following a positive shock to the oil price, the central bank amplifies the exchange rate appreciation via foreign exchange interventions. Prices for imported goods drop sharply, causing the total price level to decrease. Demand for exports declines against the background of the strong real appreciation. As a result of constant oil prices in domestic currency and shrinking exports, domestic incomes fall slightly. Consequently, consumption expenditures and wages decrease leading to also to lower domestic prices. As import prices recover in the light of the domestic currency's depreciation caused by the gradual return of the oil price to its pre-shock level, the total price level increases. With its effect on the real interest rate investment expenditures are stimulated. Even though the economy is hit much stronger by the shock in the short-term than under any other strategy, the long-run effects only slightly exceed those under the policy in place. Domestic private expenditures are even less volatile as private incomes are not directly affected by the shock. However, this holds true only for temporary shocks to the oil price and consequently temporary real exchange rate misvaluations. As a strategy to primarily fend off short-term fluctuations, ruble price of oil targeting proves ineffective and even rather destabilizing when considering the economy as a whole. Herz et al. (2015) come to a similar conclusion.

Again, as in the case of exchange rate pegs, shocks to foreign capital flows can be fully neutralized by central bank interventions so that the effects of oil price shocks on the economy are the same independent of a contemporaneous capital flow shock.

Also, relative effects compared to the policy in place and other alternatives do not differ substantially.

5.6 Alternative policy forecast error variance decomposition

After the analysis of the effects of shocks to oil prices and capital flows under different policy regimes, we turn our attention to how domestic variables are affected from all modeled disturbances under possible policy alternatives. Therefore, we simulate the model for the strategies presented in the preceding sections and compare the forecast error variance decompositions at different time horizons to the estimated policy in place. For reasons of consistency, we exclude the two monetary policy shocks in the model and adjust the deviations in the alternative scenarios respectively. Results are presented in the Table 3 as well as online Tables A.6, A.7, A.8 and A.9.

Compared to the monetary policy strategy in place, the relative impact of oil price shocks on the volatility of inflation and output can only be reduced at all horizons when adapting hybrid targeting. In addition, it most strongly increases the relative importance of technology shocks in describing the behavior of real variables, to comply with the theory of real business cycles. Also in line with theory, hybrid targeting of inflation and output leads to a tradeoff for the central bank in the presence of supply shocks and consequently a higher relative impact of these disturbance on the inflation rate compared to the current strategy.

As already proposed by the consideration of single capital flow shocks, the relative importance of these disturbances to fluctuations of nearly all domestic variables can substantially be reduced at all horizons by adapting any of the proposed policy alternatives. Analogously, however, in all of the three proposed inflation targeting regimes real GDP is affected stronger on impact.

Under a fixed exchange rate regime, capital flow shocks would be fully compensated by respective foreign exchange interventions and thus have no effect on domestic variables. However, oil price shocks would result in an amplification of their inherent impact on the exchange rate, imported prices and total inflation that the central bank cannot mitigate due to the abandonment of an independent monetary policy.

Ruble price of oil targeting proves inferior to the policy in place as well as the other alternatives. Whereas it offsets the impact on nominal exchange rate dynamics caused by non-fundamental capital flows, it induces exchange rate fluctuations according to movements in oil prices that affect the domestic economy via an increased volatility of absolute and relative prices.

6 Conclusion

Russian monetary policy has been challenged by large and continuous private capital outflows and a sharp drop in oil prices during 2014, with both ongoings having put a significant depreciation pressure on the ruble. In order to mitigate the impact

Table 3 Forecast error variance decomposition at different horizons under inflation targeting, in percentage point deviations from the current policy, adjusted for absence of monetary policy shocks

1 Quarter	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	5.3	−3.1	1.2	0.0	0.0	−1.3	−1.2	−0.9	0.0
Consumption	0.5	1.6	−1.4	0.0	−1.7	0.0	−0.2	1.2	0.0
Investment	−0.1	0.7	−0.9	0.0	0.4	0.0	−0.8	0.6	0.0
Exports	11.0	−1.9	7.7	0.0	−5.8	−0.1	0.0	−2.1	−8.8
Imports	−0.3	−0.8	−6.2	0.0	5.9	0.1	1.2	−0.1	0.2
Real Wages	−2.2	2.2	−4.0	0.0	3.6	0.0	−0.3	0.1	0.6
Inflation	−13.2	−1.2	−2.2	0.0	11.0	0.2	0.0	3.0	2.4
Dom. Prices	−9.4	−1.3	−2.7	0.0	9.2	0.2	−0.1	2.4	1.7
Real ER	3.2	−1.7	5.6	0.0	−5.4	−0.1	0.0	−2.0	0.3
4 Quarters	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	−0.4	0.1	−1.9	0.0	1.2	−0.1	−0.6	1.6	0.0
Consumption	−0.3	1.5	−1.2	0.0	−2.0	0.0	−0.1	2.2	−0.1
Investment	−0.1	1.3	−2.2	0.0	0.4	0.0	−0.1	0.9	−0.1
Exports	−5.9	−1.0	11.6	0.0	−4.3	0.0	0.1	−2.1	1.7
Imports	0.4	−0.4	−5.4	0.0	3.9	0.0	1.2	0.1	0.2
Real Wages	−2.1	2.5	−2.7	0.0	2.1	0.0	−0.3	0.2	0.4
Inflation	−21.0	−0.3	5.2	0.0	9.8	0.1	−0.1	3.2	3.1
Dom. Prices	−14.9	−0.6	3.3	0.0	7.8	0.1	−0.1	2.4	2.1
Real ER	7.0	−1.9	3.5	0.0	−6.3	0.0	0.1	−3.3	1.0
8 Quarters	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	−0.5	2.0	−4.7	0.0	0.9	0.0	0.3	2.0	0.0
Consumption	−0.2	2.9	−3.8	0.0	−0.9	0.0	−0.1	2.3	−0.1
Investment	0.0	2.6	−5.7	0.0	0.0	0.0	2.3	1.0	−0.2
Exports	−2.5	−0.5	3.7	0.0	−1.6	0.0	0.2	−1.1	1.8
Imports	−0.6	−0.1	−2.0	0.0	1.7	0.0	0.7	0.0	0.2
Real Wages	−1.6	1.7	−1.6	0.0	1.3	0.0	−0.2	0.2	0.3
Inflation	−19.2	0.0	3.6	0.0	10.0	0.1	0.0	2.9	2.6
Dom. Prices	−13.7	−0.4	2.1	0.0	8.0	0.1	0.0	2.1	1.7
Real ER	12.4	−1.3	−6.6	0.0	−3.3	0.0	0.1	−2.0	0.7
y∞	η^{ω^*}	η^a	η^{po}	η^{oild}	η^b	η^g	η^i	η^l	η^*
Real GDP	−0.3	5.3	−7.6	0.0	0.5	0.0	0.8	1.5	−0.1
Consumption	−0.6	3.2	−3.7	0.0	−0.3	0.0	0.1	1.2	−0.1
Investment	−0.8	3.7	−7.4	0.0	−0.2	0.0	4.4	0.6	−0.2
Exports	−3.3	1.2	2.6	0.0	−1.6	0.0	0.3	−0.9	1.6
Imports	−2.7	−0.5	3.2	0.0	−0.2	0.0	0.5	−0.5	0.2
Real Wages	−0.9	0.5	−0.2	0.0	0.6	0.0	−0.2	0.1	0.1
Inflation	−18.4	0.3	1.1	0.0	10.8	0.2	0.1	3.3	2.6
Dom. Prices	−13.1	0.1	−0.7	0.0	9.2	0.1	0.0	2.6	1.7
Real ER	11.1	0.1	−7.5	0.0	−2.8	0.0	0.1	−1.5	0.6

on its currency, the central bank repeatedly raised its key policy rate and directly intervened on the foreign exchange market. However, its policy measures could not prevent a strong depreciation of the ruble, while raised interest rates might have posed an additional obstacle for the already weak economy. This work estimates a small open economy model for Russia, featuring an oil price sector and extended by a specification of the foreign exchange market to correctly account for systematic central bank interventions. We find that shocks to the oil price and private capital flows substantially affect domestic variables, such as inflation, output and the exchange rate. Simulations of the model for the estimated actual strategy and five alternative regimes suggest that the vulnerability of the Russian economy to external shocks can be substantially lowered by adopting some form of inflation targeting strategy. Foreign exchange intervention-based policy strategies to target the nominal exchange rate or the ruble price of oil, on the other hand, prove inferior to the policy in place, in particular because of the lacking ability of conducting independent monetary policy via the interest rate. However, in the presence of non-fundamental capital flow shocks, interventions may be helpful to offset destabilizing effects from their impact on the exchange rate. Although these implications do not qualitatively differ from the ones argued for in comparable studies in the past, the analysis in this work has been conducted by properly accounting for foreign exchange interventions of the central bank and also by introducing non-fundamental capital flows that have a direct impact on the exchange rate and thus on potential policy strategies that aim at a stabilization of the latter. Even though capital flows are regarded as non-fundamental in the sense that their dynamics are not explained by other model variables, large and continuous capital outflows are not random in reality. Since our analysis finds them to strongly affect the domestic economy, any political arbitrariness as well as legal and political uncertainty that might cause them should be regarded as obstacles to a sound economic development. The full-scale invasion of Ukraine in February 2022 eclipsed everything previously seen in that context. Dramatically worsened prospects for the Russian economy as a result of the attack itself and amplified by sanctions led to an enormous capital flight. With the access to its foreign exchange reserves held abroad being blocked as part of the sanctions, the central bank found itself unable to counter devaluation pressures of the ruble that would be the optimal policy response. In addition, as Russian assets became unattractive, the stabilization of the exchange rate through an increase in the policy rate has been neither an equivalently effective nor recommended measure since it puts further constraints on an already struggling economy. Monetary policy has thus not been able to prevent the domestic currency from a strong depreciation that will translate to a sharp increase in the price level in the very near term. The negative longer term effects on the Russian economy and its production potential through the lack of crucial imports, a loss of trust or a faster reduction in demand for its fossil fuels, among others, are even further beyond the ability of the central bank to mitigate.

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