Humboldt University in Berlin

Institute of Economic Policy I & Schumpeter Institute
Macroeconomics, Money and Capital Markets

Optimal policy rules in an export-oriented economy

in Pursuit of the Degree
Master of Science in Economics and Management
at the School of Business and Economics
Humboldt-University Berlin

Presented by
Atamanchuk Maria
512603
maria.atamanchuk@gmail.com

Examiner:
Professor Harald Uhlig, Ph.D.

Berlin, 16th July 2007

Affidavit/statutory declaration

I herewith declare, in lieu of oath, that I have prepared this paper on my own, using only the materials (devices) mentioned. Ideas taken, directly or indirectly, from other sources, are identified as such.

This work has not been submitted in equal or similar form to another examination office and has not been published.

Berlin, July 16, 2007 ____________________________

signature

Abstract

Research is determined by the necessity of finding the set of optimal feedback coefficients of fiscal and monetary policies within an export-oriented economy with emphasis on the oil industry such as Russia. To address this issue we build the open economy general equilibrium model that can be seen as RBC model augmented with some additional features. As a benchmark we take the model of Schmitt-Grohe and Uribe (2004). We expand their model by including the external sector, non-producing oil sector and a fund for accumulating the huge revenues from oil export to our analysis. We calibrate the economy for the case of Russia. Our main findings are: under oil price shock optimal monetary policy rule features a significant response to output; the coefficient of nominal interest rate varies significantly for different shocks; considering stabilization fund under passive fiscal policy with liability targeting each value of liability targeting coefficient could either produce no deviation from steady state given any value of inflation feedback coefficient or cause a deviation which is exactly the same.

Contents

1. Introduction

During the last few years searching for the optimal rules of the government and the central bank has attracted significant interest. As such, they are crucial in determining macroeconomic policies in the European Union (the optimal policy rules of the European Central Bank and the EU governments), the best policies of the central bank and the government aimed at the stabilization of debt and inflation, and in determining the influence of macroeconomic policies on inflation, production, etc. Although the search for optimal fiscal and monetary policy rules in Western economic literature has been studied in detail, many of the results cannot be directly applied to the current situation in Russia's economy. There are two major reasons for this: the export-oriented character of the Russian economy and some specific characteristics, such as a significant role of the stabilization fund, which have an impact on finding the optimal feedback rules' coefficients and on studying their influence on the economy.

Research is determined by the necessity of finding the optimal feedback coefficients of fiscal and monetary policies within an export-oriented economy with emphasis on the oil industry such as Russia. In the economy with nominal rigidities considered in this research under different fiscal priorities the efficiency of monetary policy also would be differing. If the government is mainly oriented on balanced budget targeting, then the optimal feedback coefficients of monetary policy rule could vary dramatically with the situation of liability targeting.

However, our aim does not consist in determining a single optimal rule for all states of the world. But we do clarify the possible set of optimal feedback coefficients under a particular shock in the economy. Obviously, when a technology shock occurs, then government policy should differ from the one under an oil shock. Thus, we determine a set of coefficients that satisfy the requirement of optimal policy in an export-oriented economy with emphasis on the oil industry. At that we rely on the following criteria of optimality: the optimal policy rule is determined through minimization of variables' deviations from their steady-state. The practical contribution of our work also consists in providing the program based on a Toolkit program[1] for MATLAB implementation. It could answer the question about the optimality of a particular policy. It means that under values of feedback coefficients which are certain (with possibly one uncertain value), the impulse responses could be easily found. In case of more uncertainties the program shows deviations from steady state under all possible variants of feedback coefficient combinations in a particular moment.

[1] For the program details see Uhlig (1997)

To address the issue outlined above we build a general equilibrium model for an export-oriented economy. As a benchmark we take Schmitt-Grohe and Uribe (2004), who compute optimal fiscal and monetary policy rules in a modified real business cycle model. One of the key elements of our model consists in analyzing the economy with huge oil revenues, part of which is accumulated in a stabilization fund, to avoid too high inflation, among other reasons. We calibrate the economy for the case of Russia. To do this we conduct extensive research of the Russian economy within the period from 2001 to the beginning of 2007 and formulate stylized facts on basis of it. We build impulse responses and calculate deviations from steady-states under technology, government purchases, oil flow and oil prices shocks.

Our main findings are: under oil price shock optimal monetary policy rule features a significant response to output; the coefficient of nominal interest rate varies significantly for different shocks; considering stabilization fund under passive fiscal policy with liability targeting each value of liability targeting coefficient could either produce no deviation from steady state given any value of inflation feedback coefficient or cause a deviation which is exactly the same.

The remainder of the paper consists of seven sections. Section 2 presents a brief survey of the literature studying the search for optimal fiscal and monetary policy rules. Section 3 elucidates the particular facts of the Russian economy that were used to build and to calibrate the model. The model and its analysis are presented in Section 4 and 5, respectively. Section 6 provides the results we have obtained. Section 7 contains the discussion of the achieved results. Section 8 concludes.

2. Literature

A considerable amount of analysis seeking optimal monetary and fiscal policy rules has taken place over the last 20 years. Alternative monetary rules as well as fiscal policy targets were developed in a number of countries' investigations.

The superiority of rules was initially shown by Robert Hall (1984), Bennett McCallum (1984), John Taylor (1986a).

In the resent years, in most of this literature monetary policy rule presumed to have a form of an interest-rate feedback rule that considers the nominal interest rate as a function of inflation and some characteristics of aggregate activity (usually, output). The paper by Taylor (1993) was groundbreaking: the author suggested simple and tractable interest rate rule for Central Bank. Owing to that the practice of using Taylor-type rules became widespread in economic modeling. Initially, this rule was elaborated for industrialized countries. However, the experience of the advanced emerging markets researches showed that interest rate rules describe the policy setting behavior of the monetary authority rather quality (see, for instance, Calderon and Schmidt-Hebbel, 2003, Mohanty and Klau, 2003, Minella et al., 2003, Torres Garcia, 2003).

Considering an export-oriented economy and describing some of the peculiarities of the Russian economy, we also rely on Taylor rule. The first research on the optimal rule for monetary policy in Russia was produced by Drobyshevsky and Kozlovskay (2002). Following Clarida, Gali and Getler (1998) the authors used the GMM methodology for searching for the optimal interest rate response but failed to incorporate output in the analysis. However, Vdovichenko, Voronina (2004) also seeking for the optimal monetary rule analyzed Russian economy within the post crisis period, 1999-2003, taking this lesson into account. Using econometric modeling, they estimated different monetary policy rules, as well as Taylor-type rule, and found out that interest rate policy of the Bank of Russia has been rather adaptive and that the money supply instrument performed the stabilizing role. Succeed also the activists of including output in monetary policy criterion function, Hall (1984) and Taylor (1986a), we do not exclude GDP from monetary rule in our analysis.

Esanov, Merkl, Vinhas de Souza (2004) searching for the optimal monetary rule analyzed the period of 1993 - 2002 in Russia and found out that Tailor rule did not correspond to the economic processes properly. However, they made the empirical estimation of policy rules, other than we expand the theoretical general equilibrium model with oil sector and stabilization fund.

We do analyze the export-oriented economy with emphasis to oil industry by the example of the subsequent period of Russian economy that differs dramatically from 1993-2002[2].

Considering different shocks we are mainly interested in the the influence of the oil price shock on the economy. This question for a number of different countries was also studied in Bernake et al. (1997), Estwood (1982), Fry and Lilien (1986). The reaction of monetary and fiscal policy to oil shocks, 1973 - 1974, in 55 developing and developed countries, was studied by last-named authors, who found that accommodation of monetary policy can even reduce output growth in the long run period. The longer the time of accommodation the less effective is positive policy influence on output. The expansionary fiscal policy produces the same results. Two possible strategies for monetary policy under oil shock of 1990 were suggested by Taylor (1993). If oil shock is temporary, then possibly it is better not to increase interest rate (though in reality, Central Bank did), but then the deviation in policy rule is required. The other variant proposes not to change policy at all. Searching the answer to the issue of desirable policy strategies under the oil shock, we study different policy targets and seek for the optimal set of policy coefficients.

In addition to the situation of active monetary policy our analysis includes the consideration of the active fiscal policy influence on the price index. There are studies in literature of the conditions under which inflation is determined solely either by fiscal or monetary policy (Woodford (1995), Canzoneri et al. (1998), Schmitt-Grohe and Uribe (1997), Cochrane (1998)) identified that in order for the monetary policy not to affect prices it is necessary that government expenditure and taxes be exogenous processes. These and further assumptions are introduced to make the real interest rate be determined only by the availability of real resources, but not by monetary policy. In our analysis we follow Schmitt-Grohe and Uribe (2004, 2006) and model only government expenditure as a univiarate autoregressive process, but however, let us implement the situation of active fiscal policy. Real interest rate is pressured by the initial price level which is adjusting to be consistent with a bounded path of government liabilities.

Searching for an optimal policy rule, different optimality criteria can be applied. Maximization of welfare function and choosing the feedback policy coefficients under the existence of rational expectations equilibrium is one way. In particular, Schmidt-Grohe and Uribe (2004, 2006) relied on that searching for a policy that yields the highest level of lifetime utility given the contingent plans for consumption and hours of work .

[2] For more details see also section “Facts”

Woodford (2002, ch.7) suggests a more complicated criteria of searching for the optimal rule in forward-looking models. A quadratic loss criterion is divided into two components: the deterministic component of the equilibrium paths of the target variables and the stable part that depends only on the equilibrium responses to unexpected shocks in periods after t_0. The optimal feedback coefficients should minimize the second part. But the deterministic component does not have to be minimized, but a rule is chosen that is consistent with the long-run average values that occur under the t_0. Woodford (2002) asserts that this criterion helps to avoid time-inconsistency of policy choice in forward-looking policy rules.

However, we rely on a simpler criterion that is consistent in the case of a contemporaneous policy rule. Optimal policy rule is determined as minimization of variables' deviations from their steady-state. It is directly interconnected with widespread idea of minimizing loss functions and then determining the optimal policy coefficients (see Tabellini (1986), van Arle, Bovenberg and Raith (1995)). This definition of optimality for policy rules was used in, for example, Currie and Levine (1991).

The analysis in this paper is mainly based on Schmitt-Grohe and Uribe (2004). An in-depth description of the paper concept is provided underneath.

Benchmark paper

In the research paper "Optimal Simple And Implementable Monetary and Fiscal Rules" (2004), Stephanie Schmitt-Grohe and Martin Uribe aim to compute optimal fiscal and monetary policy rules in a modified real business cycle model. Specifically, their model includes sticky prices, a demand for money, distortionary taxation and stochastic government consumption. Furthermore, they account for capital accumulation and an active fiscal policy, and do not rely on the presence of lump-sum subsidies to undo the distortions created by monopolistic competition. These specifications make the economic environment more realistic and distinguish the model from many other works in the field.

In order to find optimal policy rules the authors rely on explicit welfare calculations. For this purpose they cannot work with first order approximations, but need to approximate their model up to the second order. The reason is that all the policy regimes under consideration imply identical non-stochastic steady states, as a result of which first order approximations would yield the same levels of welfare for all possible policies[3].

[3] "…for some purposes first-order accuracy is not enough. This is true in particular for comparing welfare across policies that do not have first-order effects on the model's deterministic steady state…" p. 1, Kim, Kim, Schamburg and Sims (2003), see also Schmitt-Grohe and Uribe (2004b), Lombardo and Sutherland (2005)

The authors systematically calculate welfare levels for a large number of plausible policy coefficients to find optimal rules essentially by ‘trial and error’. As far as fiscal policy is concerned they conclude that the welfare-optimizing policy is passive, but that an active policy does only minor harm. Concerning monetary policy they find that while the inflation coefficient in the monetary rule is immaterial for welfare, is it crucial that monetary policy be insensitive to output. This key result is illustrated by impulse responses of some endogenous variables to a technology shock.

This part of the authors’ article became the bench mark for our current research. Briefly, taking General Equilibrium Model for closed economy, we included the external sector to analyze the export-oriented economy required in research. One of the crucial peculiarities of this four-agent model lies in the inclusion of the stabilization fund and oil sector into the analysis. These and some other dimensions wide the model and change some of the equations suggested by the benchmark article. Impulse responses of some endogenous variables not only to a technology shock, but also to a government purchases, oil flow and oil prices shocks are implemented. Since this work analysis does not involve the calculation of welfare levels, it could and will rely on first order approximations of the steady state. More comprehensive description of the basic model and the innovations introduced to analyze the export-oriented economy are described in the Section “Model”.

3. Facts

This chapter is devoted to a brief survey of macroeconomic policy in Russia, chiefly from 2001 to the beginning of 2007. The reason of considering just this period lies in historical events that happened in the Russian economy. Before 1991 there was no market economy, but the command regime in USSR period. After 1991 began a period of market formation. The economy developed rapidly and reached significant growth rates, but the crisis of 17 August 1998 broke off this process. The government could not pay off its debts and undermined the economy by issuing more and more liabilities. As a result of this the Russian financial system was broken. Millions of people lost their jobs, hundreds of banks became bankrupt, share prices went dozens of times down, and so on. The economy was crushed. Bit by bit it started recovering. This process took many years and the current Russian economy still bears an impact of that time. If we analyze the first years after crisis, they would distort the pattern of the current Russian economy too much. That is why we start our analysis from the first years of the rehabilitation period. Starting with the period when the economy got over this destructive shock for the most part and at last reconstruction was under way, the analysis can be carried out without a risk to get too biased results. At the same time the analysis within the period of 2001-2006 gives us an adequate time interval to come to some clear conclusions.

The goal of this part does not lie in irrefragable description of all most important macroeconomic aspects of Russian economy during the last years. Also we don't make the empirical analysis of macroeconomic processes' interactions as our aim. The object is to formulate stylized facts regarding the dynamics of the macroeconomic variables presented in our research.

Stylized facts of Fiscal and Monetary policy in Russia, 2001 -2007

The macroeconomic situation of modern Russia from 2001 to 2006 could be characterized in the following way. During the last years the inflation ratio had been gradually declining. At the same time the dynamics of money supply growth rate do not demonstrate the same trend. Currency appreciation takes place because of favorable external market conditions. High export revenues support the growth of real GDP. Data is presented in Table 3.1.

Table 3.1. Main macroeconomic characteristics of the R.F., 2001-2007

	2001	2002	2003	2004	2005	2006	Jan. – May 2007
The growth of Consumer Price Index, %	18.6	15.1	12.0	11.7	10.9	9.0	4.7
The growth of Producer Price Index, %	10.7	17.1	12.9	28.3	13.4	9.3	6.1
The growth of Money supply (in the narrow sense), %	38.1	30.4	49.6	24.9	31.7	39.6	1.7
The growth of Money supply, %	40.1	32.3	51.6	35.8	38.6	32.6	11.2
The real appreciation of exchange rate (rubles/U.S.dollar), %	8.8	6.2	18.9	15.1	10.8	10.7	3.4
The change of real effective exchange rate (rubles/foreign currencies), %			4.1	7.1	8.1	9.4	2.3
The growth of real GDP, %	5.1	4.7	7.3	7.1	6.1	6.3	

Source: Federal State Statistics Service

Among the main reasons of export growth is the increase in the Russian Federation's revenues from oil sales. Prices of energy carriers have grown confidently during the whole period under review, demonstrating the most significant growth in 2005-2006.

The Russian Federation budget had a surplus over the whole period and grew dramatically after 2005 as a result of state revenues increase from oil sales (Table 3.2). Budget surplus enters the stabilization fund, the value of which has risen greatly in Russia during the last years.

Table 3.2. Government budget of the R.F., 2001-2007

Federal budget execution		2001	2002	2003	2004	2005	2006	Jan.-May 2007
Total Revenues	*Bln.rub.*	1590.7	2202.2	2586.2	2742.9	5125.1	6276.3	2512.5
	% GDP	17.6%	19.4%	18.5%	17.9%	23.7%	23.6%	21.8%
Revenues, less revenues entered to a stabilization fund account	*Bln.rub.*					3729.23	4477.4	1994.7
	% GDP					17.3%	16.8%	17.3%
Total Expenditure	*Bln.rub.*	1325.7	2046.0	2358.5	2659.4	3512.2	4281.3	1741.9
	% GDP	14.5%	17.8%	18.0%	17.4%	16.3%	16.1%	15.1%
Surplus(+)/Deficit(-)	*Bln.rub.*	265.0	156.2	227.6	83.4	1612.9	1995.0	770.7
	% GDP	3.1%	1.6%	0.6%	0.5%	7.5%	7.5%	6.7%

Surplus(+)/Deficit(-), less revenues entered to a stabilization fund account	*Bln.rub.*					217.0	196.1	252.8
	% GDP					1.0%	0.7%	2.2%

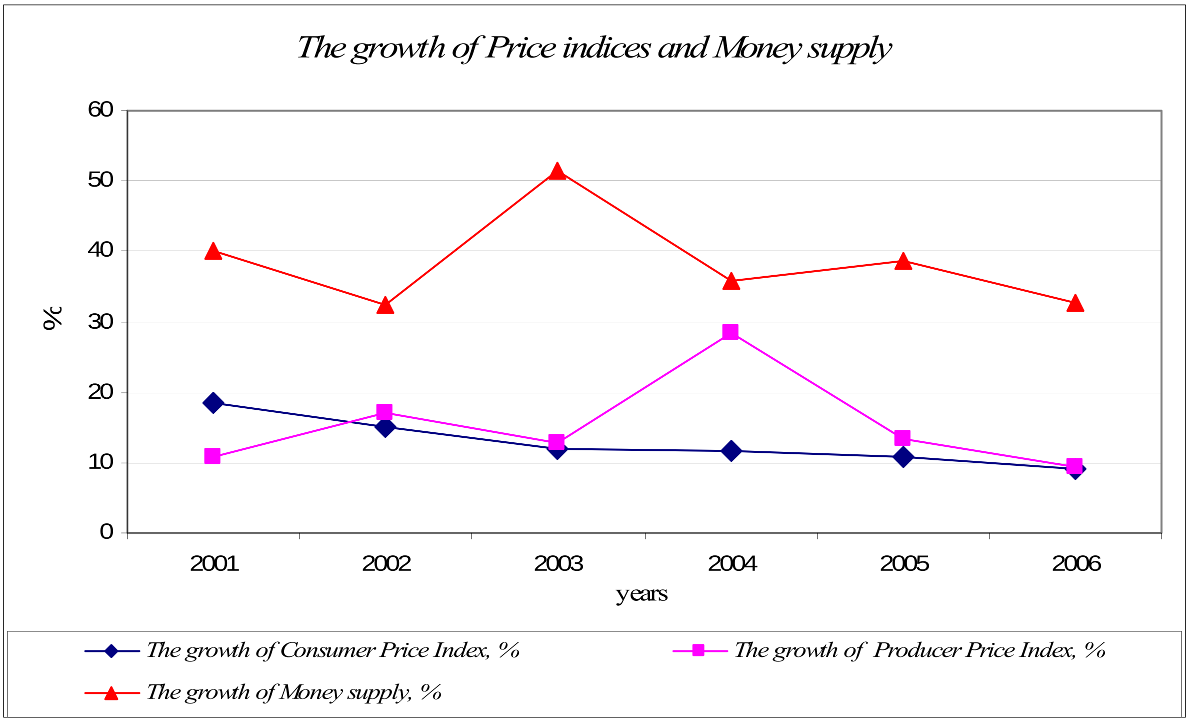
Source: Federal State Statistics Service, Bank of Russia

Let us consider important for our analysis macroeconomic processes in greater detail.

Inflation and Money supply

Generally, inflation rate stabilization is observed in Russia. Within the period under review inflation has had a temperate nature. Figure 3.1 illustrates the dynamics of annual Consumption Price Index, Producer Price Index[4] and Money supply.

Figure 3.1 The dynamics of Price indices and Money supply



Data source: Bank of Russia, our calculations

Within the whole period the price index, defined by CPI, has declined confidently. This was in spite of the fact that money supply growth rate was observed during some periods. Moreover, we could not observe a stable decrease of money supply growth rate[5], unlike we did with inflation.

[4] As evident from figure 3.1 the inflation dynamics depend on how we determine it, either using Consumer Price Index or Producer Price Index. Such a big difference could be explained by the fact of including oil prices in the latter.

[5] A moderate inflation jump could be expected in the future, that is due to previous growth of money supply. Taking into consideration that the growth of money supply influences inflation indices with some time lag and this influence lasts longer than one period, the previous increase of money supply tells on price index of 2007 in full measure. This fact gives grounds not to forecast inflation at a greatly smaller rate than it was.

<u>*Stylized fact №1:*</u> Inflation rate was positive and significantly large, but decreased regardless of the high growth rate of money supply. Reduction of inflation was almost notwithstanding monetary policy of Bank of Russia in 2001-2007.

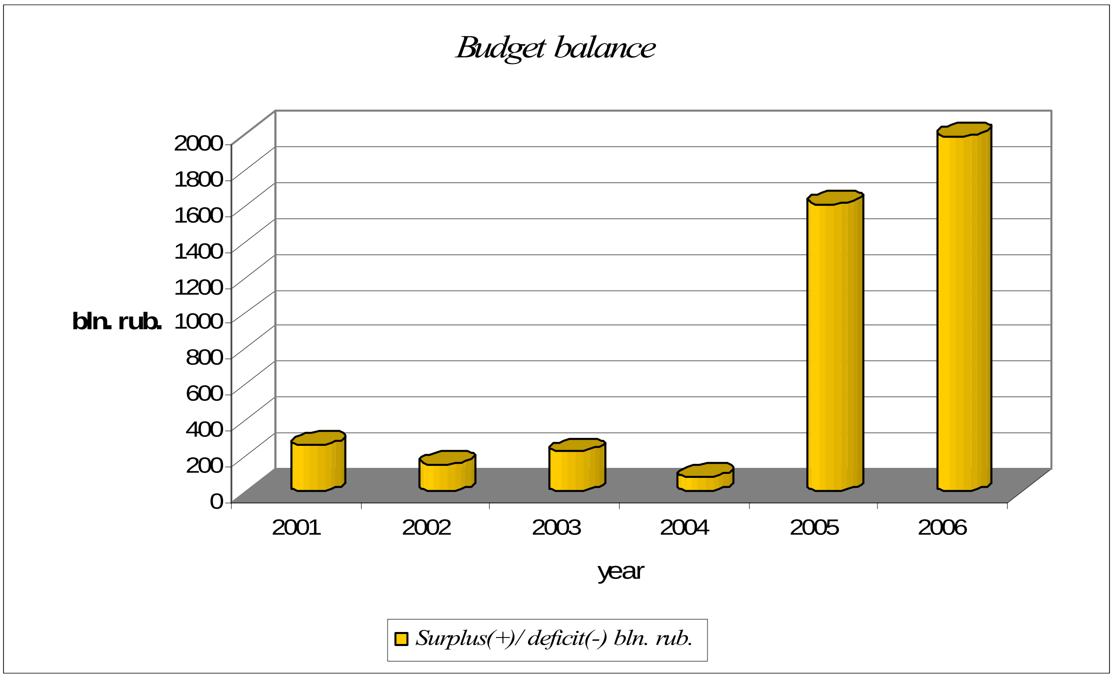
This surprising, at first glance, fact could be explained by dynamics of money velocity. It means when money supply was growing up dramatically, money velocity was coming down, thus, restraining the inflation growth.

Interest rate as an instrument of monetary policy for inflation control is found as a not the most substantial one. It could be explained by the existence of high, even excess, liquidity in Russian economy during the analyzable period. The significant inflow of foreign currency was determined by high oil prices. Open market operations could be admitted as more important instrument of inflation regulation, but interest rate role is also gradually increasing.

Budget

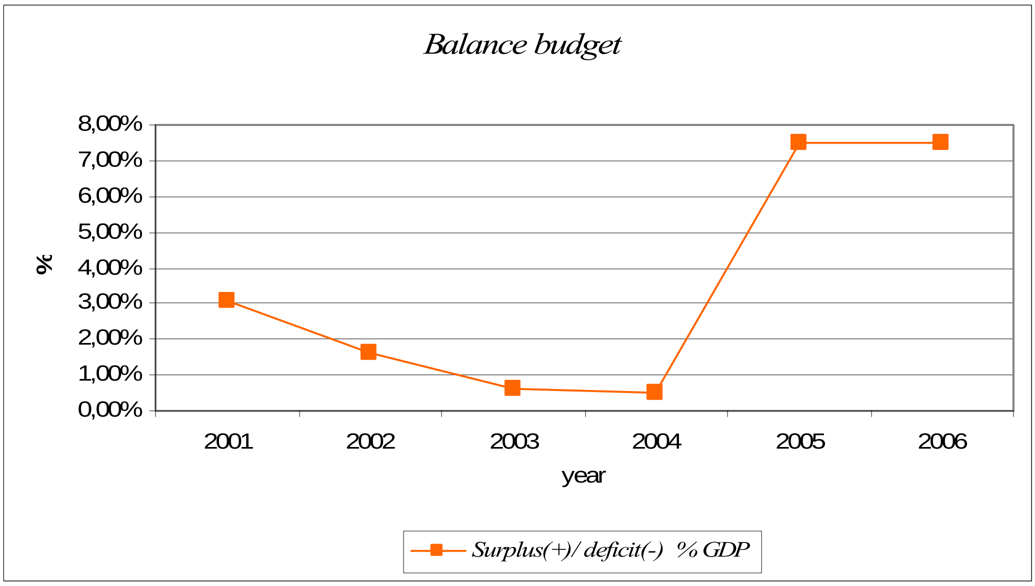
Every year from 2001 to 2006 the budget surplus has taken place in Russian economy. Figures 3.2 and 3.3 depict federal budget balance in the absolute value and in percent of annual GDP, respectively.

Figure 3.2. Federal Budget Balance



Data source: Bank of Russia

Figure 3.3. Federal Budget Balance in percent of GDP



Data source: Bank of Russia, our calculations

Sharp growth of state budget surplus in 2005-2006 was caused by increase in export duties which, in their turn, had been provoked by high oil prices. Since export duties were a big part of federal budget revenues during the last years (especially, in 2005-2006), which is shown in table 3.3, this important fact is taken into consideration in our model. We split export duties as a separate part of tax function.

Stylized fact №2: Due to high oil export duties oil taxes constitute a huge fraction of the total taxes.

Table 3.3 Consolidated budget, 2005 - 2006

	2005, billions of rubles.	*2005, % GDP*	2006, billions of rubles	*2006, % GDP*
Total revenues	5125,1	*23,7%*	6276,3	*23,6%*
of which Export duties	1351,9	*6,3%*	1895,8	*7,1%*
Total expenditure	3512,2	*16,3%*	4281,3	*16,1%*

Source: Economic Expert Group

In 2006 export duties accounted for about 18 percent (and about 20 percent in 2005) of budget revenues, as evident from table 3.3. Most part of these taxes was entered at the R.F. stabilization fund account[6].

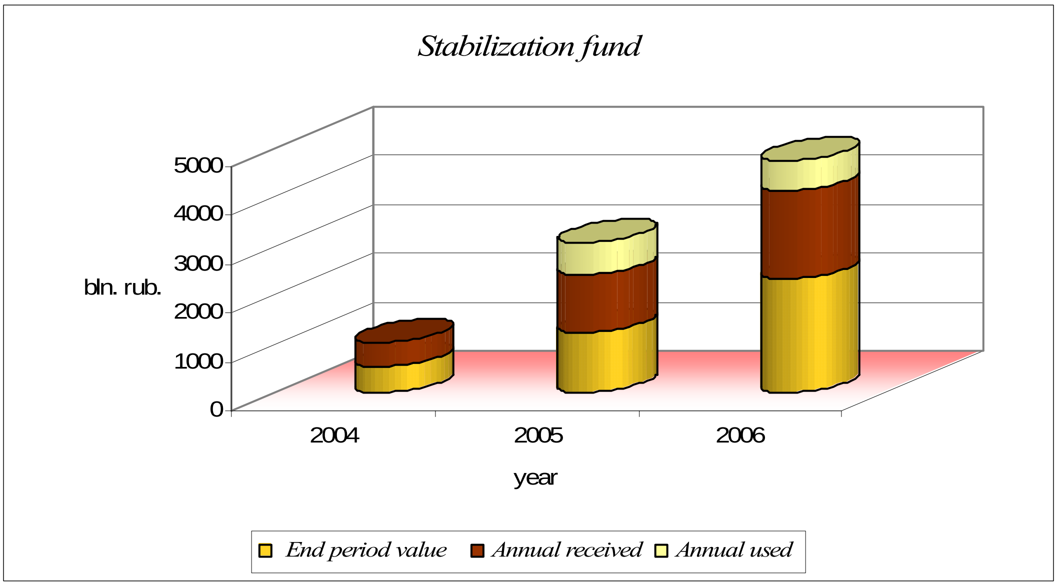
[6] The order and conditions for stabilization fund creation in the R.F. are described in the R.F. Budget Code, asset 96-1

Stylized fact №3: Budget balance of the Russian Federation had the surplus within the analyzable period that was caused by high oil prices.

Stabilization fund

Stabilization fund of the Russian Federation, established on the first of January 2004 and being a part of the federal budget is among the main objects of our research. Per se, stabilization fund is used for storage of cash means that have not been spent by the government within this period, but can be spent afterwards to cover the debt. This is, in a sense, a strategic asset that could be used in case of substantial decrease of budget revenues or in case of an unexpected expenditure rise. Figure 3.4 illustrates the annual funds used, received and end period value of the R.F. stabilization fund from 2004 to 2006.

Figure 3.4. Stabilization fund



Data source: Bank of Russia

The official size of stabilization fund on the first of June 2007, declared by the Ministry of Finance of the Russian Federation, was 3 026.68 billion rubles (that is equivalent to approximately 117.762 billion. U.S. dollars).[7]

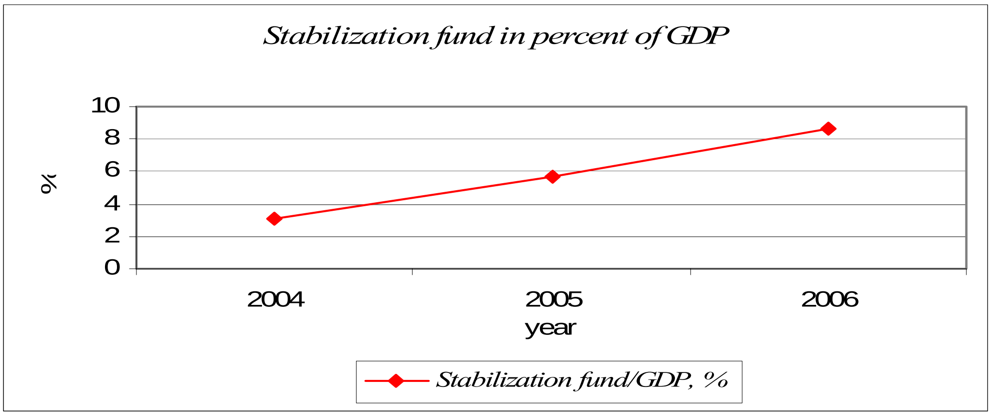
It is worth to mention that the main sources for stabilization fund are the oil production tax and oil export duties (to put it more precisely, the part of export duties formed due to the oil price in excess of its cut-off value)[8]. Also, all of the unspent (unplanned) budget surpluses are transferred to a stabilization fund account.

[7] At the exchange rate of Bank of Russia, 10.07.2007
[8] The annual cut-off oil price per barrel is settled legislatively by the Government of the Russian Federation

Stylized fact №4: Within the period of 2004 - 2006 large black ink of federal budget has produced rapid accumulation of funds in stabilization fund.

Figure 3.5 depicts the dynamics of stabilization fund in percent of the R.F. GDP.

Figure 3.5. Stabilization fund in percent of GDP



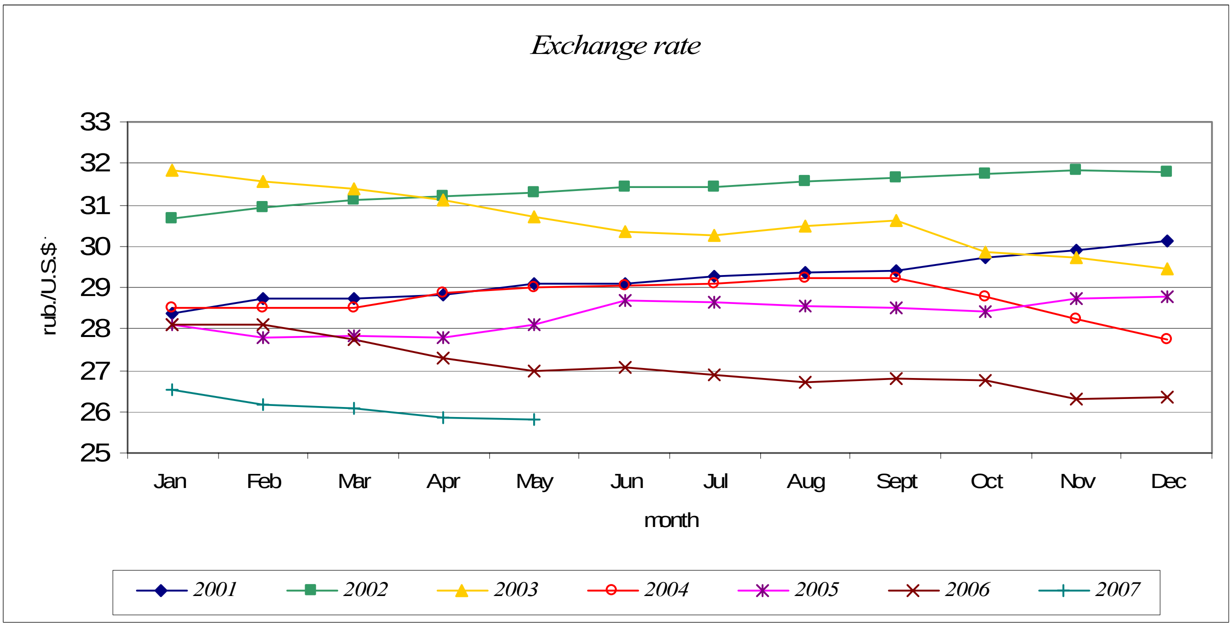
Data source: Bank of Russia, our calculations

The relative value of stabilization fund was growing inside of a period, and its meaning, according to forecasts, would reach 9.2 percent of GDP by the end of 2007.

Exchange rate

The monthly dynamics of exchange rate are presented on figure 3.6.

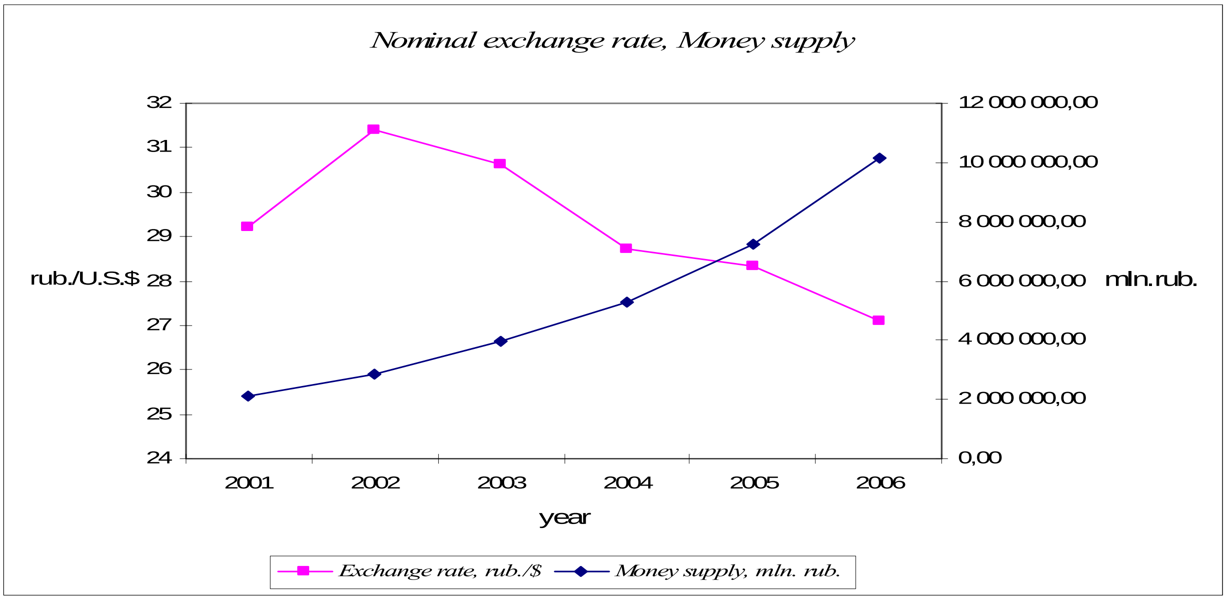
Figure 3.6. Nominal exchange rate (rubles/U.S. dollars)



Data source: Bank of Russia

We could observe the increase in the value of the ruble with respect to U.S. dollar since 2002. An interesting fact is currency appreciation against a background of money supply increase (see figure 3.7).

Figure 3.7. The dynamics of nominal exchange rate and money supply



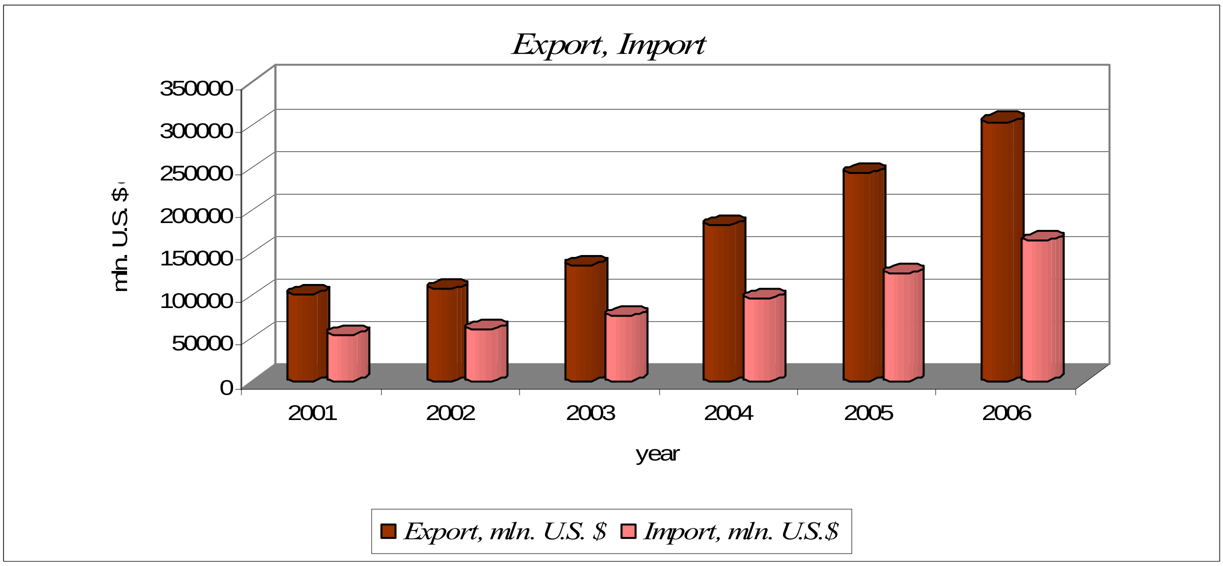
Data source: Bank of Russia

The increase of ruble exchange rate is clarified by export growth to a great extent, all the data is provided underneath. Export increase effect was bigger then money expansion effect in terms of influencing on exchange rate.

External economic activity

This paragraph supports the basis for the fact Russia has an export-oriented economy at the present time. Figures 3.8 and 3.9 present the annual export and import data in absolute value and in percent to GDP from 2001 to 2006. Figure 3.10 illustrates the growth rate of Russian export and import within the same period. It is significant to mention that in spite of essential growth of trade balance variables, their share in GDP did not change significantly.

Figure 3.8. The dynamics of Export and Import



Data source: Bank of Russia

Figure 3.9. The dynamics of Export and Import in percent to GDP

Data source: Bank of Russia, our calculations

Figure 3.10. The growth rate of Export and Import

Data source: Bank of Russia, our calculations

<u>Stylized fact №5:</u> Russia has an export-oriented economy. Export permanently equals to about one third of aggregate expenditure and has exceeded import almost two times within the whole period under review.

The overrepresented figures show that export's absolute value and its rate of growth has risen annually. Import also has grown annually, but for all that its growth rate had slightly fallen down last year. Since export has had extremely high growth rates for the last two years, let us consider this period in more detail. Table 3.4 includes the export and import data of Russia in 2006, and its value relative to 2005.

Table 3.4. Export and Import in 2006

	2006 (bln. U.S.$)	**Value relative to 2005**
Export	304,5	125
Import	163,9	130,8
Foreign trade turnover	468,4	127
Trade balance	140,7	118,9

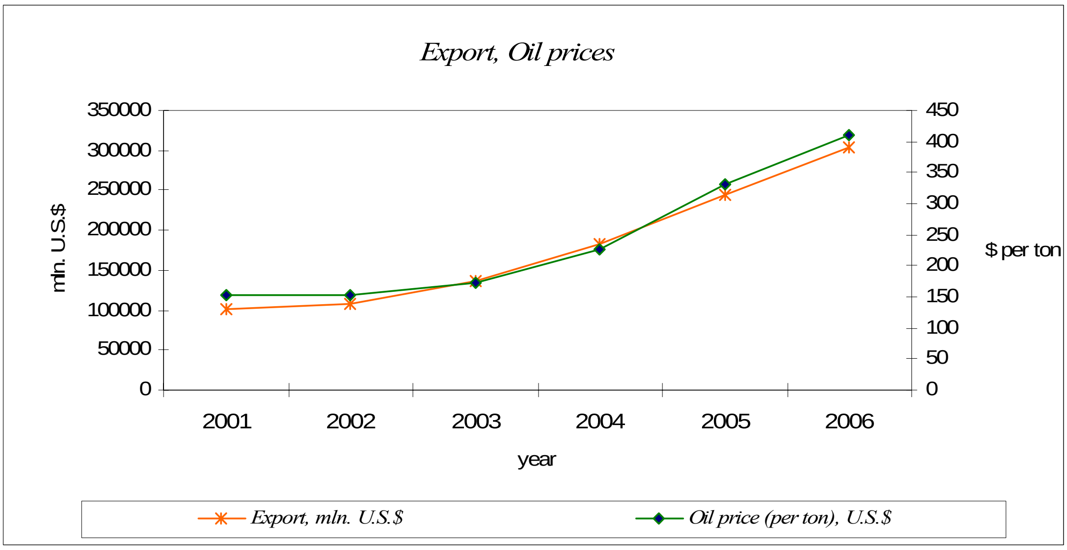
Source: Bank of Russia

Table 3.4 shows that Russian export exceeded import in 2006 dramatically, though import growth was higher in relative terms. As it has already been mentioned, such a big export could be warranted by favorable situation in energy market. Import grew because of ruble appreciation.

It is interesting to compare the dynamics of Russian export with oil prices. Figure 3.12 illustrates high positive correlation between these two variables.

<u>Stylized fact №6:</u> Oil constitutes a huge part of Russian export.

Figure 3.11. The dynamics of Export and Oil prices



Date source: Bank of Russia, our calculations

4. The Model

The open economy general equilibrium model presented in our work can be seen as RBC model augmented with some additional features. Some of them, such as the existence of nominal rigidities, time-varying distortionary taxation, demand for money and monopolistic competition on product markets were introduced by Schmitt-Grohe and Uribe (2004) who built general equilibrium model for the closed-economy. We expand their model by including the external sector, non-producing oil sector and a fund for accumulating the huge revenues from oil export to our analysis. By doing this we alter the model in order to make it applicable to describing the current processes in the Russian economy.

There are four economic agents: Households, Firms, the Government and the External sector. Households and firms solve their optimization problems and the Government, presented by Monetary and Fiscal authorities, follows its policy rules. The External sector is modeled in terms of additional restrictions to the model. Oil sector is integrated into the model as an extra non-producing sector. The policy rule for the stabilization fund is introduced.

Households

There is a continuum of identical households in the economy. The preferences of a typical household (over consumption, c_t, and labor effort, h_t) are given by the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[c_t (1-h_t)^{\gamma}\right]^{1-\sigma} - 1}{1-\sigma}, \tag{1}$$

where σ is the intertemporal elasticity of consumption, and γ denotes a preference parameter, $\beta \in (0,1)$ means a subjective discount factor. From the technical point of view, the utility function is strictly increasing in its first argument, strictly decreasing in the second, and strictly concave.

The consumption good is produced with the variety of differentiated goods, c_{it}, $i \in [0,1]$,

$$c_t = \left[\int_0^1 c_{it}^{1-1/\eta} di\right]^{1/(1-1/\eta)},$$

where $\eta > 1$ is the intratemporal elasticity of substitution across the range of differentiated goods.

Then, the optimal level of a good of variety i is expressed by $c_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} c_t$. This is the optimal level of c_{it} for the minimization problem of total expenditure under the given level of consumption of the composite good subject to its aforementioned aggregation constraint. P_{it} is the nominal price of a good of variety i at time t, and nominal price index is specified as $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di \right]^{1/(1-\eta)}$.

Since households could participate in all nominal contingent claims, their period-by-period budget constraint is

$$E_t r_{t,t+1} \frac{x_{t+1}}{P_t} + c_t + i_t + \tau_t^L = \frac{x_t}{P_t} + (1-\tau_t^D)[w_t h_t + u_t k_t] + \tilde{\phi}_t + \lambda^o e_t' p_t^* o_t (1-\tau_t^o), \tag{2}$$

where x_s is a nominal random payment in period $s \geq t$, $r_{t,t+s}$ denotes a stochastic discount factor, P_t is the aggregate price level, k_t is capital, i_t is investment, $\lambda^o e_t' p_t^* o_t (1-\tau_t^o)$ is the after-tax income from shares in oil industry[9], and the variable $\tilde{\phi}_t$ denotes after-income-tax profits from firm-ownership[10]. There is a lump-sum tax, τ_t^L, an income tax rate, τ_t^D, and oil tax rate, τ_t^o. The necessity to distinguish the oil tax as a separate part of the tax function could be explained by the export-orientation of the modeled economy which gets huge export duties, mainly from oil exportation[11]. The prices of labor and capital are w_t and u_t, respectively.

The capital accumulation equation (with constant depreciation rate, δ) is

$$k_{t+1} = (1-\delta)k_t + i_t. \tag{3}$$

The investment good is a composite of continuum of intermediate goods, i_{it}, $i \in [0,1]$, the demand for which is given by $i_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} i_t$.

[9] For more details, see next Subsection "Oil industry".

[10] Assumption: Profits are derived from "production firms". For more details, see next subsection "Oil industry".

[11] About 18% of Russian state revenues (in 2006) fell at originate from export duties (20% in 2005). The high proportion of revenues from export duties in the total revenues was explained by high oil prices. For more details, see section "Facts".

Maximizing the households' utility function subject to equations (2) and (3) and the no-Ponzi-game borrowing limit[12] yields the first order conditions

$$c_t^{-\delta}(1-h_t)^{\gamma(1-\delta)} = \lambda_t\,, \tag{4}$$

$$\lambda_t r_{t,t+1} = \beta\lambda_{t+1}\frac{P_t}{P_{t+1}}\,,$$

$$-\frac{c_t\gamma}{1-h_t} = w_t(1-\tau_t^D)\,, \tag{5}$$

$$\lambda_t = \beta E_t\left\{\lambda_{t+1}[(1-\tau_{t+1}^D)u_{t+1} + 1-\delta]\right\}, \tag{6}$$

where λ_t is the Lagrange multiplier.

The oil sector

The oil sector is modeled under the assumption that oil is extracted by non-producing firms. It means that there are two types of the firms: the first group compounds of producing firms, it produces all the goods in the economy. And the second one compounds of oil extracting companies. Under "Firms" in our model we mean agents producing all goods, except oil. Hence, oil producing companies are excluded from this sense.

It could be justified by the fact that oil flow is mainly determined by the natural resources of a country, but not by capital or labour. Then, oil is modeled as an AR(1)-exogenous process

$$o_{t+1} = \rho_o o_t + (1-\rho_o)\overline{o} + \varepsilon_o\,,$$

where o_t is a flow of oil in period t, $\overline{o}$ denotes the steady-state level of oil flow.

The oil price is determined on the world market, and hence, each country could be considered mainly as the price-taker. The influence of the countries on the oil price is neglected not to make the analysis too complicated. A univariate autoregressive process for oil price

$$p_{t+1}^* = \rho_p p_t^* + (1-\rho_p)\overline{p}^* + \varepsilon_p\,,$$

[12] The no-Ponzi-game condition is introduced to guarantee the absence of Ponzi borrowing schemes. They could take place if no borrowing limitation for households was introduced.

where p_t^* is world oil price, which is set in the foreign currency[13], not in the national one, and where $\overline{p}^*$ denotes the steady-state level of p_t^*.

Then, $p_t^* o_t$ are total revenues from oil, in U.S. dollars. We assume that all of oil extracted within a country is exported.

Since, in reality, oil revenues (stocks of oil companies) belong to the Government as well as to Households, we include them in our model in accordance with this fact. Then, the total revenues from oil could be determined by the identity

$$p_t^* o_t = (1-\lambda^o) p_t^* o_t + \tau^o \lambda^o p_t^* o_t + (1-\tau^o)\lambda^o p_t^* o_t .$$

Here λ^o and $(1-\lambda^o)$ describe parts of oil income that belong to households and the government, correspondingly, that are received due to their share fraction in oil producing companies, and τ^0 is an oil revenue tax rate.

The Government

Government expenditure, g_t, is determined exogenously by the AR(1)-process $g_t = \rho_g g_{t-1} + (1-\rho_g)\overline{g} + e_t^g$, where $\overline{g}$ denotes the steady-state level of g_t. This expenditure can be financed by collecting taxes, τ_t, printing money, M_t, by issuing one-period risk-free debt, B_t, with internal, risk-free, nominal gross interest rate, R_t, and by spending part of stabilization fund, $div_{o,t}^*$. Stabilization fund dividends are estimated at a foreign currency and converted into rubles at a nominal exchange rate, $E_t^{'}$. Altogether, this yields the period-by-period consolidated government budget constraint (in nominal values)

$$M_t + B_t = R_{t-1} B_{t-1} + M_{t-1} + P_t g_t - P_t \tau_t - E_t' div_{o,t}^* .$$

We build our model under the untypical assumption, suggested by Schmitt-Grohe and Uribe (2004), that the government minimizes the cost of producing government goods. Then, the public demand for an intermediate good, g_{it}, of each variety i, is $g_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} g_t$.

[13] Under foreign currency we mean U.S. dollar.

Using two further definitions, this budget constraint can be conveniently rewritten. First, let the level of total government liabilities in real terms at the beginning of period t in units of period $t-1$ goods be denoted by $l_{t-1} \equiv (M_{t-1} + R_{t-1}B_{t-1})/P_{t-1}$. Secondly, let $m_t \equiv M_t / P_t$ be the total amount of real balances in circulation. Then the budget constraint can be transformed to

$$l_t = (R_t / \pi_t) l_{t-1} + R_t (g_t - \tau_t) - m_t (R_t - 1) - \frac{E_t' div_{o,t}^*}{\pi_t}, \tag{7}$$

where e_t' is the real exchange rate, $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the inflation rate. Also assuming $P_{t-1} = 1$, we come to simplification of coinciding the inflation rate and price index.

The Euler equation, which combines households' first order condition, $\lambda_t r_{t,t+1} = \beta \lambda_{t+1} (P_t / P_{t+1})$, and the no-arbitrage condition, $R_t = 1/E_t(r_{t,t+1})$, which shows the inverse connection between R_t and t period price of a portfolio that pays one dollar in $t+1$ period, is given by

$$\lambda_t = \beta R_t E_t \frac{\lambda_{t+1}}{\pi_{t+1}}. \tag{8}$$

Since taxes in the model consist not only of the sum of lump-sum taxes, and (distortionary) income tax rate, so that the closed-economy taxes, τ_t, are determined by

$$\tau_t = \tau_t^L + \tau_t^D y_t, \tag{9}$$

but also include oil tax rate, then the whole tax revenue, T_t, for an export-oriented economy is

$$T_t = \tau_t + \tau^o p_t^* o_t \lambda^o. \tag{10}$$

The government sets the tax rate based on a fiscal rule which is a function of the deviation of total liabilities, l_{t-1}, from their target level, l, and of the real secondary fiscal deficit[14]

[14] We use this term for $\left[g_t + \left(\frac{R_{t-1} - 1}{R_{t-1}} \right) \left(\frac{l_{t-1} - m_{t-1}}{\pi_t} \right) \right]$ introduced by Schmitt-Grohe and Uribe (2004).

$$\tau_t + \frac{E'_t \, div^*_{o,t}}{\pi_t} = \gamma_0 + \gamma_1 (l_{t-1} - l) + \gamma_2 \left[g_t + \left(\frac{R_{t-1} - 1}{R_{t-1}} \right) \left(\frac{l_{t-1} - m_{t-1}}{\pi_t} \right) \right], \tag{11}$$

where γ_1 and γ_2 are coefficients stating the responsiveness of fiscal policy to the respective indicators, and γ_0 is an autonomous tax component. It is important to note, however, that Schmitt-Grohe and Uribe never rely on both targets simultaneously, but test liability targeting (γ_2 set to zero) and balanced budget targeting (γ_0 and γ_1 set to zero) separately. In our model we also implement either the case of balanced budget targeting or the state of liability targeting.

It is shown in Schmitt-Grohe and Uribe (2000) that in order to make the fiscal policy following a balanced-budget rule and consisting of lump-sum taxation, have no influence on price level determination, the long-run nominal interest rate has to be strictly positive. We will be consistent with this result in our research.

In the case of simultaneous liability targeting and lump-sum taxation the fiscal policy is called active, according to the term suggested by Leeper (1991). In this situation it influences on price level determination. The restrictions implied on the coefficient γ_1 consist of assuming it, from the one hand, to be positive, and from the other hand, to be less than deterministic real interest rate. Altogether, this represents a very important innovation comparing to other articles that assume fiscal policy to be passive from the very outset. This modification lets the monetary policy play not only an active role, but spreading the variants of possible equilibriums.

Monetary policy is conducted based on a Taylor[15]-type rule

$$\ln(R_t / \overline{R}) = \alpha_R \ln(R_{t-1} / \overline{R}) + \alpha_\pi E_t \ln(\pi_t / \pi^*) + \alpha_y E_t \ln(y_t / y) \tag{12}$$

where $\overline{R}$, π^*, y are the target levels of the corresponding variables and α_R, α_π, α_y are the parameters of the corresponding variables' weights for Monetary agent. In our paper we implement the situation of contemporaneous policy rule.

Stabilization fund

One of the central features of our model consists of adding the stabilization fund to the analysis. The dynamics of stabilization fund, F_t^*, in period t, is determined by foreign, risk-free,

[15] Taylor (1993)

nominal, gross interest rate, R^*, resulted from the floating stabilization fund of previous period, F_{t-1}^*, abroad, for example, in U.S. treasuries.

$$F_t^* = R^* F_{t-1}^* + rev_{o,t}^* - div_{o,t}^* . \tag{13}$$

Here, $rev_{o,t}^*$ denotes government revenues from oil received from its possession in oil producing companies, or from taxes imposed on households' oil income.

$$rev_{o,t}^* = (1-\lambda^o) p_t^* o_t + \tau^o \lambda p_t^* o_t . \tag{14}$$

To simplify the analysis it is assumed that oil revenues are the only source for the replenishment of the stabilization fund, since, in reality, it mainly consists of oil income[16].

Then, $div_{o,t}^*$ is a part of stabilization fund, spent within period t. Like the government revenues from oil, oil dividends are also estimated in foreign currency, U.S. dollars. Dividends are determined according to the stabilization fund's policy rule

$$div_{o,t}^* = \xi(F_t^* - \overline{F}), \tag{15}$$

where $\overline{F}$ is a target level of stabilization fund. Intuitively, this equation could be explained so that in order to determine the part of stabilization fund which should be spent, the deviation of its current level from its target level is used. And this deviation is smoothed with some speed, ξ.

It is important to clear the situation with the existence of two different gross one-period, risk-free, nominal interest-rates, R^* and R_t in our model. R^* denotes the constant foreign interest-rate, at which only the government can put up money (accumulated in the stabilization fund). This fact requires the imposing of a new restriction on stabilization fund: $\overline{F} > 0$. And R_t is an interest rate that is paid on internal debt and at this rate not only the government can invest assets, but also other agents.

[16] This fact is proved in Section "Facts"

Firms

Each firm in the model produces a particular good[17] $i \in [0,1]$, in a monopolistically competitive environment (i.e. the goods are imperfect substitutes). The identical production technology used by all firms[18] is described by a Cobb-Douglas production function and by the technology shock, z_t, which is driven by the autoregressive process $z_t = \rho_z z_{t-1} + (1-\rho_z)\bar{z} + \varepsilon_t^z$, where $\bar{z}$ is the steady-state value of z_t

$$z_t F(k_t, h_t) = z_t k_t^{\theta} h_t^{1-\theta}.$$

The production function is homogenous of degree one, concave, and has the positive first derivative of both function arguments: capital services, k_{it}, and labor services, l_{it}. θ means the cost share of capital.

The aggregate demand for a domestic good i, denoted by $a_{it} = c_{it} + i_{it} + g_{it} - im_{it}$, is equal to the aggregate absorption minus import of this good. Then, the aggregate demand for all domestics goods is given by: $a_t = a_{it}\left(P_{it}/P_t\right)^{\eta}$.

Firms can hold money and bonds so the total wealth of a firm includes the revenues from off-take and from holding the financial assets. Each firm maximizes the present discount value of profits ϕ_{it} [19]

$$E_t \sum_{s=t}^{\infty} \left[r_{t,s} P_s \phi_{is} \right] = E_t \sum_{s=t}^{\infty} \left[r_{t,s} P_s \left(\frac{P_{it}}{P_t} a_{it} - u_t k_{it} - w_t h_{it} - (1 - R_t^{-1}) m_{it} \right) \right].$$

It is typically assumed (as well as in Schmitt-Grohe and Uribe, 2004, Christiano et al., 2003, Kollman, 2003, Rotemberg and Woodford, 1992) that capital could be easily reallocated across industries.

Each firm always satisfies the demand at its chosen price that gives the following constraint to the firm's problem

$$z_t F(k_{it}, h_{it}) \geq \left(\frac{P_{it}}{P_t} \right)^{-\eta} a_t.$$

[17] Reminding: in our analysis we don't include oil producers in term "Firms"
[18] We make the aggregation of the firms from the very outset, where it does not cause problems with understanding the model. Technically, it means that we just drop the subscript i of a particular expression.
[19] To see the firms' profit derivation apply to Schmitt-Grohe and Uribe, 2004, appendix A

Also, firms have to satisfy a cash-in-advance constraint of the form $m_t \geq vw_t h_t$, which implies that a fraction v of wages has to be paid in cash. Parameter v is charged with existence money in the model, then it is $v \geq 0$. In case of $v = 0$ we consider cashless economy, otherwise with cash. Since holding cash is costly (we presume strictly positive nominal interest rate) it is assumed that firms hold only the required amount so that in equilibrium the constraint holds with equality

$$m_t = vw_t h_t . \tag{16}$$

The first order conditions of the firms' problem (here, again, we made the aggregation of firms) with respect to h_t and k_t, which represent the firms' demand equations for labour and capital

$$mc_t z_t (1-\theta) k_t^{\theta} h_t^{-\theta} = w_t \left[1 + v \frac{R_t - 1}{R_t} \right] \tag{17}$$

$$mc_t z_t \theta k_t^{\theta-1} h_t^{1-\theta} = u_t , \tag{18}$$

where mc_t denotes marginal costs.

Both of these first order conditions are identical among all the firms in the model. This is not so with the third condition which arises from the fact of two-group-of-firms partitioning.

Prices are assumed to be sticky, which is modeled with the Calvo[20] method, which means that in each period a randomly chosen fraction α of firms are forced to maintain their prices of the previous period, while the remaining fraction of $(1-\alpha)$ firms can choose the prices optimally within any period. The prices that are being reset are given by $\widetilde{P}_t$.

The first order condition of the firms' problem with respect to the price $\widetilde{P}_t$ is then

$$E_t \sum_{s=t}^{\infty} r_{t,s} \alpha^{s-t} \left(\frac{\widetilde{P}_t}{P_s} \right)^{-1-\eta} a_s \left[mc_s - \frac{\eta - 1}{\eta} \frac{\widetilde{P}_t}{P_s} \right] = 0 ,$$

which can be rewritten, with two auxiliary variables essential for calculation simplifications, as

[20] See Calvo (1983) and Yun (1996)

$$x_t^2 - \frac{\eta}{\eta - 1} x_t^1 = 0\,, \tag{19}$$

where x_t^1[21] and x_t^2 are defined recursively as

$$\begin{aligned}
x_t^1 &\equiv E_t \sum_{s=t}^{\infty} r_{t,s} \alpha^{s-t} \left(\frac{\widetilde{P}_t}{P_s} \right)^{-1-\eta} a_s mc_s \\
&= \left(\frac{\widetilde{P}_t}{P_t} \right)^{-1-\eta} a_t mc_t + E_t \sum_{s=t+1}^{\infty} r_{t,s} \alpha^{s-t} \left(\frac{\widetilde{P}_t}{P_s} \right)^{-1-\eta} a_s mc_s \\
&= \left(\frac{\widetilde{P}_t}{P_t} \right)^{-1-\eta} a_t mc_t + \alpha E_t r_{t,t+1} \left(\frac{\widetilde{P}_t}{\widetilde{P}_{t+1}} \right)^{-1-\eta} E_{t+1} \sum_{s=t+1}^{\infty} r_{t+1,s} \alpha^{s-t-1} \left(\frac{\widetilde{P}_{t+1}}{P_s} \right)^{-1-\eta} a_s mc_s \\
&= \left(\frac{\widetilde{P}_t}{P_t} \right)^{-1-\eta} a_t mc_t + \alpha E_t r_{t,t+1} \left(\frac{\widetilde{P}_t}{\widetilde{P}_{t+1}} \right)^{-1-\eta} x_{t+1}^1
\end{aligned}$$

$$= \widetilde{p}_t^{-1-\eta} a_t mc_t + \alpha\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \pi_{t+1}^{\eta} \left(\frac{\widetilde{p}_t}{\widetilde{p}_{t+1}} \right)^{-1-\eta} x_{t+1}^1 \tag{20}$$

$$x_t^2 = \widetilde{p}_t^{-\eta} a_t + \alpha\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \pi_{t+1}^{\eta-1} \left(\frac{\widetilde{p}_t}{\widetilde{p}_{t+1}} \right)^{-\eta} x_{t+1}^2 \tag{21}$$

The aforementioned first order condition means that firms are able to choose the price optimally in the current period, choose the level in such a way that the weighted average of current and future differences between marginal costs and marginal revenues are equal to zero. That is consistent with the standard economic condition of profit maximization.

The aggregate price level is the weighted average of the prices unchanged from the previous period, P_{t-1}, and the prices reset in the current period $\widetilde{P}_t$. Divided through by $P_t^{1-\eta}$, the expression for the price level becomes

$$1 = \alpha \pi_t^{-1+\eta} + (1-\alpha) \widetilde{p}_t^{1-\eta}\,, \tag{22}$$

where $\widetilde{p}_t = \widetilde{P}_t / P_t$.

[21] The computation of x_t^1 is copied from Schmitt-Grohe and Uribe (2004), p.12. Additionally, we remind that $\pi_{t+1} = P_{t+1}/P_t$ and $\left(\frac{\widetilde{p}_t}{\widetilde{p}_{t+1}} \right) = \left(\frac{\widetilde{P}_t / P_t}{\widetilde{P}_{t+1}/P_{t+1}} \right)$

In order to determine the average mark-up, we apply to a later version of the article, Schmidt-Grohe and Uribe (2006). The average mark-up, am_t, is given as the quotient of marginal costs and the aggregate price level. The relative price level is $x_t = \int_0^1 \frac{P_{it}}{P_t} di$, where P_{it} are the prices of all the individual varieties, and P_t is the aggregate absolute price level in period *t*. Based on this definition the price level can be computed recursively as

$$x_t = (1-\alpha)\widetilde{p}_t + \alpha(x_{t-1}/\pi_t). \tag{23}$$

The intuition of this computation is that a fraction of $(1-\alpha)$ of all firms can adjust their prices in every period, and set a relative price $\widetilde{p}_t$. The remaining firms keep their price from the previous period which is given by $\int_0^1 \frac{P_{i,t-1}}{P_t} di = \int_0^1 \frac{P_{i,t-1}}{P_{t-1}\pi_t} di = \frac{x_{t-1}}{\pi_t}$.

Then, the average mark-up is given by

$$am_t = x_t mc_t. \tag{24}$$

The external sector

Our analysis extends the research paper by Schmitt-Grohe and Uribe (2004) also by including external sector to the model. The necessity of including the fourth agent is in the fact of considering an export-oriented economy that gets a large part of its profits from international trade, in particular, from oil export. Then, the balance of payments is

$$CA_t + KA_t \equiv 0, \tag{25}$$

where KA_t is capital account[22], CA_t denotes current account. Their sum is equal to zero since the floating exchange rate regime is considered. Capital account is created due to the difference between gross one-period, risk-free, nominal interest-rates, R^* and R_t. We implement the situation when internal rate, R_t, is smaller than external, R^* in period t, then capital account

[22] Also known as financial account

deficit forms. It corresponds to the export-orientation of our economy, which implies current account surplus.

The standard equation showing the interaction between nominal and real exchange rates is

$$E_t' = P_t e_t'. \tag{26}$$

It is assumed that unilateral transfers and net factor payments are equal to zero, then current account equation is defined as export, $Ex_t = e_t' o_t\, p_t^*$, minus import, Im_t

$$CA_t = e_t' o_t\, p_t^* - \mathrm{Im}_t. \tag{27}$$

We assume that the country exports only oil. We could make this simplification since the main part of export revenues come from oil[23]. Import plays a secondary part in our analysis it is modeled as a univariate autoregressive process

$$\mathrm{Im}_{t+1} = \rho_{\mathrm{Im}}\, \mathrm{Im}_t + (1 - \rho_{\mathrm{Im}})\, \overline{\mathrm{Im}} + \varepsilon_{\mathrm{Im}},$$

where $\overline{\mathrm{Im}}$ denotes the steady-state level of import.

[23] See also Section "Facts" in our work

5. Model Analysis

From a technical point of view, we have implemented the model into the Toolkit program in the standard way by determining the equilibrium, calibrating, log-linearizing 33 equations, finding steady-states, building matrixes and deriving impulse-responses to a technology, government purchases, oil flow and oil price shocks.

Equilibrium

The market equilibrium condition, as usual, is for demand and supply to be equal, $z_t k_t^{\theta} h_t^{1-\theta} = y_t s_t$ which is here represented as

$$y_t = \frac{z_t}{s_t} k_t^{\theta} h_t^{1-\theta}, \tag{28}$$

where s_t denotes the costs induced by the inefficient price dispersion brought about by the Calvo mechanism.

$$s_t = (1-\alpha)\widetilde{p}_t^{-\eta} + \alpha \pi_t^{\eta} s_{t-1} \tag{29}$$

Also, in equilibrium the typical resource constraint must hold

$$y_t = c_t + i_t + g_t + Ex_t - \mathrm{Im}_t. \tag{30}$$

A stationary competitive equilibrium is determined by the equations of agents' problem optimization, policy rules, balance of payments and (8), (9), (13), (14), (10), (27), (26) equations. It means that for a set of processes c_t, h_t, λ_t, w_t, τ_t^D, τ_t^L, τ_t , T_t, u_t, mc_t, k_{t+1}, R_t, i_t, y_t, s_t, $\widetilde{p}_t$, π_t, l_t, m_t, x_t^1, x_t^2, F_t^*, $res_{o,t}^*$, $div_{o,t}^*$, KA_t, CA_t, $E_t^{'}$ for $t = 0,1...$ that satisfy the equations (3) – (30) and either $\tau_t^L = 0$ or $\tau_t^D = 0$. The initial conditions for the state endogenous variables are given as well as the exogenous stochastic processes for g_t, z_t , o_t, p_t^*, Im_t.

Log-linearization

In this section we provide the log-linearization for the equations that determine the equilibrium. We present them in groups for the problems of the various agents and sectors, and stochastic processes.

Households

$$\bar{k}\hat{k}_t - (1-\delta)\bar{k}\hat{k}_{t-1} - \bar{i}\,\hat{i}_t = 0 \tag{3}$$

$$\hat{\lambda}_t + \sigma\hat{c}_t + \gamma(1-\sigma)\left(\frac{\bar{h}\hat{h}_t}{1-\bar{h}}\right) = 0 \tag{4}$$

$$\hat{c}_t + \frac{\bar{h}\hat{h}_t}{1-\bar{h}} - \hat{w}_t + \frac{\hat{\tau}_t^D\bar{\tau}^D}{1-\bar{\tau}^D} = 0 \tag{5}$$

$$\hat{\lambda}_t - E_t\left(\hat{\lambda}_{t+1} + \frac{\bar{u}\hat{u}_{t+1} - \overline{\tau u}\,\hat{\tau}_{t+1}^D - \bar{\tau}^D\bar{u}\hat{u}_{t+1}}{\bar{u} - \overline{\tau u} + 1 - \delta}\right) = 0 \tag{6}$$

The Government

$$\begin{aligned}&\bar{l}\hat{l}_t - \frac{\bar{R}}{\bar{\pi}}\bar{l}(\hat{R}_t - \hat{\pi}_t + \hat{l}_{t-1}) - \bar{R}\bar{g}(\hat{R}_t + \hat{g}_t) + \bar{R}\,\bar{\tau}(\hat{R}_t + \hat{\tau}_t) + \bar{R}\bar{m}(\hat{R}_t + \hat{m}_t) - \\ &- \bar{m}\hat{m}_t + \frac{\bar{E}'d\bar{i}v_o^*}{\bar{\pi}}\left(\hat{E}_t' + d\hat{i}v_{o,t}^* - \hat{\pi}_t\right) = 0\end{aligned} \tag{7}$$

$$\hat{\lambda}_t - \hat{R}_t - E_t(\hat{\lambda}_{t+1} - \hat{\pi}_{t+1}) = 0 \tag{8}$$

$$\bar{\tau}\hat{\tau}_t - \bar{\tau}^L\hat{\tau}_t^L - \bar{\tau}^D\bar{y}(\hat{\tau}_t^D + \hat{y}_t) = 0 \tag{9}$$

$$\bar{T}\hat{T}_t - \bar{\tau}\hat{\tau}_t - [\tau^o\lambda^o\bar{p}^*\bar{o}](\hat{p}_t^* + \hat{o}_t) = 0 \tag{10}$$

$$\begin{aligned}&\bar{\tau}\hat{\tau}_t + \frac{\bar{E}'d\bar{i}v_o^*}{\bar{\pi}}\left(\hat{E}_t' + d\hat{i}v_{o,t}^* - \hat{\pi}_t\right) - \gamma_1\bar{l}\hat{l}_{t-1} - \\ &- \gamma_2\left(\bar{g}\hat{g}_t + \frac{\hat{R}_{t-1}}{\bar{R}-1} + \frac{\bar{l}(\hat{l}_{t-1} - \hat{\pi}_t) - \bar{m}(\hat{m}_{t-1} - \hat{\pi}_t)}{\bar{l} - \bar{m}}\right) = 0\end{aligned} \tag{11}$$

$$\hat{R}_t - \alpha_R\hat{R}_{t-1} - \alpha_\pi\hat{\pi}_t - \alpha_y\hat{y}_t = 0 \tag{12}$$

Stabilization fund

$$\bar{F}^*\hat{F}_t^* - R^*\bar{F}^*\hat{F}_{t-1}^* - r\bar{e}v_o^* r\hat{e}v_{o,t}^* + d\bar{i}v_o^* d\hat{i}v_{o,t}^* = 0 \tag{13}$$

$$r\bar{e}v_o^* r\hat{e}v_{o,t}^* - [(1-\lambda^o)\bar{p}^*\bar{o}](\hat{p}_t^* + \hat{o}_t) - [\tau^o\lambda^o\bar{p}^*\bar{o}](\hat{p}_t^* + \hat{o}_t) = 0 \tag{14}$$

$$d\bar{i}v_o^* d\hat{i}v_{o,t}^* - \xi\bar{F}^*\hat{F}_{o,t}^* = 0 \tag{15}$$

Firms

$$\hat{m}_t - \hat{w}_t - \hat{h}_t = 0 \tag{16}$$

$$\hat{m}c_t + \hat{z}_t + \theta\hat{k}_{t-1} - \theta\hat{h}_t - \hat{w}_t - \nu\frac{\hat{R}_t}{\bar{R} + \bar{R}\nu - \nu} = 0 \tag{17}$$

$$\hat{m}c_t + \hat{z}_t + (\theta - 1)\hat{k}_{t-1} + (1-\theta)\hat{h}_t - \hat{u}_t = 0 \tag{18}$$

$$\hat{x}_t^1 - \hat{x}_t^2 = 0 \tag{19}$$

Since $y_t = c_t + i_t + g_t + Ex_t - \mathrm{Im}_t$ and $a_t = c_t + i_t + g_t - \mathrm{Im}_t$, $Ex_t = e_t' o_t p_t^*$, we substitute a_t by $(y_t - e'_t o_t p_t^*)$.

$$\begin{aligned}&\bar{x}^1\hat{x}_t^1 - \bar{\tilde{p}}^{-1-\eta}(\bar{y} - \bar{e}'\overline{op}^*)\overline{m}c\left[(-1-\eta)\hat{\tilde{p}}_t + \frac{\bar{y}\hat{y}_t - \overline{op}^*\bar{e}'(\hat{e}_t' + \hat{o}_t + \hat{p}_t^*)}{\bar{y} - \overline{op}^*\bar{e}'} + \hat{m}c_t\right] - \\ &-\alpha\beta\bar{\pi}^\eta\bar{x}^1\left[-\hat{\lambda}_t - (1+\eta)\hat{\tilde{p}}_t + E_t(\hat{\lambda}_{t+1} + \eta\hat{\pi}_{t+1} + (1+\eta)\hat{\tilde{p}}_{t+1} + \hat{x}_{t+1}^1)\right] = 0\end{aligned} \tag{20}$$

$$\begin{aligned}&\bar{x}^2\hat{x}_t^2 - \bar{\tilde{p}}^{-\eta}(\bar{y} - \bar{e}'\overline{op}^*)\left[-\eta\hat{\tilde{p}}_t + \frac{\bar{y}\hat{y}_t - \overline{op}^*\bar{e}'(\hat{e}_t' + \hat{o}_t + \hat{p}_t^*)}{\bar{y} - \overline{op}^*\bar{e}'}\right] - \\ &-\alpha\beta\bar{\pi}^{\eta-1}\bar{x}^2\left[-\hat{\lambda}_t - \eta\hat{\tilde{p}}_t + E_t(\hat{\lambda}_{t+1} + (\eta-1)\hat{\pi}_{t+1} + \eta\hat{\tilde{p}}_{t+1} + \hat{x}_{t+1}^2)\right] = 0\end{aligned} \tag{21}$$

$$\alpha\bar{\pi}^{-1+\eta}(-1+\eta)\hat{\pi}_t + (1-\alpha)\bar{\tilde{p}}^{1-\eta}(1-\eta)\hat{\tilde{p}}_t = 0 \tag{22}$$

$$\hat{x}_t - \frac{\alpha}{\bar{\pi}}\hat{x}_{t-1} + \frac{\alpha/\bar{\pi} - \alpha\bar{\pi}^{\eta-1}}{1 - \alpha\bar{\pi}^{\eta-1}}\hat{\pi}_t = 0 \tag{23}$$

$$a\hat{m}_t - \hat{x}_t + m\hat{c}_t = 0 \tag{24}$$

$$\hat{y}_t - \hat{z}_t + \hat{s}_t - \theta\hat{k}_{t-1} - (1-\theta)\hat{h}_t = 0 \tag{28}$$

$$\bar{s}\hat{s}_t + (1-\alpha)\bar{\tilde{p}}^{-\eta}\eta\hat{\tilde{p}}_t - \alpha\bar{\pi}^\eta\bar{s}(\eta\hat{\pi}_t + \hat{s}_{t-1}) = 0 \tag{29}$$

$$\bar{y}\hat{y}_t - \bar{c}\hat{c}_t - \bar{i}\hat{i}_t - \bar{g}\hat{g}_t - \bar{e}'\bar{p}^*\bar{o}(\hat{e}_t' + \hat{p}_t^* + \hat{o}_t) + \bar{\mathrm{I}}\mathrm{m}\,\hat{\mathrm{I}}\mathrm{m}_t = 0 \tag{30}$$

External sector

$$C\bar{A}\,C\hat{A}_t + K\bar{A}K\hat{A}_t = 0 \tag{25}$$

$$\hat{E}'_t - \hat{\pi}_t - \hat{\varepsilon}'_t = 0 \tag{26}$$

$$C\bar{A}\,C\hat{A}_t - \bar{e}'\overline{op}^*(\hat{e}_t + \hat{o}_t + \hat{p}_t^*) + \bar{\mathrm{I}}\mathrm{m}\,\hat{\mathrm{I}}\mathrm{m}_t = 0 \tag{27}$$

Stochastic processes

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \varepsilon_t^g$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z$$

$$\hat{o}_{t+1} = \rho_o \hat{o}_t + \varepsilon_{t+1}^o$$

$$\hat{p}_{t+1} = \rho_p \hat{p}_t + \varepsilon_{t+1}^p$$

$$\hat{\mathrm{Im}}_{t+1} = \rho_{\mathrm{Im}} \hat{\mathrm{Im}}_t + \varepsilon_{t+1}^{\mathrm{Im}}$$

Steady-state

In the following we present our identification of the steady state values of the model for all the variables of the equilibrium. Solving this system of 33 equations was the challenging part of our work. This was achieved through the isolation of a submodel consisting of the equations 3, 5, 6, 7, 17, 18, 19, 20, 21, 22, 28, 29 and 30, which was solved first. We also made use of the common practice of introducing some intermediate variables, in this case $\bar{k}/\bar{h}$ and $\bar{y}/\bar{h}$. In order to fully identify the steady states we also had to make use of the ratios $\bar{g}/\bar{y}, \bar{m}/\bar{y}, \bar{\tau}/\bar{y}, \bar{p}^*\bar{o}/\bar{y}, \bar{\mathrm{Im}}/\bar{y}$, that are given in the calibration part of the model.

$$\bar{R} = \frac{\bar{\pi}}{\beta} \tag{8}$$

$$\bar{u} = \frac{\beta^{-1} - (1-\delta)}{1-\bar{\tau}^D} \tag{6}$$

$$\bar{\tilde{p}} = \left[\frac{1-\alpha\bar{\pi}^{-1+\eta}}{1-\alpha}\right]^{\frac{1}{1-\eta}} \tag{22}$$

$$\bar{s} = \frac{(1-\alpha)\bar{\tilde{p}}^{-\eta}}{1-\alpha\bar{\pi}^{\eta}} \tag{29}$$

$$\bar{m}c = \frac{\eta-1}{\eta}\frac{(1-\alpha\beta\bar{\pi}^{\eta})}{(1-\alpha\beta\bar{\pi}^{\eta-1})}\bar{\tilde{p}} \tag{19)+ (20) + (21}$$

$$\frac{\bar{k}}{\bar{h}} = \left[\frac{\bar{u}}{\bar{m}c\bar{z}\theta}\right]^{\frac{1}{\theta-1}} \tag{18}$$

$$\overline{w} = \frac{\overline{m}c\overline{z}(1-\theta)\left(\frac{\overline{k}}{\overline{h}}\right)^{\theta}}{1+v\frac{\overline{R}-1}{\overline{R}}} \tag{17}$$

$$\frac{\overline{y}}{\overline{h}} = \frac{\overline{z}}{\overline{s}}\left(\frac{\overline{k}}{\overline{h}}\right)^{\theta} \tag{28}$$

$$\overline{h} = \left(\frac{\overline{y}}{\overline{h}} + \frac{\overline{w}}{\gamma}(1-\overline{\tau}^{D}) - \delta\frac{\overline{k}}{\overline{h}} - s_g\frac{\overline{y}}{\overline{h}} - s_o\frac{\overline{y}}{\overline{h}} + s_{\mathrm{Im}}\frac{\overline{y}}{\overline{h}}\right)^{-1}\frac{\overline{w}}{\gamma}(1-\overline{\tau}^{D}) \tag{30}$$

$$\overline{y} = \frac{\overline{y}}{\overline{h}}\overline{h}$$

$$\overline{c} = \frac{\overline{w}}{\gamma}(1-\overline{\tau}^{D})(1-\overline{h}) \tag{5}$$

$$\overline{k} = \frac{\overline{k}}{\overline{h}}\overline{h}$$

$$\overline{i} = \overline{k}\delta \tag{3}$$

$$\overline{g} = s_g\overline{y}$$

$$\overline{\lambda} = \overline{c}^{-\delta}(1-\overline{h})^{\gamma(1-\delta)} \tag{4}$$

$$\overline{\tau}^{L} = (s_{\tau} - \overline{\tau}^{D})\overline{y}$$

$$\overline{\tau} = \overline{\tau}^{L} + \overline{\tau}^{D}\overline{y} \tag{9}$$

$$\overline{m} = s_m\overline{y}$$

$$\overline{l} = \frac{\overline{R}(\overline{g}-\overline{\tau}) - \overline{m}(\overline{R}-1) - d\overline{i}v^{*}_{o,t}\overline{e}'/\overline{\pi}}{1-\frac{\overline{R}}{\overline{\pi}}} \tag{7}$$

$$\overline{x}^{1} = \frac{\overline{\tilde{p}}^{-1-\eta}(\overline{y} - \overline{p}^{*}\overline{o})\overline{m}c}{1-\alpha\beta\overline{\pi}^{\eta}} \tag{20}$$

$$\overline{x}^{2} = \frac{\overline{\tilde{p}}^{-\eta}(\overline{y} - \overline{p}^{*}\overline{o})}{1-\alpha\beta\overline{\pi}^{\eta-1}} \tag{21}$$

$$d\overline{i}v^{*}_{o,t} = 0 \tag{15}$$

$$\bar{\tau}^{o} = s_{\tau^{o}}\bar{y}$$

$$r\bar{e}v_{o,t}^{*} = (1-\lambda^{o})\bar{p}^{*}\bar{o} + \tau^{o}\lambda^{o}\bar{p}^{*}\bar{o} \quad (14)$$

$$\bar{F}^{*} = \frac{r\bar{e}v_{o,t}^{*} - d\bar{i}v_{o,t}^{*}}{1-R^{*}} \quad (13)$$

$$\bar{T} = \bar{\tau} + \tau^{o}\lambda^{o}\bar{p}^{*}\bar{o} \quad (10)$$

$$C\bar{A} = \bar{e}'\overline{op}^{*} - \bar{\mathrm{I}}\mathrm{m} \quad (27)$$

$$K\bar{A} = -C\bar{A} \quad (25)$$

$$\bar{E}' = \bar{e}'\bar{\pi} \quad (26)$$

Calibration

To find the optimal monetary and fiscal policy rules we search over the coefficients of monetary policy rule, α_{π}, α_{y} and α_{R}, under either the balanced-budget or liability targeting fiscal policy rule. These coefficients are the functions of model's parameters. Thus, we have to give the numerical values to the parameters to achieve our goal.

Since the proposed model is built for an export-oriented economy, that describes some typical characteristics of the Russian economy, we calibrate it to the Russian economy. The time unit is equal to a quarter.

The main sources we applied to calibrate the model, were statistical Russian publications, the principal ones are provided by Bank of Russia[24], Economic Expert Group[25], Federal State Statistics Service[26]. The part of calibration that does not depend on economical peculiarities of the country, was taken from some articles, Schmitt-Grohe and Uribe (2004, 2006), Sbordone (2002), Gali and Gertler (1999), Prescott (1986) and some others, under-mentioned.

Considering the households' problem, we set the intertemporal elasticity of consumption, $1/\sigma$, equal to 0.5, and the implied value of preference parameter, $\gamma = 3.4080$, relying on Schmitt-Grohe and Uribe (2004) and Prescott (1986). The preference parameter gets its implied value under steady-state conditions and under assumption that people devote about 20 percent of their time to work. The value of quarterly subjective discount rate is assigned a value of $1.04^{-1/4}$, that is compatible with the annual real rate of interest of 4 percent (Prescott, 1986). Since this value was found mainly for U.S. economy, in our analysis it would be this meaning for foreign interest rate.

[24] Web-site: www.cbr.ru
[25] Web-site: www.eeg.ru
[26] Web-site: http://www.gks.ru/wps/portal/english

We assign the value of 10 percent to the annual depreciation, δ, a rate normally used in real business cycles models.

Allowing for Cobb-Douglas production function, the cost share of capital, ϑ, is set equal to 0.6, which is much higher then in U.S. or European economy, but corresponds to the current Russian situation. It means that only about 40 percent of total firms' costs fall at wages.

The price elasticity of demand, η, is equal to 5 (see Schmitt-Grohe and Uribe, 2004).

The inflation rate is equal to 9 percent per year in steady state that corresponds to the official level, declared by Bank of Russia in the result of 2006.

The share of governments purchases in GDP in steady state is equal to 16 percent, the ratio of oil revenues in GDP is set to 20 percent in steady state, and the share of steady-state import has a value of 16.37 percent in GDP. Steady-state non-oil tax revenues to GDP ratio is equal to 14 percent. All of these values were calculated on the basis of statistical data provided by Bank of Russia, Economic Expert Group and Federal State Statistics Service published in economic reports of 2006.

The ratio of money aggregate, M1 to quarterly GDP is assumed to be on the same level as Schmitt-Grohe and Uribe (2004) suggested, $s_m = 0.45$ in steady state. This level is very close to Russian situation in 2006. Then, it is consistent with the percent of cash that firms retain as wage, $\nu = 0.82$.

The share of the firms that cannot change their price within any period is assumed to be equal to 2/3 (see Schmitt-Grohe and Uribe, 2004, Sbordone, 2002, Gali and Gertler, 1999). It means that on average, firms change prices three periods within a year. Then, the remain part of the firms, $1-\alpha$, able to change prices has value of 1/3.

Calibrating oil sector, we set its meanings in consistence with official data, provided by the aforementioned sources in Russia in 2006. The oil tax rate equals to 54 percent. Since oil producing companies belong to households as well as to the government, their shares are equal to a value of 0.73 and 0.27, respectively.

In our model there are five sources of uncertainty: government purchases, technology shock, oil flow, oil price and import. Every one is modeled in form of a univariate autoregressive process. The first-order correlation of government purchases shock, ρ_g, is equal to 0.9; of technology shock, ρ_z, is 0.82; of an oil flow shock, ρ_o, is 0.75; of an oil price shock, ρ_p, is 0.85; of an import shock, ρ_{Im}, is 0.8. The standard deviation is set to 0.0074 for government purchases shock; to 0.0056 for technology shock, to 0.0065 for an oil flow shock; to 0.0060 for an oil price shock; to 0.0063 for an import shock. The first two values of first-order correlation and standard deviation were taken from Schmitt-Grohe and Uribe (2004), and the rest ones were decided by 'trial and error', their meanings do not influence on the results significantly.

In table 5.1 we summarize the calibrated parameters.

Table 5.1. Calibrated Parameters

$\sigma = 1/2$	Intertemporal elasticity of consumption
$\theta = 0.6$	Cost share of capital
$\beta = 1.04^{-1/4}$	Quarterly subjective discount rate
$\eta = 5$	Price elasticity of demand
$s_g = 0.16$	Steady state share of government purchases
$\bar{\pi} = 1.09^{1/4}$	Gross quarterly inflation rate
$\delta = 1.1^{1/4} - 1$	Quarterly depreciation rate
$s_m = 0.45$	Ratio of M1 held by firms to quarterly GDP
$\alpha = 2/3$	Share of firms that can change their price each period
$\gamma = 3.4080$	Preference Parameter
$s_\tau = 0.14$	Steady state non-oil tax revenue to GDP ratio
$\nu = 0.82$	Cash requirement (if $\nu = 0 \rightarrow$ cashless economy)
$R^* = 1.04^{1/4}$	Quarterly foreign interest rate
$\tau^o = 0.54$	Oil revenues tax rate
$\lambda^o = 0.73$	Share of households in oil sector
$s_o = 0.2$	Steady-state share of oil revenues
$s_{\mathrm{Im}} = 0.1637$	Steady-state share of Import
$\rho_g = 0.9$	First order serial correlation of g_t
$\sigma_{\varepsilon_g} = 0.0074$	Standard Deviation of government purchases shock
$\rho_z = 0.82$	First order serial correlation of z_t
$\sigma_{\varepsilon_z} = 0.0056$	Standard Deviation of technology shock
$\rho_o = 0.75$	First order serial correlation of o_t
$\sigma_{\varepsilon_o} = 0.0065$	Standard Deviation of oil flow shock
$\rho_p = 0.85$	First order serial correlation of p^*_t
$\sigma_{\varepsilon_p} = 0.0060$	Standard Deviation of oil price shock
$\rho_{\mathrm{Im}} = 0.8$	First order serial correlation of Im_t
$\sigma_{\varepsilon_{\mathrm{Im}}} = 0.0063$	Standard Deviation of import shock

Technical peculiarities of program implementation

This part briefly describes some revisions we made to implement our program. To determine optimal policy feedback coefficients and to build impulse responses we used Toolkit program, that is MATLAB program for Analyzing Non-linear Dynamic Stochastic Models (see Uhlig, 1997). From the practical standpoint, to put a model into this program all of the log-linearized equations should be divided into three groups according to the following system:

$$0 = AA\hat{x}_t + BB\hat{x}_{t-1} + CC\hat{y}_t + DD\hat{z}_t$$

$$0 = E_t[FF\hat{x}_{t+1} + GG\hat{x}_t + HH\hat{x}_{t-1} + JJ\hat{y}_{t+1} + KK\hat{y}_t + LL\hat{z}_{t+1} + MM\hat{z}_t]$$

$$\hat{z}_{t+1} = NN\hat{z}_t + e_{t+1}.$$

In our model equations (3), (4), (5), (7), (9) – (19), (22) – (30) belong to the group that determine state endogenous variables; the equations with other endogenous variables (6), (8), (20), (21) relate to the second group; five equations for government purchases, technology, oil flow, oil price and import introduce shocks to the model.

Variables have to be allocated to the vectors x, y and z, comprising endogenous states, other endogenous variables, and exogenous stochastic processes, respectively. We identify capital, liabilities, money demand, the nominal interest rate, price dispersion, total price level and stabilization fund as endogenous states, government expenditure, oil price, oil flow, technology and import as exogenous stochastic processes and all the others as endogenous variables.

The indexing of the variables has to be such that only indexes of t, $t-1$ and expectations of $t+1$ are used. The capital accumulation equation – given in the model as $k_{t+1} = (1-\delta)k_t + i_t$ – does not fulfil this condition. In order to make clear for the Toolkit program that capital is a state variable that cannot be changed when the shock occurs, it is necessary to lag all k by one period, so that k_t becomes k_{t-1} and k_{t+1} becomes k_t in all equations. Now, k_{t-1} is the stock of capital that is being used for production in period t – but it can only be changed in period $t-1$.

Matrixes should be formed in compliance with the above system of equations.

One of the peculiarities of Toolkit implementation consists in requirement to matrix CC: its rank should be not less then the number of endogenous variables included in it. Unfortunately, the classification to the vectors x, y and z, that is described above, produces a CC matrix that contains 21 variables but only has a rank of 20, which can therefore not be processed by the Toolkit. The reason for this problem is that the variables x_1 and x_2 – introduced to express the firms' profit maximisation problem in recursive form – are linearly dependent. We deal with this problem by moving the variable x_2 into the vector x of endogenous states.

A problem of the same class has been arisen when it was discovered that the steady-state level of government dividends (spent from stabilization fund) was equal to zero. To solve this problem the dividends were set to $0.1*10^{-12}$ in steady state, the minimum level given which program distinguishes them from zero.

When all the parameters are identified, the system of equations is fully determined and implemented to the Toolkit program taking into consideration to the features described above, the impulse responses for the variables of interest could be found. Appendix 3 contains the full version of MATLAB code that allows getting them.

However, this is not enough to find optimal feedback coefficients of policy rules, since this program produces impulse responses only for one particular set of coefficient values. We used the MATLAB codes presented in Appendices 4A, 4B that let us vary two or three coefficients at the same time. In this case it is possible to see the deviations of a particular variable for each combination of these coefficients' values[27].

[27] For more details, see Chapter "Model results"

6. Model Results

In this chapter we introduce the results we achieved. The method of analysis is mainly based on 'trial and error'. We built a General Equilibrium Model for the export-oriented economy and used a Toolkit program for MATLAB implementation to find the set of optimal policy rules. We consider an economy without income taxes; hence, we implement the model for $\tau_D = 0$. A monetary economy is analysed, but some results have also been checked for a non-cash economy. Fiscal policy rules are considered, first budget balance, then liability targeting.

Balanced budget policy rule

The results are presented in accordance with the aim we set. First, we search for the optimal coefficients of monetary policy rule in case of balanced budget targeting fiscal policy. Technically, we use MATLAB code from Appendix 4a containing the program which let us see the deviations of any model variable that occur under one of five 1 % shocks at a particular moment. The results are presented in the form of 3D matrices that show the size of deviations given all values of tree-coefficient-combinations. To do this we removed the specific coefficient values from the model implementation presented in Appendix 3. For α_π and α_y we search over a grid from -3 to 3,[28] however for α_R we set a framework from -1 to 1 to exclude the non-stable roots. The steps in value of α_π, α_y and α_R were 0.5, 0.5 and 0.2, respectively, for this operation. We chose three variables to estimate the deviations from the steady state: inflation, output and stabilization fund followed by shocks in government purchases, technology, oil flow and oil price. To achieve the abovementioned goal we first search for the best value of α_R to find the optimal range of values for α_y and α_π.

Table 6.1. The results for α_R in $t = 0$

Variables	Shocks				
		Government purchases	*Technology*	*Oil flow*	*Oil price*
Inflation	α_R	$\alpha_R = 0.8$	$\alpha_R = 0.2$	$\alpha_R = 0.6$	$\alpha_R = 0.2$
	Deviations from steady-state, abs. value	2.9244e-007	2.7559e-005	3.9965e-006	5.6837e-006
Output	α_R	$\alpha_R = 0.4$	$\alpha_R = -0.4$	$\alpha_R = -1$	$\alpha_R = 0.2$
	Deviations from steady-state, abs. value	1.7825e-005	3.0693e-004	5.6576e-006	6.5808e-007

[28] We rely on values suggested in Schmitt-Grohe and Uribe (2004)

Stabilization fund	α_R	$\alpha_R = -0.6$	$\alpha_R = -0.2$	$\alpha_R \in [-1;1]$	$\alpha_R \in [-1;1]$
	Deviations from steady-state, abs. value	2.3578e-019	8.1323e-018	0.0061	0.0084

The results presented in table 6.1, as well as the results found for other time moments after the shock had occurred, do not let us make a definite conclusion about the optimal levels of α_R. But it presents the results of how much the interest rate should rely on its $t-1$ value in case of, for example, priority stabilizing of output deviations given a particular shock. Later, we show what values the other two coefficients should take in this case. The value of interest rate coefficient that minimizes the absolute value of deviation from steady state differs too dramatically for inflation, output and the stabilization fund given a particular shock. This result was also checked for other time moments, and was confirmed.

However, the interesting finding was that under any value of α_R (given the meanings of other coefficients) the stabilization fund has the same deviations from steady state in the case of oil shocks. But it is true for the moment of shock occurrence. But if we look behind, then the value of α_R is significantly important for the stabilization fund deviations. Under $\alpha_R = -0.1$ the deviation from steady state was significantly smaller than under other values of this coefficient, and not only in the moments before the shock occurred. This result is important for us, since we implement the situation of an export-oriented economy with an emphasis on oil sector. In particular, oil shocks were the central ones in experience of modern Russian economy.

Further, we implement the following strategy of searching optimal policy coefficients. We give a particular value to α_R [29] and get the surface of deviations for inflation, output and the stabilization fund under all values of the other two coefficients within the interval [-3; 3] with step 0.2, given a particular shock at a specified time. Hence, we graph the surface of 31^2 points.

We consider $\alpha_R = [-1.0, -0.5, -0.3, -0.1, 0, 0.3, 0.5, 0.9, 1.0]$. Here, the values found in the previous part are taken into consideration. Unfortunately, it is not possible to present all figures found in these cases, so we will provide only some of them, in our opinion, the most interesting. We will present the results only for the moment when the shock occurs. First, α_R is set equal to 0.

The most fascinating question here is what happens with inflation, output and the stabilization fund in case of an oil price shock. Actually, these results are highly correlated with the ones found under the oil flow shock, but the oil price shock is more vital, so we concentrate

[29] This practice was also used in Schmitt-Grohe and Uribe (2004, 2006)

on its description. Here, figures 6.1a, 6.1b, 6.2a, 6.2b, 6.3a, 6.3b depict impulse responses in $t = 0$. Results are presented as a 3D-graph or/and as a 2.5D-graph. We believe this gives a better rendition.

Figure 6.1a. 3D - Impulse response of inflation to a 1 percent oil price shock, $\alpha_R = 0$

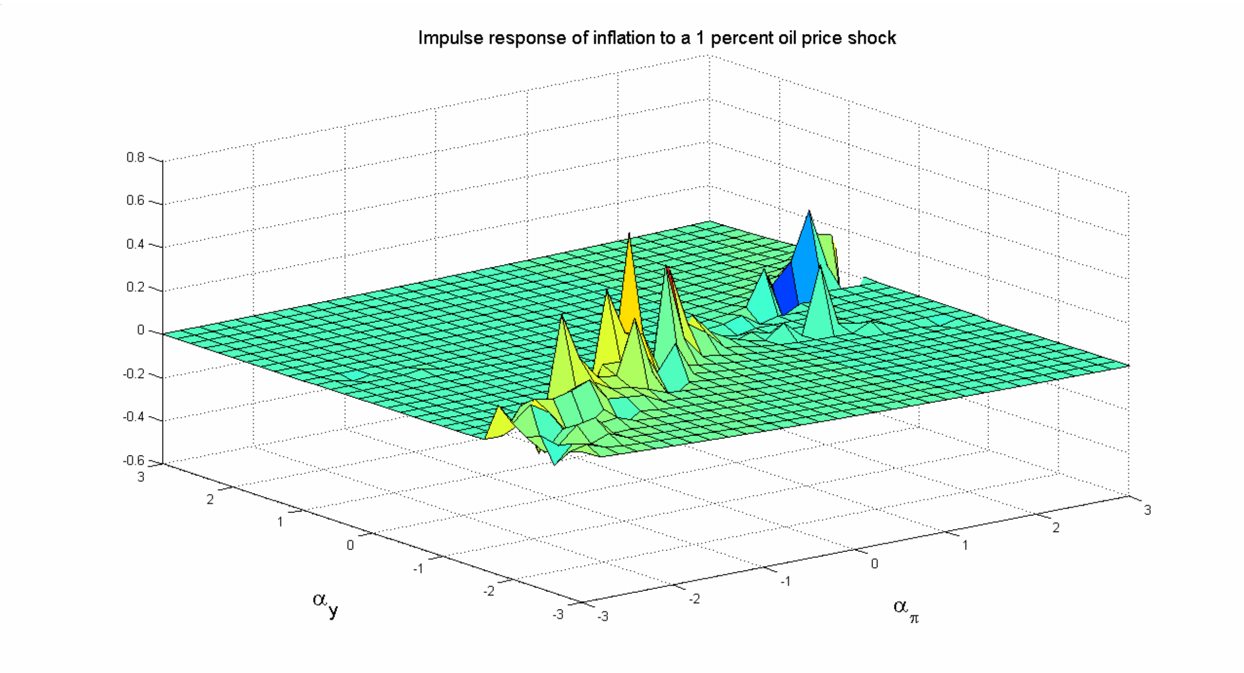


Figure 6.1b. 2.5D - Impulse response of inflation to a 1 percent oil price shock, $\alpha_R = 0$

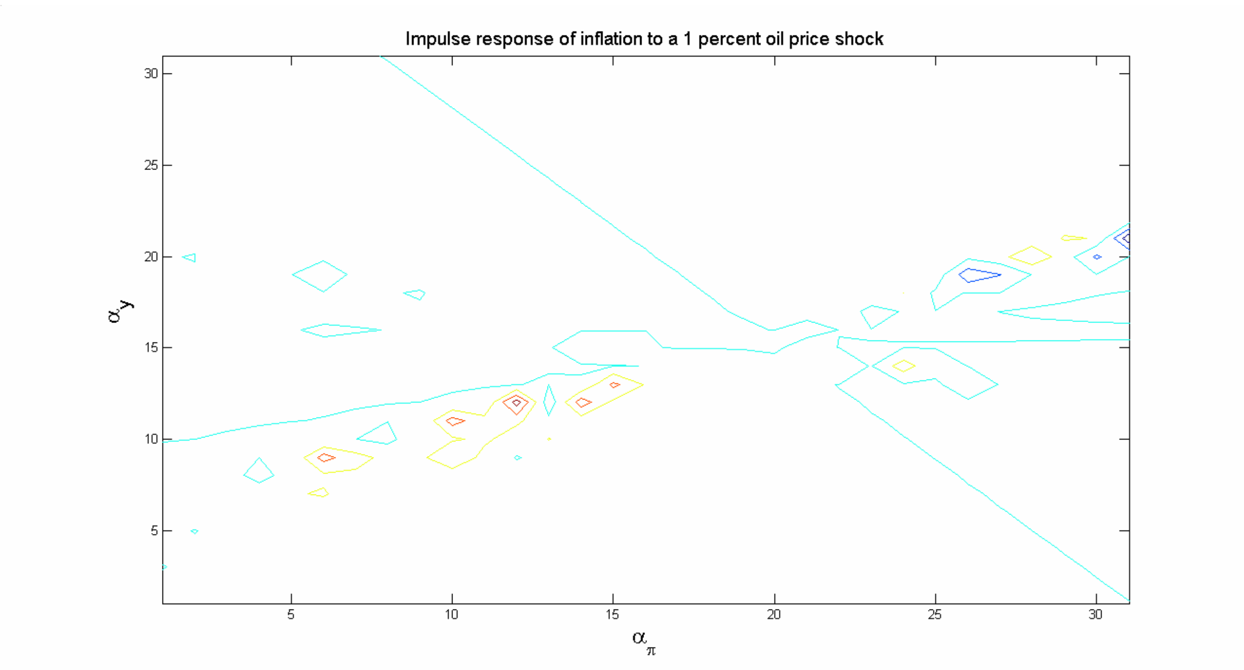


Figure 6.2a. 3D - Impulse response of output to a 1 percent oil price shock, $\alpha_R = 0$

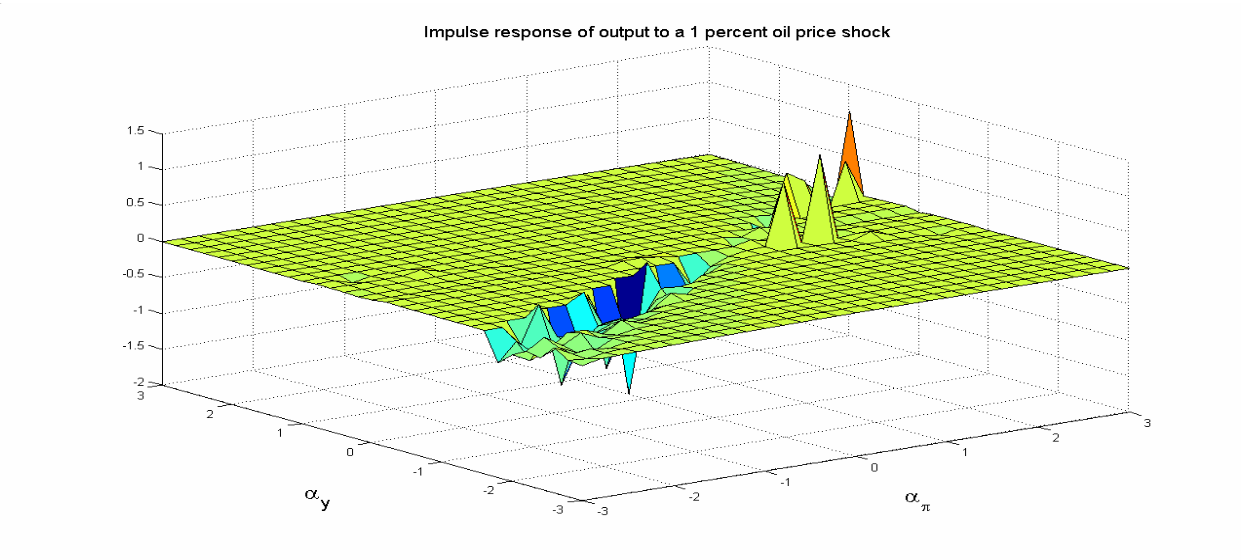


Figure 6.2b. 2.5D - Impulse response of output to a 1 percent oil price shock, $\alpha_R = 0$

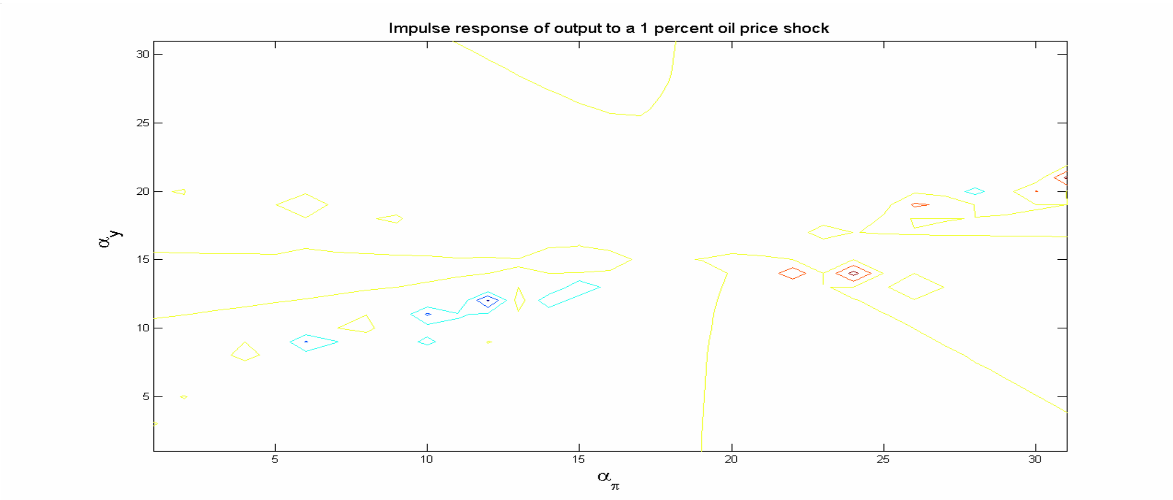


Figure 6.3a. 3D-Impulse response of stabilization fund to a 1 percent oil price shock, $\alpha_R = 0$

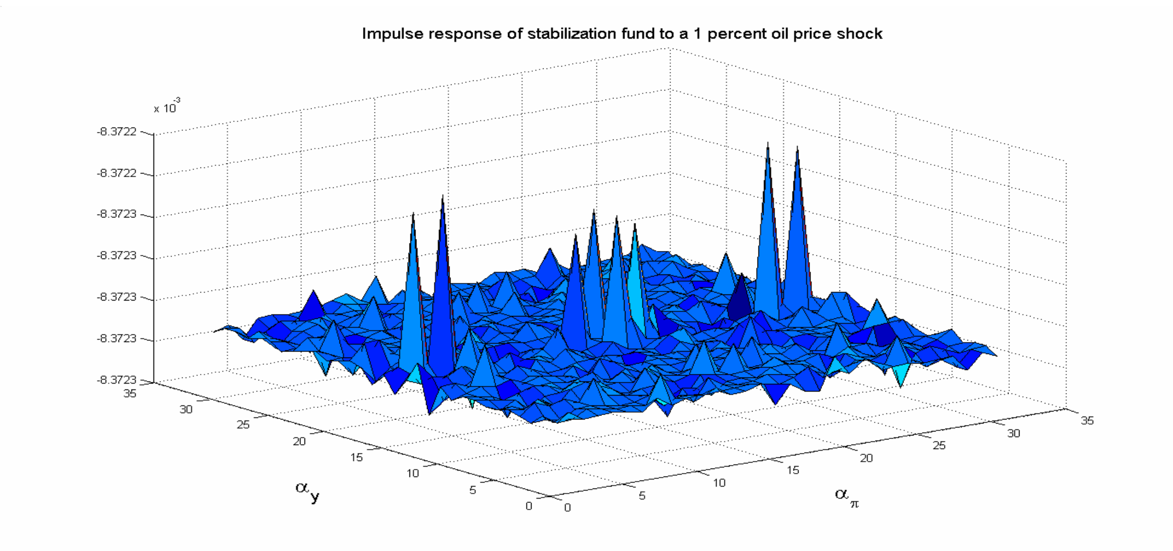
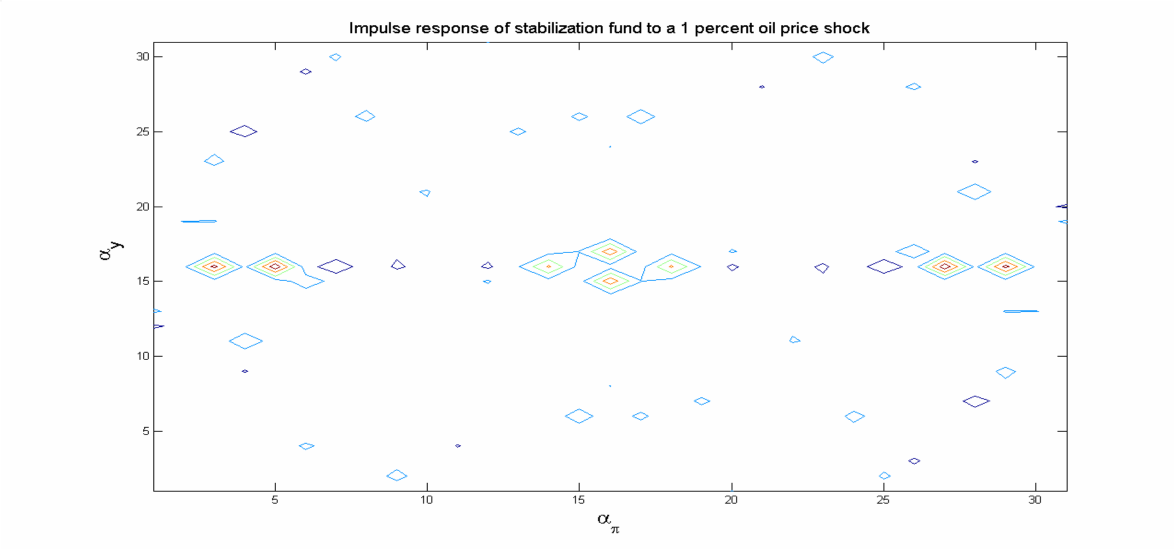


Figure 6.3b. 2.5D-Impulse response of stabilization fund to a 1 percent oil price shock, $\alpha_R = 0$



This graphs show and the calculated matrices prove that in case of $\alpha_R = 0$, interest rate should feature a sensitive response to output, for most of α_π values. In particular, α_y should be set greater than 2.

Stabilization fund impulse responses are very sensitive to oil shocks. This fact is adequate to reality, since the stabilization fund mainly consists of oil revenues.

The reason why the deviations of output and inflation are much bigger than for stabilization fund is in existence of multiplicative effect for first two variables.

The 3D- and 2.5D- impulse responses for inflation and output to 1 % government purchases shock are provided in Appendix 1. In the case of the stabilization fund there is no significant response to output or inflation shock, since it is determined by oil prices and oil flow.

Liability targeting policy rule

In this part we present the results for the case of liability targeting by fiscal policy. So far we have analyzed a passive fiscal policy, i.e. the situation when policy can not influence the price index. The influences were created by monetary policy when the fiscal policy targeted a balanced budget. However, in the case of liability targeting fiscal policy could be either passive or active.

To implement the case of a passive fiscal rule we should set $\gamma_1 \in \left(0, \dfrac{2}{\pi}\right)$, the active fiscal policy - $\gamma_1 \notin \left(0, \dfrac{2}{\pi}\right)$. The explanation of these intervals is provided in Section 7.

In our analysis, the gross quarterly inflation rate is $\bar{\pi} = 1.09^{1/4}$.

Under the restriction of $\alpha_R = 0$ we first implement a passive fiscal rule.

The steps in value of γ_1 are equal to 0.2, within the range from 0.1 to 1.9. For α_π and α_y we search over a grid from -3 to 3, as in the case of balanced budget targeting, with a step of 0.5. We find out that in most cases the meaning of $\gamma_1 \in [0.1;1.9]$ does not influence the results significantly. It means that given each value of γ_1 there is the combination of α_π and α_y that guarantees the same minimal deviation from steady state at the moment $t = 0$. The results are presented in table 6.2. This hypothesis was also tested for other moments, and it was found out that it is possible to find the combination of α_π and α_y values which does not lead to significant differences in deviations from steady-state under any particular γ_1 of the passive fiscal policy.

Table 6.2. The results for γ_1 in moment $t = 0$

Variables		**Shocks**		
		Government purchases	*Technology*	*Oil price*
Inflation	γ_1	$\gamma_1 \in [0.1;0.9]$	$\gamma_1 = [1.1;1.9]$	$\gamma_1 \in [0.1;1.9]$
	Deviations from steady-state, abs. value	1.1149e-004	0.0027	1.0328e-004
Output	γ_1	$\gamma_1 \in [0.1;1.9]$	$\gamma_1 \in [0.1;1.8]$	$\gamma_1 \in [0.1;1.9]$
	Deviations from steady-state, abs. value	1.5691e-004	0.0013	0.0011
Stabilization fund	γ_1	$\gamma_1 = 0.1$	$\gamma_1 = 0.7$	$\gamma_1 = 1.1$
	Deviations from steady-state, abs. value	1.4653e-021	3.0703e-020	5.6946e-004

From table 6.2 it is evident that if the Government cares about the stabilization fund, then in the case of each shock a particular optimal value for γ_1 exists. However, our analysis showed that the deviations in this case are significantly less for γ_1, that is why for any γ_1 the combination of monetary feedback coefficients that produces the deviation only $1*10^{-20}$ bigger could be found.

This analysis let us postulate that in case of a passive fiscal policy with liability targeting the value of γ_1 (given $\alpha_R = 0$) does not confine monetary policy rule in its response to output and inflation.

Now under the restriction of $\alpha_R = 0$ we do not require fiscal policy to be passive. We implement the case of oil price shock given $\alpha_y = 3$. As we have already mentioned, the optimal monetary policy rule should respond to output significantly, that is why we tried some values of its coefficient consistent with this fact and present here the extreme case. For α_π and γ_1 we search over a grid from -3 to 3 with the step of 0.5.

The figures in Appendix 2 show the impulse responses of our target variables to a one percent oil price shock. The most remarkable result is for the stabilization fund. Each value of γ_1 could either produce no deviation from steady state given any value of α_π or cause the same deviation for any value of α_π.

7. Discussion

In our numerical analysis we implemented the model's variant without income taxes and mainly focusing on monetary economy. We chose 'trial and error' method for searching for the optimal policy rule coefficients. We tried the model specifications under which Schmitt-Grohe and Uribe (2004) reached the most significant results, but in an expanded real business cycle model for an export-oriented economy, and we mainly focused on oil price shocks. However, we did not reach such precise results as they did.

We selected inflation, output and the stabilization fund as the major variables for our investigation because inflation is typically the main goal for stabilization policy of the Central Bank, output is the crucial variable for both policies and the stabilization fund is the key novel variable of the model.

The search of optimal policy coefficients was done for the budget balance and liability targeting fiscal rules. Under this first variant of a fiscal policy rule, we found that the value of interest rate coefficient minimizing the absolute value of deviation from steady state differs too dramatically for inflation, output and the stabilization fund given a particular shock.

However, table 6.1 provides the particular values of feedback coefficients for this case. But the deviations from the steady-state are strongly insignificant in many combinations of three coefficients, and presenting minimum of them does not show the real state of affairs. To be sure about this we also tried other steps for feedback coefficients (for example, 0.3, 0.3, 0.1; 0.5, 0.2, 0.1; 0.2, 0.2, 0.2; 0.2, 0.2, 0.1), but they gave us the same picture. The 3-D matrices found in this analysis prove the fact of existence of many combinations of coefficient values that provide insignificant deviations from the steady state. This study's experience applied to cashless economy does not change the conclusion.

The intuition of the result we got in this part is the following: when monetary policy is free to feature any two of the interest rates, inflation, output feedback coefficients, keeping one of them fixed, then it could find the optimal combination of them which produces the minimal deviation from the steady-state.

Presented in figures 1a, 1b, 2a, 2b, 3a, 3b impulse responses for inflation, output and the stabilization fund for oil price shock show that in case of $\alpha_R = 0$, the interest rate should feature a sensitive response to output, for most of the α_π values. In particular, α_y should be set greater than 2. The verification of the model for the cashless economy did not change our conclusion.

It is important to mention that compared to the most important finding of Schmitt-Grohe and Uribe (2004), that optimal α_y equals to zero in case of technology shock, thereby underlined that interest rate featured a positive response to output reduce to significant losses. Our analysis of an export-oriented economy with emphasis on the oil industry produces the opposite result.

For the case of liability targeting the fiscal rule is $\tau_t + \frac{E'_t\, div^*_{o,t}}{\pi_t} = \gamma_0 + \gamma_1(l_{t-1} - l)$, while γ_2 is equal to zero. As before it is assumed that income taxes are equal to zero, so that $\tau_t = \tau^L$. Then combining these two conditions with the budget constraint (7), we get

$$l_t = (R_t / \pi_t)(1 - \gamma_1 \pi_t) l_{t-1} + R_t \left(g_t + \frac{E'_t\, div^*_{o,t}}{\pi_t} - \gamma_0 + \gamma_1 l) \right) - m_t (R_t - 1) - \frac{E'_t div^*_{o,t}}{\pi_t}$$

If $1 - \gamma_1 \bar{\pi}$ is less then one in absolute value, then there is a stable root of government liabilities. This means that they grow at a rate less then the real interest rate, R_t / π_t. Then, fiscal policy indebtedness grows with the speed to be covered. Fiscal policy can not influence the price level, it is passive.

But if $1 - \gamma_1 \bar{\pi}$ is higher than one in absolute value, government liabilities increase quicker than at the rate of the real interest rate. In this case to provide solvency of the government inflation should be adjusted. This is the case of active fiscal policy.

Our analysis found that in the case of a passive fiscal policy with liability targeting, the value (within the interval) of balanced budget feedback coefficient in the fiscal policy rule (under the restriction that interest rate coefficient in monetary policy rule is equal to zero) does not confine monetary policy rule in its response to output and inflation.

Schmitt-Grohe and Uribe (2004) also implemented the liability targeting fiscal policy, and for the case of passive rule they provide more concrete results than we do. They found that given any value of balanced budget feedback coefficient the combination of optimal monetary coefficients, found in their previous research, exists and is the same for all γ_1.

Under the restrictions of zero-, output and interest rate feedback coefficients in the interest-rate rule we searched for the optimal γ_1 and α_π without a restriction on the nature of the fiscal policy. An interesting result was achieved for the stabilization fund. Each value of γ_1 could be either producing no deviation from the steady state given any value of α_π or causing the same deviation for any value of α_π. This result could be interpreted in the way that there is the direct link between government liabilities, inflation and part of stabilization fund (its dividends). When the liabilities grow they could be either financed by the dividends from oil or by the inflation decrease to raise the nominal value of dividends.

8. Summary and concluding remarks

In this paper we searched for a set of potentially optimal feedback coefficients under oil, technology and government purchases shocks in the economy. To address this issue we built a general equilibrium model for an economy with huge oil export revenues on the benchmark of Schmitt-Grohe and Uribe (2004). The stabilization fund was included into analysis. We took into account some important peculiarities of the Russian economy doing the calibration on the base of a Toolkit program for MATLAB implementation. Optimality was determined as minimization of variables' deviations from their steady-state.

We did not give the irrefragable answer to the question we considered, but we made progress in determining a set of coefficients satisfying the requirement of optimal policy in an export-oriented economy. Our main findings are: under oil price shock optimal monetary policy rule features a significant response to output; the coefficient of nominal interest rate varies significantly for different shocks; considering the stabilization fund under passive fiscal policy with liability targeting each value of liability targeting coefficient could either produce no deviation from steady state given any value of inflation feedback coefficient or cause exactly the same deviation.

In our future research we are going to deal with the problem more thoroughly. First of all, we will expand the computing part of our analysis by making shorter steps for coefficients so as make our test-point grid more precise. Secondly, we will make more variations for calculations, thus enhancing our 'trial and error' analysis. The next step will involve expanding the model.

Having built a general equilibrium model for an export-oriented economy with emphasis on the oil industry and having searched for the optimal policy rules, we used the Taylor rule to describe monetary policy. In our future research we will compare the results we have achieved by using contemporaneous Taylor rule with the results under other classes of monetary policy rules like McCallum's. The aim is to find the best-describing monetary policy rule for an export-oriented economy with a stabilization fund without being confined to simple rules.

The assumption of a floating exchange rate would be rejected in analyzing an economy where foreign reserves are important. This makes the analysis more complicated and increases the role of currency policy. However, it could describe some important peculiarities of the Russian economy which were neglected in this research due to scarce time recourses. Also, we are going to determine the interconnection between the stabilization fund and money supply. We are searching for an equation that best describes the relationship between these two variables.

Since in general our model is built taking distortion taxes into account, we will search for optimal policy rules under an expanded variety of fiscal instruments.

Having implemented an empirical analysis of Russian economy, we found out that money velocity has decreased much in recent years. This fact combined with money base growth and an inflation decrease constitutes a good base for theoretical modeling.

To sum up, our priorities for future research lie in extending our model of export-oriented economies with a stabilization fund chiefly in the monetary sphere to make the results more precise and applicable.

References

Aarle B. van, Bovenberg L, Raith M., “Monetary and Fiscal Policy Interaction and Government Debt Stabilization”, Journal of Economics, 62(2), 1995, 111-40.

Bernanke S.B., Gertler M., Watson M., Sims A.C., Friedman B.M., “Systematic Monetary Policy and the Effects of Oil Price Shocks”, *Brookings Papers on Economic Activity*, No. 1 1997, 91-157

Calderon, C., and Schmidt-Hebbel K., “Macroeconomic policies and performance in Latin America”, Journal of International Money and Finance, 27(7), 2003, 895–924

Calvo, G. , “Staggered prices in a utility-maximising framework”, Journal of Monetary Economics 12, 1983, 383-98

Canzoneri, M., Crumby, R. and Diba, B., “Is the price level determined by the needs of fiscal solvency?”, Centre for Economic Policy Research Working Paper No. 1772, 1998

Christiano, Lawrence J., Eichenbaum M., and Evans C., “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy,” Northwestern University, August, 2003

Clarida, R., Gali J. and Gertler M., “Monetary policy rules in practice: Some international evidence”, European Economic Review 42(6), 1998, 1033-1067, and *NBER* Working Paper 6254

Cochrane, J. H., “Long-term debt and optimal policy in the fiscal theory of the price level”, *NBER* Working Paper 6771, 1998

Drobyshevsky, S. and Kozlovskay A., “Inside aspects of Russian monetary policy”, IET Working Paper №45, 2003

Eastwood R., “Macroeconomic Impacts of Energy Shocks”, Oxford Economic Papers, New Series, vol. 44, 1992, 403-425

*Esanov A., Merkl C., Vinhas de Souza L., “*Monetary Policy Rules for Russia”, BOFIT Discussion Papers, November 2004

Fry J. M.; Lilien M.D., “Monetary Policy Responses to Exogenous Shocks”, The American Economic Review, Vol. 76, No. 2, 1986, 79-83

Hall, R., "Monetary Strategy with an Elastic Price Standard in Price Stability and Public Policy”, Federal Reserve Bank of Kansas City, 1984, 137-59

Kim J., Kim S., Schaumburg E., Sims A.S., “Calculating and using second order accurate solutions of discrete time dynamic equilibrium models”, Journal of Economic Dynamics and Control, 2007, 515-530

Kollmann, R., “Welfare Maximizing Fiscal and Monetary Policy Rules,” mimeo, University of Bonn, March 2003

Leeper, E. M, “Equilibria under ’Active’ and ’Passive’ Monetary and Fiscal Policies,” Journal of Monetary Economics 27, February 1991, 129-47.

Lombardo, G. and Sutherland, A., “Computing second-order-accurate solutions for rational expectation models using linear solution methods”, Journal of Economic Dynamics and Control, 2005

McCallum B., “Monetarist Rules in the Light of Recent Experience”, NBER Working Papers 1277, 1984

Minella, A. Springer de Freitas P., Goldfajn I., Kfoury Muinhos M., “Inflation targeting in Brazil: Constructing credibility under exchange rate volatility”, Journal of International Money and Finance, 27(7), 2003, 1015–1040

Mohanty, M. and Klau M., “Monetary policy rules in emerging market economies”, Working Paper, Kiel Institute for World Economics, September 2003.

Prescott E., “Theory Ahead of Business Cycle Measurement,” Federal Reserve Bank of Minneapolis Quarterly Review 10, Fall 1986, 9-22

Rotemberg, J. J. and Woodford, M. D., “Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity,” Journal of Political Economy 100, December 1992, 1153-1207

Schmitt-Grohe, S. and Uribe, M., “Price level determinacy and monetary policy under a balanced budget requirement”, Board of Governors of the Federal reserve System, mimeo, 1997, Journal of Monetary Economics 45, February 2000, 211-246

Schmitt-Grohe, S. and Uribe, M., “Solving dynamic general equilibrium models using a second-order approximation to the policy function”. 2004b, Journal of Economic Dynamics and Control, 2004, 755-775

Schmitt-Grohe, S. and Uribe, M., “Optimal Simple And Implementable Monetary and Fiscal Rules”, mimeo, 2004

Schmitt-Grohe, S. and Uribe, M., “Optimal Simple And Implementable Monetary and Fiscal Rules: expanded version”, National bureau of economic research, Working paper 12402, 2006

Tabellini G., “Money, Debt and Deficits in a Dynamic Game”, Journal of Economic Dynamics and Control, 10, 1986, 427-42

Taylor, J., “An Appeal for Rationality in the Policy Activism Debate”, in R. W. Hafer, ed.. The Monetary versus Fiscal Policy Debate, New Jersey: Rowman and Allanheld, 1986a, 151-63.

Taylor, J. B., “Discretion versus Policy Rules in Practice”, Carnegie Rochester Conference Series on Public Policy 39, December 1993, 195-214

Torres Garcia, A., "Monetary policy and interest rates: evidence from Mexico", Working Paper, Kiel Institute for World Economics, 2003, 11–12.

Uhlig, H., "A Toolkit for Analyzing Nonlinear Dynamic Stochastic Models Easily", mimeo Tilburg, 1997

Vdovichenko A., Voronina V., "Monetary policy rules and their application in Russia", EERC, 2004, 1–47

Woodford, M., "Price-level determinacy without control of a monetary aggregate", Carnegie-Rochester Conference Series on Public Policy, Elsevier, vol. 43, 1995, 1-46

Woodford M., "Interest and prices", 2002

Yun, T., "Nominal price rigidities, money supply endogeneity and business cycles", Journal of Monetary Economics 37, 1996, 345-370

Appendix

Appendix 1.

Impulse response of inflation and output to a 1 percent government purchases and technology shock, $\alpha_R = 0$

Figure A1.1. 3D-Impulse response of inflation to a 1 percent government purchases shock

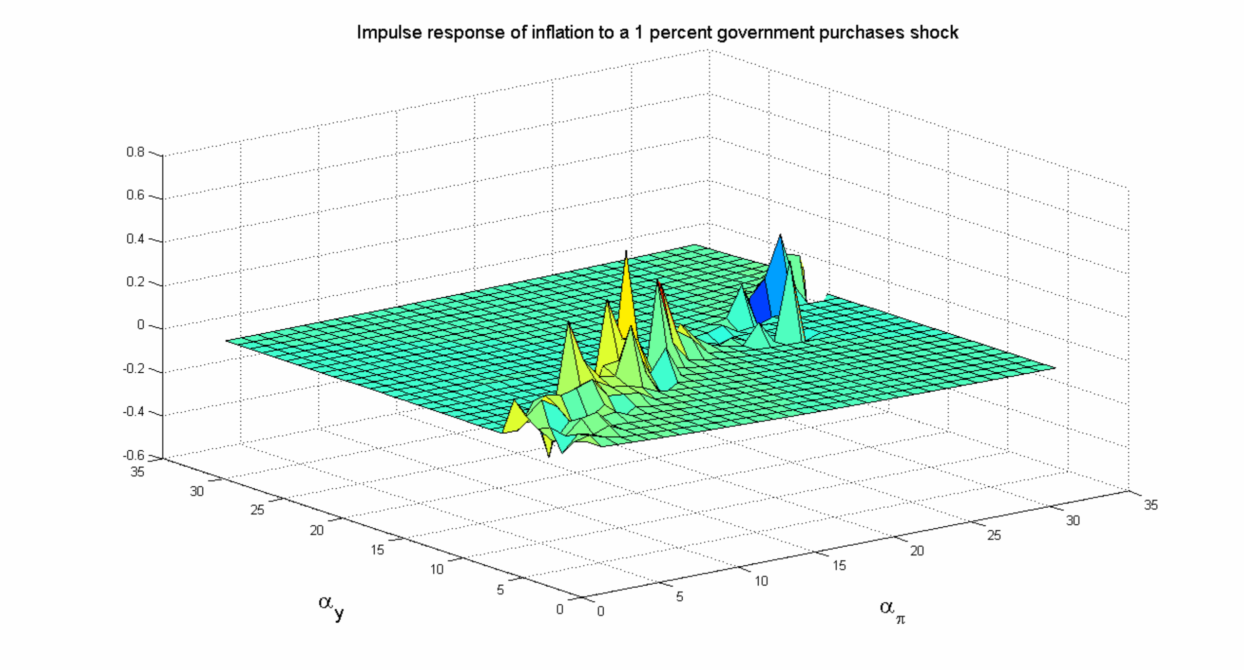


Figure A1.2. 2.5D-Impulse response of inflation to a 1 percent government purchases shock

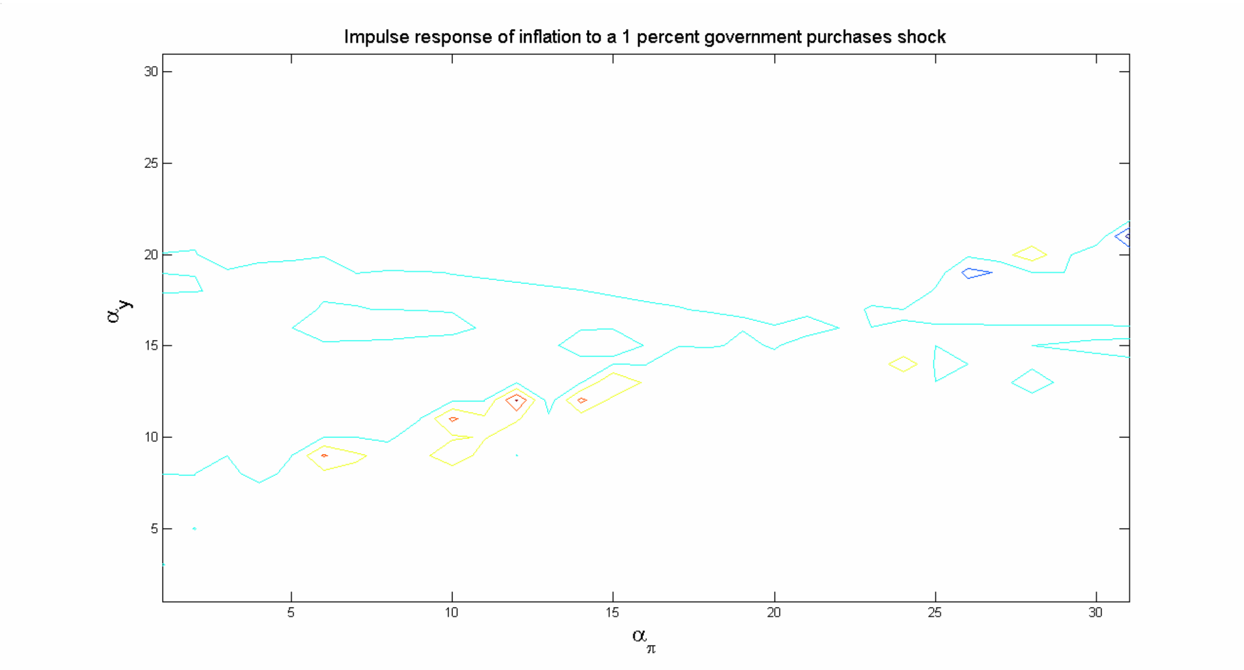


Figure A1.2. 3D-Impulse response of output to a 1 percent government purchases shock

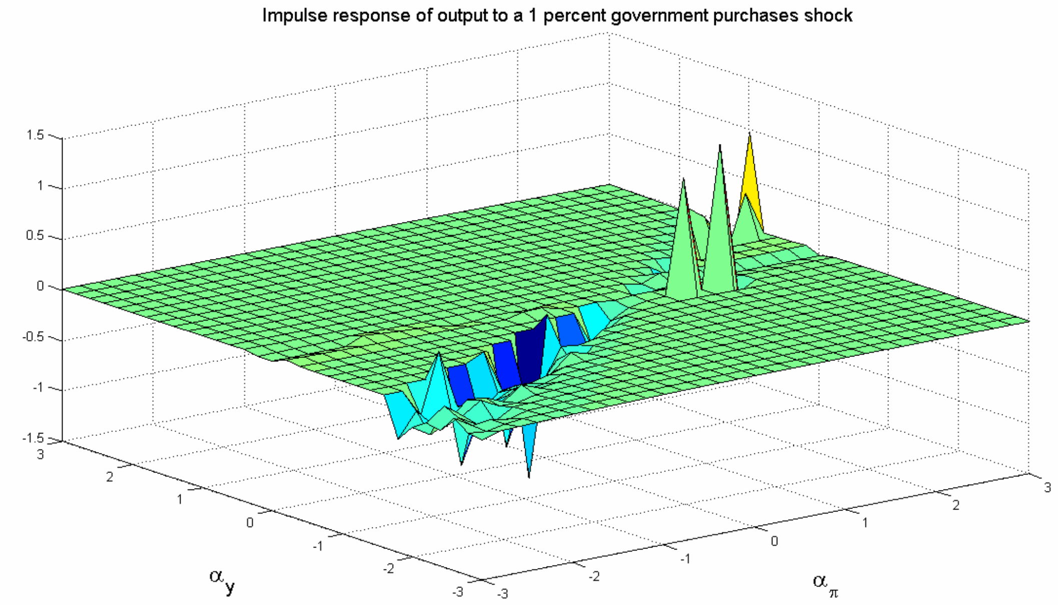
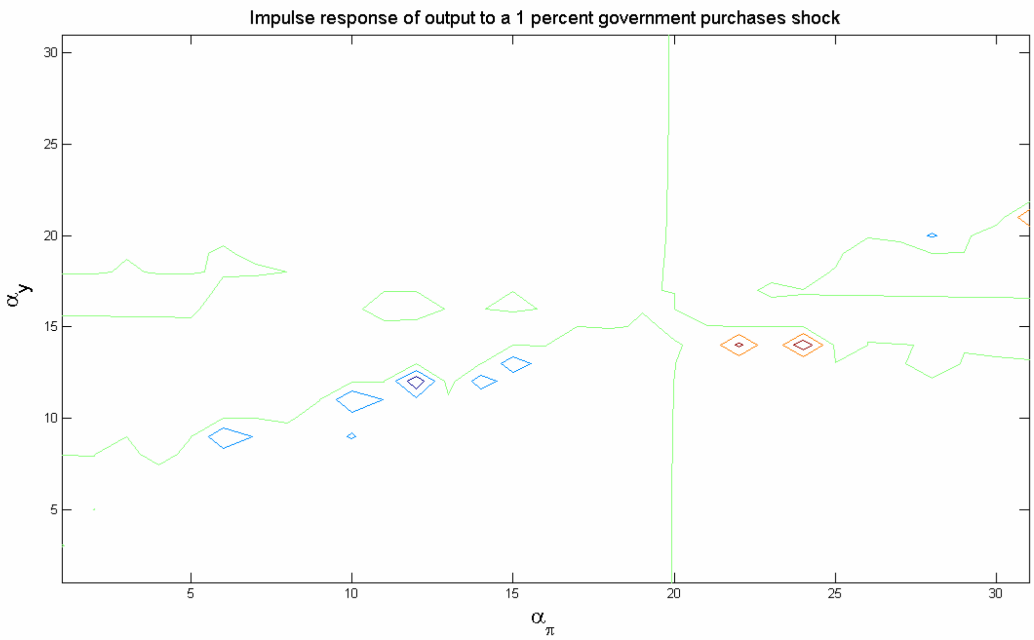


Figure A1.2. 2.5D-Impulse response of output to a 1 percent government purchases shock



Appendix 2.

Impulse response to a 1 percent oil price shock, $\alpha_R = 0$, $\alpha_y = 3$

Figure A2.1. 3D-Impulse response of stabilization fund to a 1 percent oil price shock

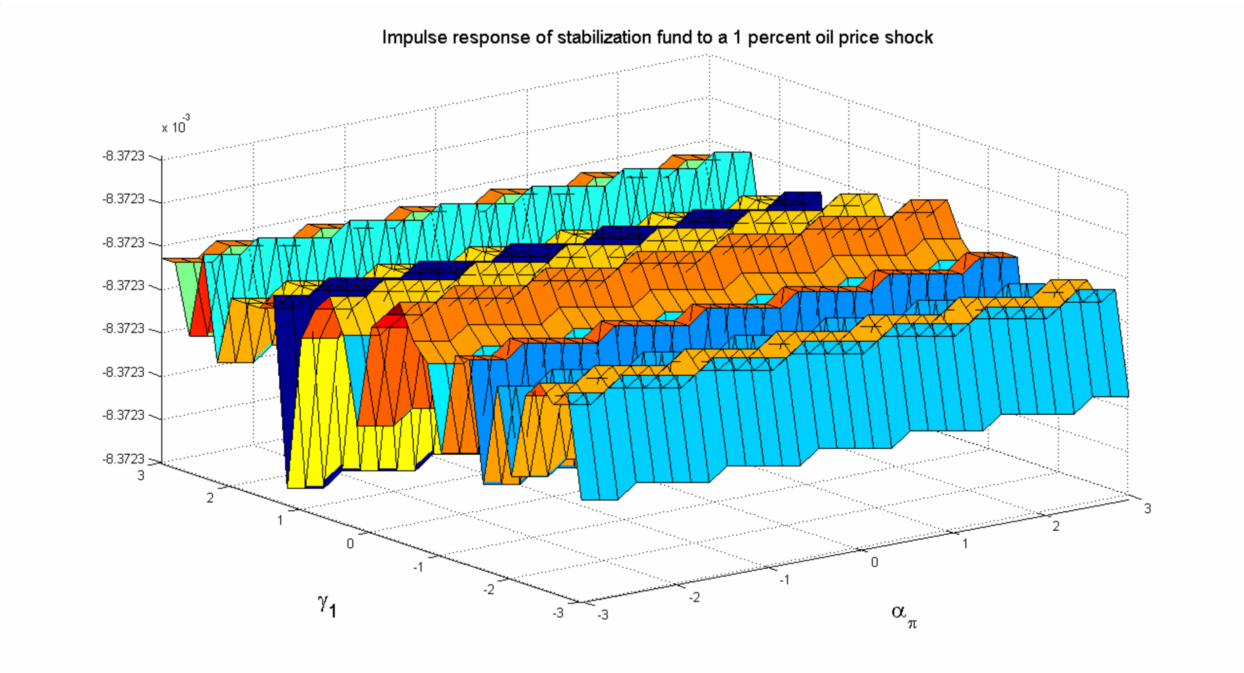


Figure A2.2. 2.5D-Impulse response of stabilization fund to a 1 percent oil price shock

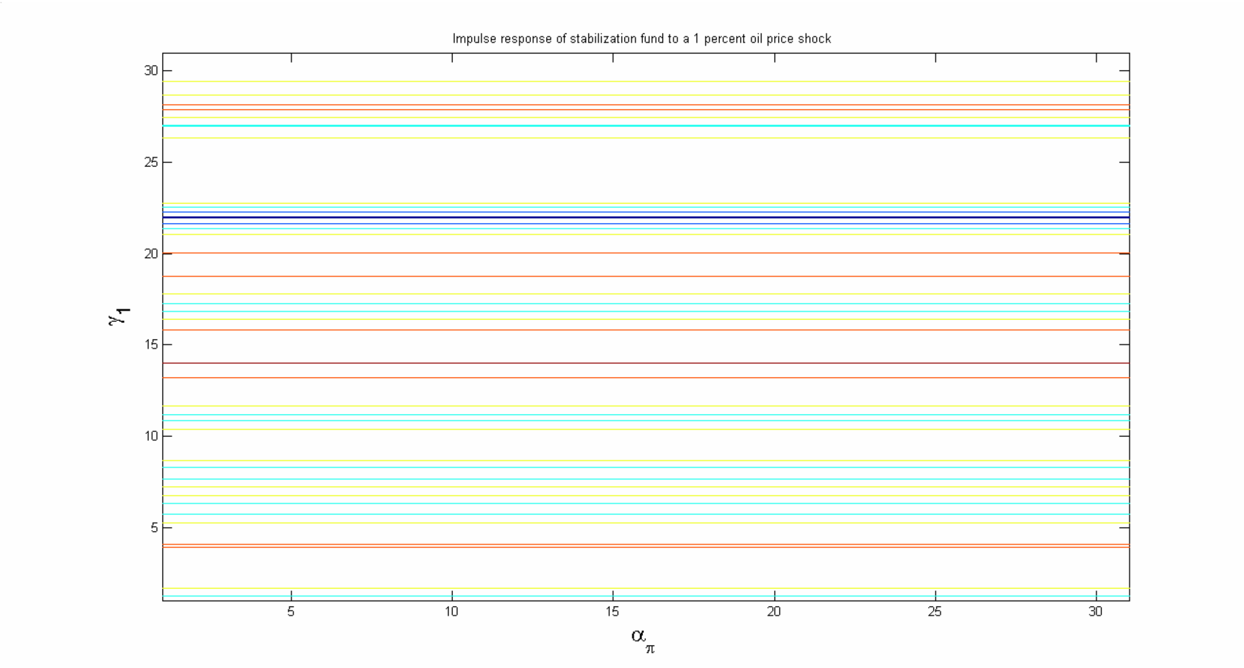


Figure A2.3. 3D-Impulse response of inflation to a 1 percent oil price shock

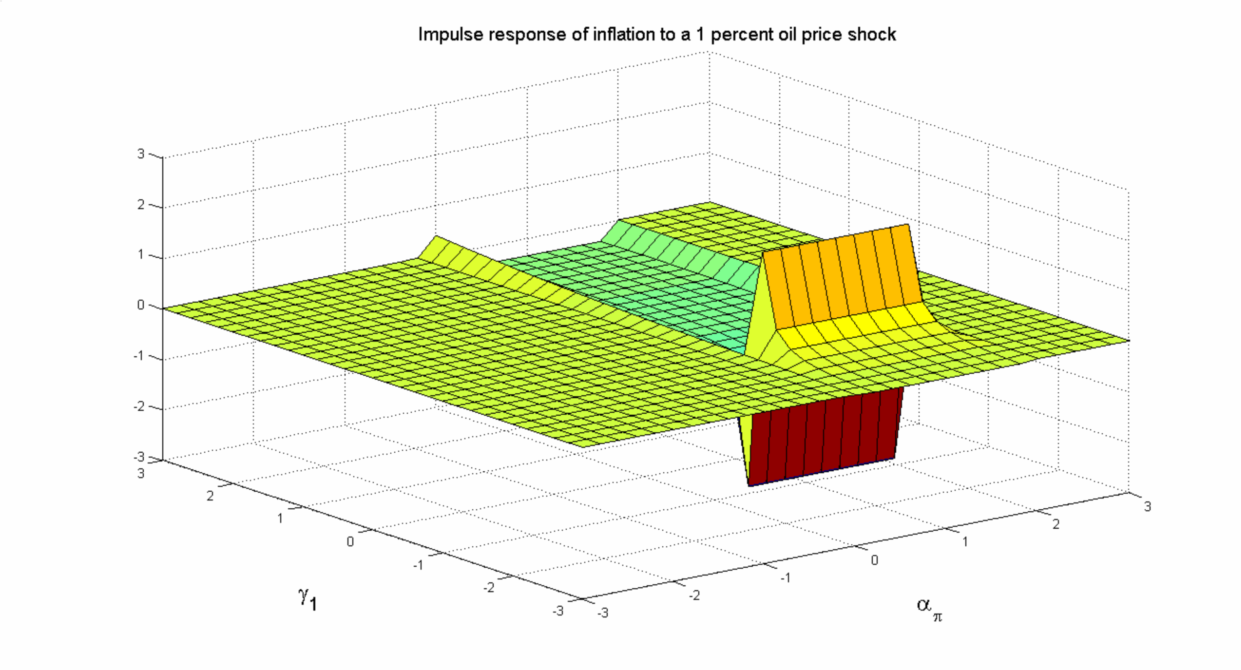


Figure A2.4. 2.5D-Impulse response of inflation to a 1 percent oil price shock

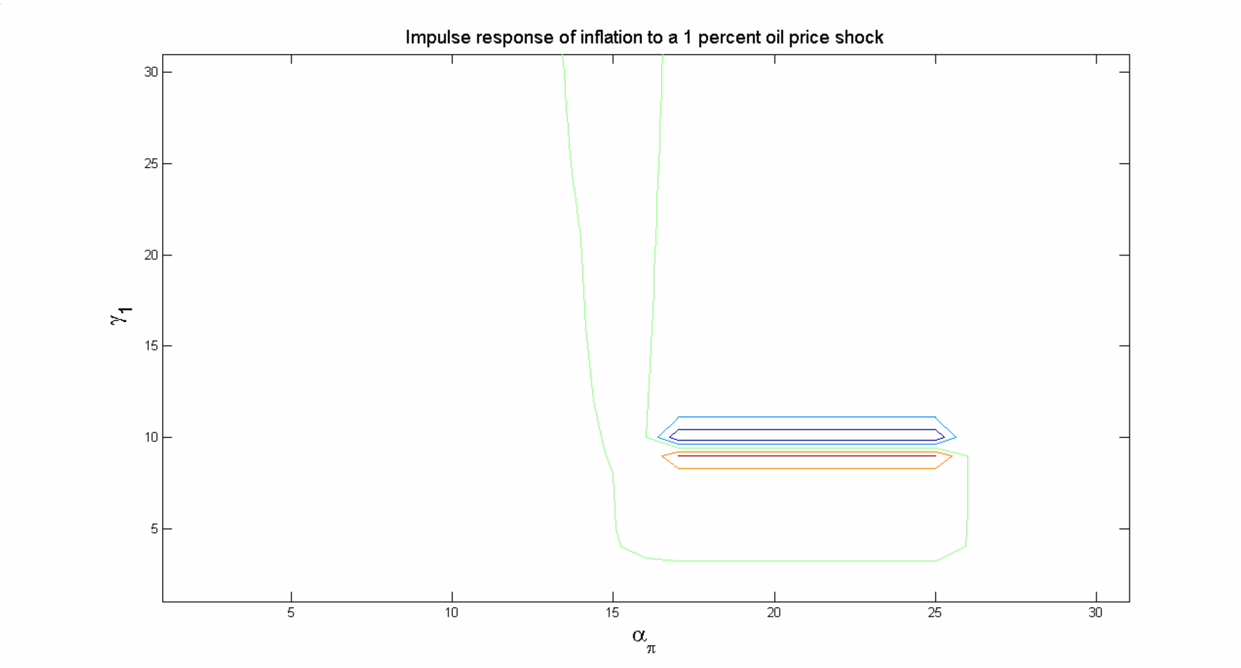


Figure A2.5. 3D-Impulse response of output to a 1 percent oil price shock

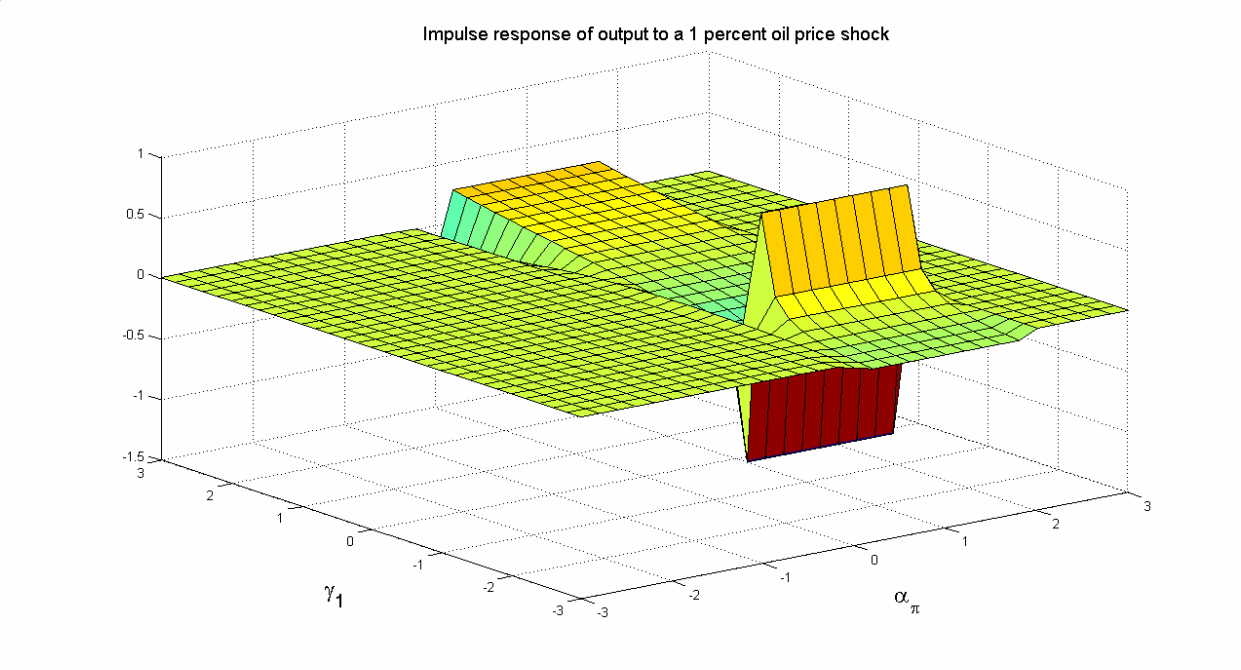
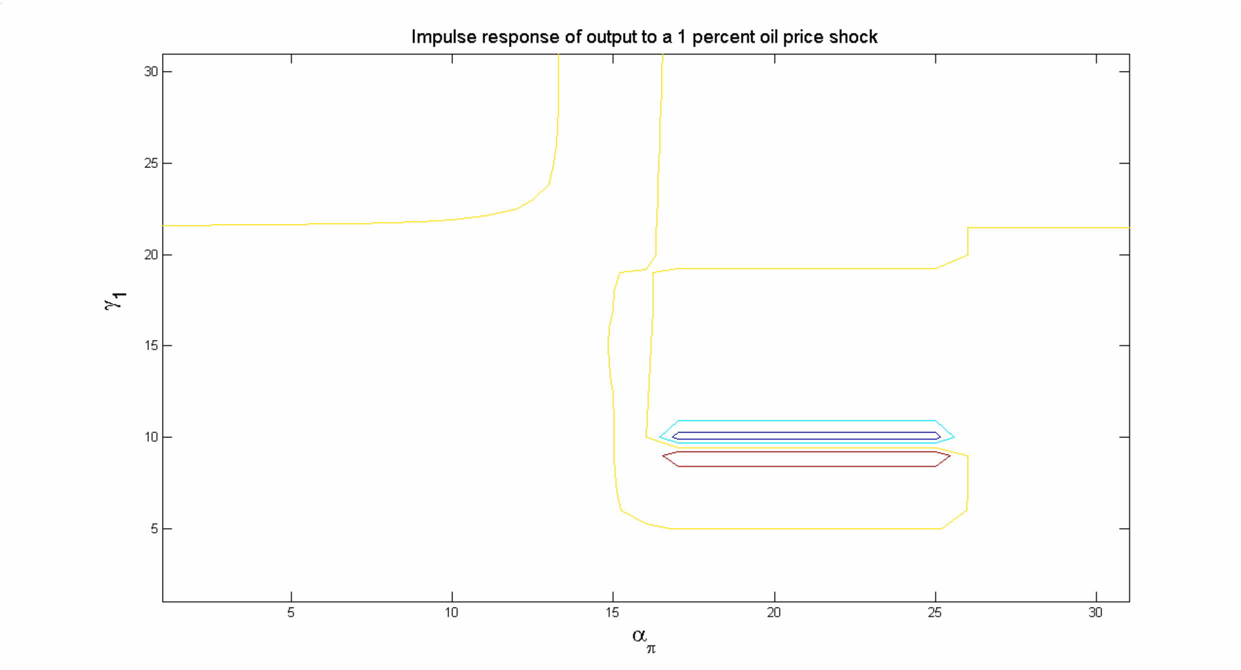


Figure A2.6. 2.5D-Impulse response of output to a 1 percent oil price shock



Appendix 3. MATLAB code for major program

```
% Master_thesis_major_program

% Setting parameters:
sigma = 2;                  % Intertemporal elasticity of consumption
theta = 0.6;                % Cost share of capital
betta = 1.04^(-1/4);        % Quarterly subjective discount rate
eta = 5;                    % Price elasticity of demand
s_g = 0.16;                 % Steady state share of government purchases (g_bar/y_bar)
pi_bar = 1.09^(1/4);        % Gross quarterly inflation rate
delta = 1.1^(1/4)-1;        % Quarterly depreciation rate
s_m = 0.17*2/3*4;           % Ratio of M1 held by firms to quarterly GDP (m_bar/y_bar)
alpha = 2/3;                % Share of firms that can change their price each period
gamma = 3.4080;             % Preference Parameter
s_tau = 0.14;               % Steady state tax revenue to GDP ratio (tau_bar/y_bar)
nu = 0.82;                  % Cash requirement (if nu=0, non-monetary economy)
R_for = 1.04^(1/4);         % Quarterly foreign interest rate
tau_o_bar = 0.54;           % Oil tax
lambda_o  = 0.73;           % Part of HH in oil sector
s_o = 0.2;                  % Ratio of Oil revenues to GDP
sigma_e_o = 0.0065;         % Standard Deviation of oil flow shock
sigma_e_p = 0.0060;         % Standard Deviation ofoil price shock
rho_o = 0.75;               % First order serial correlation of o(t)
rho_p = 0.85;               % First order serial correlation of p(t)
sigma_e_Im = 0.0063;        % Standard Deviation of Import shock
rho_Im = 0.8;               % First order serial correlation of Im(t)
s_Im = 0.1637;              % Ratio of Import to GDP
rho_g = 0.9;                % First order serial correlation of g(t)
sigma_e_g = 0.0074;         % Standard Deviation of government purchases shock
rho_z = 0.82;               % First order serial correlation of z(t)
sigma_e_z = 0.0056;         % Standard Deviation of technology shock

% Variables normalised in order to identify the model
tau_d_bar = 0;              % rate of distortionary (income) taxes
z_bar     = 1;              % steady state of produtivity shock
e_bar = 1;                  % real exchange rate

% Coefficients of fiscal policy rule
gamma0   = 0;               % constant term in fiscal policy rule
gamma1   = 0;               % feedback coefficient for deviation of last period's liabilities from target
gamma2   = 1;               % feedback coefficient for secondary government budget deficit

% Coefficients of monetary policy (Taylor) rule
```

```
alpha_pi = 3;           % feedback coefficient for contemporary inflation
alpha_y  = 2;           % feedback coefficient for output gap
alpha_r  = 0;           % feedback coefficient for interest rate

% Coefficients of stabilization fund policy rule
ksi =   0.7;   % feedback coefficient of smoothing the level of Stabilization fund to its target level

% Calculating the steady state:
R_bar         =  pi_bar/betta;      % nominal interest rate
U_bar         =  ((1.0/betta)-1+delta)/(1-tau_d_bar);   % rental rate of capital
P_bar          =  ((1-alpha*pi_bar^(-1+eta))/(1-alpha))^(1.0/(1-eta));     % relative price of goods whose price is adjusted in period t
S_bar          =  ((1-alpha)*P_bar^(-eta))/(1-alpha*pi_bar^eta);    % measure of costs induced by inefficient price dispersion
MC_bar      =  ((eta-1)/eta)*(1-alpha*betta*pi_bar^eta)/(1-alpha*betta*pi_bar^(eta-1))*P_bar;      % marginal costs of production
K_H_bar    =  (U_bar/(MC_bar*Z_bar*theta))^(1/(theta-1));     % ratio of capital to labour input
W_bar        =  (MC_bar*Z_bar*(1-theta)*K_H_bar^theta)/(1+nu*(R_bar-1)/R_bar);        % wages
Y_H_bar    =  (Z_bar/S_bar)*K_H_bar^theta;     % ratio of GDP per labour
H_bar         = (Y_H_bar+W_bar/gamma*(1-tau_d_bar)-delta*K_H_bar-s_g*Y_H_bar-s_o*Y_H_bar+s_Im*Y_H_bar)^(-1)*W_bar/gamma*(1-tau_d_bar);     % labour input
Y_bar         =  Y_H_bar*H_bar;  % output
C_bar         =  W_bar/gamma*(1-tau_d_bar)*(1-H_bar);  % consumption
K_bar         =  K_H_bar*H_bar;         % capital input
I_bar          =  K_bar*delta;      % investment spending
G_bar         =  s_g*Y_bar;  % government spending
Lamda_bar  =  C_bar^(-sigma)*(1-H_bar)^(gamma*(1-sigma));   % marginal utility of consumption (lagrange coefficient)
tau_l_bar    =  (s_tau-tau_d_bar)*Y_bar;       % lump-sum taxes
tau_bar       =  tau_l_bar + tau_d_bar*Y_bar;       % income and lump-sum taxes
M_bar        =  s_m*Y_bar;         % cash requirement
div_o_bar    =  0.0000000000001;       % dividends, the part of stabilization fund that government spends
L_bar          =  (R_bar*(G_bar-tau_bar)-M_bar*(R_bar-1)-div_o_bar*e_bar)*(1-R_bar/pi_bar)^(-1);       % government liabilities
P_bar_o_bar =  s_o*Y_bar;      % total revenues from oil
X_1_bar     =  (P_bar^(-1-eta)*(Y_bar-P_bar_o_bar)*MC_bar)/(1-alpha*betta*pi_bar^(eta));       % auxiliary variable used for rewriting firms' equilibrium conditions
X_2_bar     = (P_bar^(-eta)*(Y_bar-P_bar_o_bar))/(1-alpha*betta*pi_bar^(eta-1));       % auxiliary variable used for rewriting firms' equilibrium conditions
rev_o_bar   = (1-lambda_o)*s_o*Y_bar+tau_o_bar*lambda_o*s_o*Y_bar;         % government revenues from oil, that expand stabilization fund
F_bar          = (rev_o_bar-div_o_bar)/(1-R_for);        % stabilization fund
T_bar         = tau_bar+tau_o_bar*s_o*Y_bar*lambda_o;         % all taxes, including oil taxes
E_bar         = e_bar*pi_bar;         % nominal exchange rate
Im_bar       = s_Im*Y_bar;         % Import
CA_bar      = e_bar*P_bar_o_bar-Im_bar;        % current account
KA_bar      = -CA_bar;        % capital account


% Declaring the matrices.
VARNAMES = ['capital                    '  %1
                       'liabilities                 '  %2
                      'money demand            '  %3
```

```
'interest                      '  %4
'costs of price dispersion     '  %5
'x2                            '  %6
'price level                   '  %7
'stabilization fund            '  %8
'lamda                         '  %9
'consumption                   '  %10
'hours                         '  %11
'income and lump-sum taxes     '  %12
'lump-sum taxes                '  %13
'rental rate                   '  %14
'investment                    '  %15
'inflation                     '  %16
'output                        '  %17
'marginal costs                '  %18
'wage                          '  %19
'new prices                    '  %20
'x1                            '  %21
'average markup                '  %22
'gov revenues from oil         '  %23
'dividends from oil            '  %24
'all taxes                     '  %25
'current account               '  %26
'capital account               '  %27
'nominal exchange rate         '  %28
'government purchases          '  %29
'technology                    '  %30
'flow of oil                   '  %31
'oil price                     '  %32
'import                        ']; %33


% Translating into coefficient matrices.

% Endogenous state variables "x(t)": k(t), l(t), m(t), R(t), S(t), PL(t), F(t)
% Endogenous other variables "y(t)": lamda(t), C(t), H(t), tau(t), tau_l(t), u(t), I(t), Pi(t), y(t), mc(t), w(t), p(t), x1(t), x2(t), AM(t), rev*_oil(t), div*_oil(t), Taxes(t), CA(t), KA(t), E'(t)
% Exogenous state variables  "z(t)": g(t), z(t), p(t), o(t), Im(t)
% Switch to that notation.  Find matrices for format
% 0 = AA x(t) + BB x(t-1) + CC y(t) + DD z(t)
% 0 = E_t [ FF x(t+1) + GG x(t) + HH x(t-1) + JJ y(t+1) + KK y(t) + LL z(t+1) + MM z(t)]
% z(t+1) = NN z(t) + epsilon(t+1) with E_t [ epsilon(t+1) ] = 0,
```

```
% for   k(t)        l(t)       m(t)           R(t)        S(t)           x2(t)          PL(t)       F(t)
AA = [K_bar,     0,             0,              0,              0,              0,              0,           0 %(3)
         0,           0,              0,              0,              0,              0,              0,           0 %(4)
         0,           0,              0,              0,              0,              0,              0,           0 %(5)
         0, L_bar, M_bar*R_bar-M_bar, -R_bar*L_bar/pi_bar-R_bar*G_bar+R_bar*tau_bar+M_bar*R_bar, 0, 0, 0,   0 %(7)
         0,           0,              0,              0,              0,              0,              0,           0 %(9)
         0,           0,              0,              0,              0,              0,              0,           0 %(11)
         0,           0,              0,              1,              0,              0,              0,           0 %(12)
         0,           0,              0,    -nu/(R_bar+R_bar*nu-nu),  0,     0,     0,           0 %(17)
         0,           0,              0,              0,              0,              0,              0,           0 %(18)
         0,           0,              1,              0,              0,              0,              0,           0 %(16)
         0,           0,              0,              0,              0,              0,              0,           0 %(22)
         0,           0,              0,              0,              0,             -1,              0,           0 %(19)
         0,           0,              0,              0,              1,              0,              0,           0 %(28)
         0,           0,              0,              0,              0,              0,              0,           0 %(30)
         0,           0,              0,              0,              S_bar,        0,              0,           0 %(29)
         0,           0,              0,              0,              0,              0,             -1,           0 %(23)
         0,           0,              0,              0,              0,              0,             -1,           0 %(24)
         0,           0,              0,              0,              0,              0,              0,        F_bar  %(13)
         0,           0,              0,              0,              0,              0,              0,  -ksi*F_bar   %(15)
         0,           0,              0,              0,              0,              0,              0,         0  %(14)
         0,           0,              0,              0,              0,              0,              0,         0  %(10)
         0,           0,              0,              0,              0,              0,              0,         0  %(25)
         0,           0,              0,              0,              0,              0,              0,         0  %(27)
         0,           0,              0,              0,              0,              0,              0,         0]; %(26)


% for k(t-1)        l(t-1)         m(t-1)    R(t-1)     S(t-1)          x2(t-1)     PL(t-1)   F(t-1)
BB = [-(1-delta)*K_bar, 0,  0,            0,              0,              0,              0,         0   %(3)
         0,           0,              0,              0,              0,              0,              0,         0   %(4)
         0,           0,              0,              0,              0,              0,              0,         0   %(5)
         0,   -(R_bar*L_bar)/pi_bar,  0, 0,             0,              0,              0,         0   %(7)
         0,           0,              0,              0,              0,              0,              0,         0   %(9)
         0, -(gamma1*L_bar+gamma2*L_bar/(L_bar-M_bar)), gamma2*M_bar/(L_bar-M_bar), -gamma2/(R_bar-1), 0, 0, 0,    0   %(11)
         0,          0,              0,             -alpha_r,    0,              0,              0,         0   %(12)
      theta,         0,              0,              0,              0,              0,              0,         0   %(17)
    (theta-1),       0,              0,              0,              0,              0,              0,         0   %(18)
         0,          0,              0,              0,              0,              0,              0,         0   %(16)
         0,          0,              0,              0,              0,              0,              0,         0   %(22)
         0,          0,              0,              0,              0,              0,              0,         0   %(19)
      -theta,        0,              0,              0,              0,              0,              0,         0   %(28)
         0,          0,              0,              0,              0,              0,              0,         0   %(30)
```

```
     0,       0,        0,        0, -alpha*pi_bar^eta*S_bar,    0,   0,    0  %(29)
     0,       0,        0,        0,        0,        0,        0,      0  %(23)
     0,       0,        0,        0,        0,        0,  alpha/pi_bar,  0  %(24)
     0,       0,        0,        0,        0,        0,  0,  -R_for*F_bar %(13)
     0,       0,        0,        0,        0,        0,        0,      0  %(15)
     0,       0,        0,        0,        0,        0,        0,      0  %(14)
     0,       0,        0,        0,        0,        0,        0,      0  %(10)
     0,       0,        0,        0,        0,        0,        0,      0  %(25)
     0,       0,        0,        0,        0,        0,        0,      0  %(27)
     0,       0,        0,        0,        0,        0,        0,      0]; %(26)


% for  lamda(t)   C(t)       H(t)      tau(t)      tau_l(t)      u(t)         I(t)
CC1 = [0,         0,          0,          0,          0,          0,        -I_bar   %(3)
       1,   sigma, gamma*(1-sigma)*H_bar/(1-H_bar), 0,  0,   0,      0  %(4)
       0,         1,          H_bar/(1-H_bar),   0,        0,   0,          0  %(5)
       0,         0,          0,          R_bar*tau_bar,  0,   0,          0  %(7)
       0,         0,          0,     tau_bar,      -tau_l_bar,  0,          0  %(9)
       0,         0,          0,        tau_bar,      0,          0,          0  %(11)
       0,         0,          0,          0,          0,          0,          0  %(12)
       0,         0,          -theta,     0,          0,          0,          0  %(17)
       0,         0,          1-theta,    0,          0,          -1,         0  %(18)
       0,         0,          -1,         0,          0,          0,          0  %(16)
       0,         0,          0,          0,          0,          0,          0  %(22)
       0,         0,          0,          0,          0,          0,          0  %(19)
       0,         0,          -(1-theta), 0,          0,          0,          0  %(28)
       0,         -C_bar,       0,          0,          0,          0,     -I_bar   %(30)
       0,         0,          0,          0,          0,          0,          0  %(29)
       0,         0,          0,          0,          0,          0,          0  %(23)
       0,         0,          0,          0,          0,          0,          0  %(24)
       0,         0,          0,          0,          0,          0,          0  %(13)
       0,         0,          0,          0,          0,          0,          0  %(15)
       0,         0,          0,          0,          0,          0,          0  %(14)
       0,         0,          0,          -tau_bar,   0,          0,          0  %(10)
       0,         0,          0,          0,          0,          0,          0  %(25)
       0,         0,          0,          0,          0,          0,          0  %(27)
       0,         0,          0,          0,          0,          0,          0]; %(26)

% for Pi(t)       y(t)        mc(t)      w(t)        p(t)        x1(t)      AM(t)
CC2 = [0,         0,          0,          0,          0,          0,          0  %(3)
      0,          0,          0,          0,          0,          0,          0  %(4)
      0,          0,          0,          -1,         0,          0,          0  %(5)
 R_bar*L_bar/pi_bar-E_bar*div_o_bar/pi_bar,0,  0,   0,  0,  0,          0  %(7)
     0, -tau_d_bar*Y_bar,  0,         0,          0,          0,          0  %(9)
```

```
  gamma2-E_bar*div_o_bar/pi_bar, 0, 0,  0,    0,          0,            0   %(11)
 -alpha_pi,    -alpha_y,          0,            0,            0,   0,            0   %(12)
     0,          0,             1,            -1,            0,            0,            0   %(17)
     0,          0,             1,             0,            0,            0,            0   %(18)
     0,          0,             0,            -1,            0,            0,            0   %(16)
  alpha*(pi_bar^(-1+eta))*(-1+eta), 0, 0, 0, (1-alpha)*(P_bar^(1-eta))*(1-eta),   0,   0   %(22)
     0,          0,             0,             0,            0,            1,            0   %(19)
     0,          1,             0,             0,            0,            0,            0   %(28)
     0,          Y_bar,          0,             0,            0,            0,            0   %(30)
-alpha*(pi_bar^eta)*S_bar*eta,   0, 0,      0, (1-alpha)*(P_bar^(-eta))*(eta),     0,   0   %(29)
     0,          0,             1,             0,            0,            0,            1   %(23)
-(alpha/pi_bar-alpha*pi_bar^(eta-1))/(1-alpha*pi_bar^(eta-1)), 0, 0, 0, 0,         0,   0   %(24)
     0,          0,             0,             0,            0,            0,            0   %(13)
     0,          0,             0,             0,            0,            0,            0   %(15)
     0,          0,             0,             0,            0,            0,            0   %(14)
     0,          0,             0,             0,            0,            0,            0   %(10)
     0,          0,             0,             0,            0,            0,            0   %(25)
     0,          0,             0,             0,            0,            0,            0   %(27)
     -1,         0,             0,             0,            0,            0,            0]; %(26)

% for rev*_oil(t)  div*_oil (t)  Taxes(all)(t)   CA(t)   KA(t)   E'(t)
CC3 = [0,              0,              0,            0,         0,            0              %(3)
          0,              0,              0,            0,         0,            0              %(4)
          0,              0,              0,            0,         0,            0              %(5)
          0,   E_bar*div_o_bar/pi_bar, 0,     0,         0,      E_bar*div_o_bar/pi_bar  %(7)
          0,              0,              0,            0,         0,            0              %(9)
          0,   E_bar*div_o_bar/pi_bar, 0,     0,         0,      E_bar*div_o_bar/pi_bar  %(11)
          0,              0,              0,            0,         0,            0              %(12)
          0,              0,              0,            0,         0,            0              %(17)
          0,              0,              0,            0,         0,            0              %(18)
          0,              0,              0,            0,         0,            0              %(16)
          0,              0,              0,            0,         0,            0              %(22)
          0,              0,              0,            0,         0,            0              %(19)
          0,              0,              0,            0,         0,            0              %(28)
          0,              0,              0,            0,         0,            0              %(30)
          0,              0,              0,            0,         0,            0              %(29)
          0,              0,              0,            0,         0,            0              %(23)
          0,              0,              0,            0,         0,            0              %(24)
  -rev_o_bar,   div_o_bar,          0,            0,         0,            0              %(13)
          0,      div_o_bar,          0,            0,         0,            0              %(15)
   rev_o_bar,           0,              0,            0,         0,            0              %(14)
          0,              0,            T_bar,        0,         0,            0              %(10)
          0,              0,              0,        CA_bar,   KA_bar,   0              %(25)
          0,              0,              0,            CA_bar,     0,         0              %(27)
```

```
        0,          0,          0,          0,          0,          1];        %(26)


CC = [CC1, CC2, CC3];

% for G(t)     Z(t)    o(t)    p(t)   Im(t)
DD = [0,        0,      0,      0,      0  %(3)
      0,        0,      0,      0,      0  %(4)
      0,        0,      0,      0,      0  %(5)
   -R_bar*G_bar,  0,  0,      0,      0  %(7)
      0,        0,      0,      0,      0  %(9)
  -gamma2*G_bar, 0, 0,      0,      0  %(11)
      0,        0,      0,      0,      0  %(12)
      0,        1,      0,      0,      0  %(17)
      0,        1,      0,      0,      0  %(18)
      0,        0,      0,      0,      0  %(16)
      0,        0,      0,      0,      0  %(22)
      0,        0,      0,      0,      0  %(19)
      0,       -1,      0,      0,      0  %(28)
   -G_bar,      0,   -P_bar_o_bar, -P_bar_o_bar, Im_bar  %(30)
      0,        0,      0,      0,      0  %(29)
      0,        0,      0,      0,      0  %(23)
      0,        0,      0,      0,      0  %(24)
      0,        0,      0,      0,      0  %(13)
      0,        0,      0,      0,      0  %(15)
      0,        0, -(1-lambda_o)*P_bar_o_bar-tau_o_bar*lambda_o*P_bar_o_bar, -(1-lambda_o)*P_bar_o_bar-tau_o_bar*lambda_o*P_bar_o_bar,    0    %(14)
      0,        0,  -tau_o_bar*lambda_o*P_bar_o_bar, -tau_o_bar*lambda_o*P_bar_o_bar,   0  %(10)
      0,        0,      0,      0,      0  %(25)
      0,        0, -P_bar_o_bar,  -P_bar_o_bar,    Im_bar  %(27)
      0,        0,      0,      0,      0];  %(26)


% for k(t+1)  l(t+1)     m(t+1)     R(t+1)      S(t+1)     x2(t+1)   PL(t+1)  F(t+1)
FF = [0,        0,          0,          0,          0,          0,          0,      0   %(6)
      0,        0,          0,          0,          0,          0,          0,      0   %(8)
      0,        0,          0,          0,          0,          0,          0,      0   %(20)
      0,        0,          0,          0,    0, -alpha*betta*pi_bar^(eta-1)*X_2_bar, 0, 0]; %(21)


% for k(t)       l(t)       m(t)         R(t)         S(t)          x2(t)     PL(t)    F(t)
GG = [0,         0,          0,           0,           0,            0,          0,      0   %(6)
      0,         0,          0,          -1,           0,            0,          0,      0   %(8)
      0,         0,          0,           0,           0,            0,          0,      0   %(20)
```

```
      0,          0,           0,           0,           0,            X_2_bar,     0,      0]; %(21)


% for k(t-1)    l(t-1)      m(t-1)        R(t-1)     S(t-1)       x2(t-1)    PL(t-1)  F(t-1)
HH = [0,          0,           0,           0,           0,            0,          0,      0   %(6)
         0,          0,           0,           0,           0,            0,          0,      0   %(8)
         0,          0,           0,           0,           0,            0,          0,      0   %(20)
         0,          0,           0,           0,           0,            0,          0,      0]; %(21)


% for lamda(t+1)  c(t+1)  h(t+1)    tau(t+1)     tau_l(t+1)     u(t+1)         i(t+1)
JJ1= [-1,              0,         0, 0, 0, -(1-tau_d_bar)*U_bar/(U_bar-tau_d_bar*U_bar+1-delta), 0   %(6)
        -1,              0,         0,            0,           0,              0,               0   %(8)
     -alpha*betta*pi_bar^eta*X_1_bar,  0, 0,    0,  0,              0,               0   %(20)
     -alpha*betta*pi_bar^(eta-1)*X_2_bar, 0, 0,    0,   0,          0,               0]; %(21)

% for Pi(t+1)      y(t+1)   mc(t+1)    w(t+1)      p(t+1)      x1(t+1)       AM(t+1)
JJ2= [0,               0,           0,            0,            0,            0,           0   %(6)
        1,               0,           0,            0,            0,            0,           0   %(8)
-alpha*betta*pi_bar^eta*X_1_bar*eta,0,0,0,-alpha*betta*pi_bar^eta*X_1_bar*(1+eta),-alpha*betta*pi_bar^eta*X_1_bar,0 %(20)
-alpha*betta*pi_bar^(eta-1)*X_2_bar*(eta-1),0, 0,   0, -alpha*betta*pi_bar^(eta-1)*X_2_bar*eta, 0, 0]; %(21)

% for rev*_oil(t+1) div*_oil(t+1) Taxes(t+1)  CA(t+1)   KA(t+1)    E'(t+1)
JJ3= [0,                0,               0,               0,            0,               0    %(6)
        0,                0,               0,               0,            0,               0    %(8)
        0,                0,               0,               0,            0,               0    %(20)
        0,                0,               0,               0,            0,               0];   %(21)

JJ = [JJ1, JJ2, JJ3];


% for  lamda(t)      C(t)       H(t)        tau(t)        tau_l(t)     u(t)          I(t)
KK1 = [1,              0,          0,            0,            0,            0,            0    %(6)
           1,              0,          0,            0,            0,            0,            0    %(8)
      alpha*betta*(pi_bar^eta)*X_1_bar, 0,      0, 0,  0,            0,            0    %(20)
      alpha*betta*(pi_bar^(eta-1))*X_2_bar, 0,  0, 0,   0,         0,            0];  %(21)

% for Pi(t)        y(t)          mc(t)          w(t)          p(t)        x1(t)       AM(t)
KK2 = [0,          0,             0,               0,            0,            0,            0    %(6)
           0,          0,             0,               0,            0,            0,            0    %(8)
           0, -(P_bar^(-1-eta))*(Y_bar-P_bar_o_bar)*MC_bar*Y_bar/(Y_bar-P_bar_o_bar), -(P_bar^(-1-eta))*(Y_bar-P_bar_o_bar)*MC_bar, 0, -(P_bar^(-1-eta))*(Y_bar-P_bar_o_bar)*MC_bar*(-1-
eta)+alpha*betta*(pi_bar^eta)*X_1_bar*(1+eta), X_1_bar, 0 %(20)
          0,  -(P_bar^(-eta))*(Y_bar-P_bar_o_bar)*Y_bar/(Y_bar-P_bar_o_bar),   0, 0, (P_bar^(-eta))*(Y_bar-P_bar_o_bar)*eta+alpha*betta*(pi_bar^(eta-1))*X_2_bar*(eta), 0, 0];  %(21)
```

```
 % for rev*_oil(t)   div*_oil(t)   Taxes(t)   CA(t)    KA(t)              E'(t)
KK3= [0,                0,             0,             0,            0,                0   %(6)
          0,                0,             0,             0,            0,                0   %(8)
          0,                0,             0,             0,            0,                0   %(20)
          0,                0,             0,             0,            0,                0]; %(21)

KK=[KK1, KK2, KK3];

% for G(t+1) Z(t+1) O(t+1)   p_O(t+1)   Im(t+1)
LL=[ 0,       0,         0,            0,           0       %(6)
       0,       0,         0,            0,           0       %(8)
       0,       0,         0,            0,           0       %(20)
       0,       0,         0,            0,           0];     %(21)

% for G(t)   Z(t)      O(t)      p_O(t)       Im(t)
 MM=[0,    0,         0,            0,           0       %(6)
         0,    0,         0,            0,           0       %(8)
      0,     0,  -(P_bar^(-1-eta))*(Y_bar-P_bar_o_bar)*MC_bar*(-P_bar_o_bar)/(Y_bar-P_bar_o_bar),  -(P_bar^(-1-eta))*(Y_bar-P_bar_o_bar)*MC_bar*(-P_bar_o_bar)/(Y_bar-P_bar_o_bar),  0       %(20)
         0,     0,  -(P_bar^(-eta))*(Y_bar-P_bar_o_bar)*(-P_bar_o_bar)/(Y_bar-P_bar_o_bar), -(P_bar^(-eta))*(Y_bar-P_bar_o_bar)*(-P_bar_o_bar)/(Y_bar-P_bar_o_bar),  0];     %(21)

 NN=[rho_g,     0,      0,          0,            0
         0,        rho_z,  0,          0,            0
         0,         0,  rho_o,         0,            0
         0,         0,       0,         rho_p,     0
         0,         0,       0,           0,        rho_Im];

 Sigma = [sigma_e_g,    0,          0,     0,      0
              0,      sigma_e_z,       0,     0,      0
              0,        0,      sigma_e_o,       0,     0
              0,        0,          0,      sigma_e_p,  0
              0,        0,          0,     0,    sigma_e_Im];


% Setting the options:
[l_equ,m_states] = size(AA);
[l_equ,n_endog ] = size(CC);
[l_equ,k_exog  ] = size(DD);


PERIOD     = 4;  % number of periods per year, i.e. 12 for monthly, 4 for quarterly
GNP_INDEX  = 17; % Index of output among the variables selected for HP filter
IMP_SELECT = [8]; % a vector containing the indices of the variables to be plotted
HORIZON    = 15; % number of quarters for impulse responses
DO_SIMUL   = 0; % Calculates simulations
```

```
SIM_LENGTH = 150;
DO_MOMENTS = 0; % Calculates moments based on frequency-domain methods
HP_SELECT  = 1:(m_states+n_endog+k_exog); % Selecting the variables for the HP Filter calcs.
DO_COLOR_PRINT = 1;

% Starting the calculations:
do_it;
```

Appendix 4a. MATLAB code for searching 3 feedback coefficients

```
shock=3
shocknumber=33*shock+8;
alpha_y = 0;
alpha_pi = 0;
alpha_r = 0;
alpha_pi_arr = -3:0.5:3;
alpha_y_arr = -3:0.5:3;
alpha_r_arr = -1:0.2:1;
len_pi = length(alpha_pi_arr);
len_y  = length(alpha_y_arr);
len_r  = length(alpha_r_arr);
results = zeros(len_pi,len_y,len_r);
for i_pi = 1 : len_pi;
    for i_y = 1 : len_y;
        for i_r= 1 : len_r;
            alpha_pi = alpha_pi_arr(i_pi);
            alpha_y  = alpha_y_arr(i_y);
            alpha_r  = alpha_r_arr(i_r);
            Master_thesis_major_program
            results(i_pi,i_y,i_r)=Resp_mat(shocknumber,5);
        end;
    end
end;
```

Appendix 4b. MATLAB code for searching 2 feedback coefficients

```
shock=3
shocknumber=33*shock+8;
alpha_y = 0;
alpha_pi = 0;
alpha_pi_arr = -3:0.2:3;
alpha_y_arr = -3:0.2:3;
len_pi = length(alpha_pi_arr);
len_y  = length(alpha_y_arr);
results = zeros(len_y,len_pi);
for i_pi = 1 : len_pi;
   for i_y = 1 : len_y;
      alpha_pi = alpha_pi_arr(i_pi);
      alpha_y  = alpha_y_arr(i_y);
      Master_thesis_major_program
      results(i_y,i_pi)=Resp_mat(shocknumber,5);
   end;
end

surf(alpha_pi_arr,alpha_y_arr,results);
xlabel('\alpha_\pi');
ylabel('\alpha_y');
```