Centre for
Economic
and Financial
Research
at
New Economic
School

May 2007

Monetary Policy in an Economy Sick with Dutch Disease

Kirill Sosunov
Oleg Zamulin

Working Paper No 101

CEFIR / NES Working Paper series

Monetary Policy in an Economy Sick with Dutch Disease

Kirill Sosunov, Oleg Zamulin *

May 3, 2007

Abstract

The paper studies monetary policy in an economy, in which the manufacturing sector is ousted completely by the presence of a large natural resource industry. Thus, the economy produces only non-tradable goods, which can complement or substitute imported goods, and the primary shock to the economy comes from the fluctuations in the world price of the exported commodity. A model of such an economy is calibrated using parameters relevant for Russia, which is an example of an economy sick with Dutch Disease, and several conventional policy rules are considered. It is shown that in absence of a well-functioning fiscal stabilization fund, it may be optimal for monetary authorities to respond to the real exchange rate, as the Bank of Russia allegedly does, using purchases of foreign reserves as the policy instrument. The logic of these actions is to replace the absent fiscal stabilization policy. In case monetary policy is conducted using an interest rate instrument, there should be no reaction to the real exchange rate and only slight one - to inflation.

Keywords: Dutch disease, Monetary Policy, Russia.
JEL classification: E52, F4

*Sosunov: Higher School of Economics, Moscow; Zamulin: New Economic School, Moscow. The research has been supported by the New Economic School Research Center. The authors thank Stephen Cecchetti, as well as seminar participants at NES/CEFIR, Stockholm School of Economics, the Institute for International Economic Studies, the Norgesbank, and the Riksbank research departments for valuable comments and suggestions. The authors can be contacted at Nakhimovskiy prospekt, 47, Office 1721, Moscow 117418, Russia, or at ksosunov@nes.ru and ozamulin@nes.ru.

1 Introduction

The "Dutch disease" has been a subject of great interest since around early 1980s (Bruno and Sachs 1982, Gelb 1988). In an economy which suffers from such a problem, the industrial sector, which can potentially compete with imports, effectively becomes ousted, as, for example, in the model of Krugman (1987). The economy reduces to two sectors: the natural resource exporting sector and a domestic service sector. All tradable goods, on the other hand, are purchased in the international markets in exchange for the raw material export revenues. Furthermore, the non-standard situation is that the domestic production of services is highly likely to be complementary, not substitutable, to imported goods.

This paper addresses the observation that countries sick with the Dutch disease face a non-standard monetary policy dilemma. A unique feature is that the primary exogenous shocks faced by the the central banks in these countries are shocks to the price of exported commodity (usually oil or gas), which can be considered supply shocks on the one hand (households can afford more tradable goods without extra work), and demand shocks on the other hand (demand for domestically-produced non-tradable goods and services is affected by the inflow of "petrodollars"). Most of the domestically produced goods are complementary to the imported tradables, and improvements of the terms of trade raise the relative price of domestic goods, leading to a real appreciation. Hence, movements in the real exchange rate, which result from the fluctuations in the international price of the exported commodities, signal not so much the degree of competitiveness of the domestic goods, but rather the level of the aggregate economic activity, which is highly dependent on the international markets. Therefore, in spite of the lack of a big import-competing sector, the real exchange rate can still be a good indicator for the monetary authorities.

Another important feature is that countries vulnerable to terms of trade shocks frequently adhere to international reserve management as an important monetary policy tool (Aizenman 2006). Indeed, given the poorly developed financial and money markets in such countries, standard policy tools, such as short-term interest rates, cannot be used. What is less understood, however, is that purchases of foreign reserves is not just a monetary instrument – it is a fiscal instrument as well, in the sense that by purchasing foreign exchange, a central bank removes resources, which could be spent on imports. In this way, the central bank effectively taxes away a part of the income when income is excessive or makes a transfer to the economy at the time when terms of trade worsen and income falls. To the extent that financial market are poorly developed, consumers cannot always borrow from abroad to substitute for this removal of resources. This tax is a standard inflation tax, and therefore, it comes with a cost.

Russia is a good example of a country that seems to be stuck in such a situation. Both the statements of the Russian central bankers and empirical evidence (Esanov, Merkl and de Souza 2005, Vdovichenko and Voronina 2004) suggest that the Bank of Russia is choosing between inflation and the real exchange rate (RER), instead of utilizing the more standard inflation-output trade-off.[1].

[1] At the same time, Calvo, Reinhart and Vegh (1995) show that the real exchange rate is a variable of interest to

Furthermore, these papers also find that the policy instrument of the Bank of Russia is probably the international reserves management. Hence, we will use the Russian case as the stimulating example.

In Section 2 of this paper we build a simple model of a country sick with Dutch disease and calibrate it using parameters relevant for the Russian economy. We then simulate the model economy under several monetary policy rules, and demonstrate that the rule similar to that used by the Bank of Russia (response to inflation and the real exchange rate) can help achieve lower volatility of most real variables, most notably non-oil output and inflation.

Then, in Section 3 we discuss several important extensions. We first introduce an import-competing manufacturing sector to the model, and demonstrate that the results are largely unchanged. We then show that the optimal rule will change if the dominant shocks are assumed to be to money demand. In such a case, inflation targeting is a superior strategy. We then demonstrate that the monetary authority would not need to heed the real exchange rate if it could use a nominal interest rate as its policy instrument — reacting to inflation would suffice. However, usage of an interest rate does not help reduce the volatility of inflation and output. Therefore, foreign reserve management may be useful even when financial markets are developed and other policy tools are available. Finally, we argue that a stabilizing monetary policy would not be necessary if a perfect fiscal stabilization fund were available, which would tax away all of the windfall export earnings at the time of high export prices and use them at the time of low export prices.

In Section 4 we briefly analyze some recent Russian experience in light of this model, and then conclude in Section 5.

2 The Model

The model presented here is highly stylized, and is constructed with the Russian economy structure in mind. The model suggests that the only produced good in the economy is a composite of imperfectly substitutable nontradables, whose prices are sticky. The economy also has a constant endowment of a natural resource, which is sold at the stochastic world price in the international market, in exchange for tradable goods. Only a fraction of consumers are allowed to smooth their consumption and therefore the current account behavior depends entirely on these consumers - others follow rule-of-thumb behavior, and consume their current labor income.

The assumption of no final goods exporting sector may seem extreme, but we argue that this assumption is not overly unrealistic. Thus, well over 80 per cent of all Russian exports consist of natural resources, mostly oil, gas, and metals. Of course, these sectors cannot be considered pure endowment, since they employ a sizable part of the labor force, and, arguably, their output itself depends on the world prices of the resources. However, we posit that as long as extraction is not elastic with respect to short run fluctuations in the world commodity prices, and labor is

many developing countries, not necessarily those that export raw materials. Also, see Uribe (2003), who shows that policy of RER targeting can lead to instability.

not highly mobile across sectors, endowment is a reasonable approximation of the natural resource sector. Most importantly, production in the natural resource sector is unlikely to be very responsive to monetary policy. Finally, modeling the resource export sector as endowment is the easiest way to generate fluctuations in the resource rent received by the country at the time of high commodity prices, to which the monetary authority should respond.

The rule-of-thumb Keynesian consumption behavior can be justified by borrowing constraints, extreme precautionary savings, or short planning horizon. The modeling of such behavior is borrowed from Gali, Lopez-Salido and Voiles (2004), who demonstrate that the monetary policy rules can be very different in the case when consumers behave according to a rule-of-thumb, rather than purely according to life-cycle considerations. Even in developed economies, such as the USA, evidence suggests that only about a half of households are permanent income consumers (Campbell and Mankiw 1989), and this share is probably lower in countries with less developed financial markets and higher risks. Borrowing constraints and precautionary savings, as well as lack of trust for all standard savings instruments, must dictate that consumers try to spend all of their current income. It is easy to see in the statistics that imports in Russia grow very strongly at times of high oil prices, which contradicts pure consumption smoothing. At the same time, capital flows are also there. Therefore, it is likely that both types of consumer behavior is present in the Russian economy.

2.1 Setup

Consumer behavior is modeled separately for the optimizing agents and for the rule-of-thumb consumers, as in Gali et al. (2004). The optimizing agents, whose share in the economy is given by λ, choose the optimal path for their holdings of international assets B_t. The value function $V(B_t)$ is defined through recursive utility maximization

$$V_t(B_t) = \max_{C^o_{M,t}, C^o_{N,t}, L_t} \{U(C^o_t, L^o_t) + \beta(B_t) E_t V_{t+1}(B_{t+1})\}, \tag{1}$$

where C_M is consumption of the imported manufactured good, C_N is the composite of nontradable goods (services), L is the labor supply, and

$$C^i \equiv \left[(1-\alpha)^{\frac{1}{\eta}} (C^i_N)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C^i_M)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

is a CES aggregate of the two types of goods in the utility function. The superscript "o" denotes that these variables are relevant for the optimizing agents, while the rule-of-thumb consumer will be labeled by "r". The superscript "i" means that the equation works for both types of consumers, and the aggregate variables do not have superscripts at all. It is best to think about C_M as the manufactured good, although in this baseline case of the model this good can only be imported. In an extension in Section 3.1, C_M will be re-written as an aggregate of domestic and foreign goods, which will be imperfect substitutes of each other.

The felicity function is taken as

$$U(C_t^i, L_t^i) = \ln C_t^i - v(L_t^i). \tag{2}$$

This maximization implies an endogenous rate of time preferences $\beta(B_t)$ (Uzawa 1968, Obstfeld 1981, Mendoza 1991). This is one of two standard ways to ensure a stationary steady state in an open economy model, although usually the rate of time preference is made endogenous to consumption, rather than assets. An alternative, frequently used in papers devoted both to business cycle and monetary policy analysis is introduction of complete financial markets (Chari, Kehoe and McGrattan 2002, Gali and Monacelli 2005, Parrado 2004). We believe that the assumption of complete markets is much less realistic than endogenous rate of time preferences. First, complete markets imply extreme development of financial markets, which is hardly in line with the assumption of rule-of-thumb behavior among a larger fraction of consumers. Second, complete markets shut down the current account, which is a great cost to incur. Of course, endogenous rate of time preferences is also a highly artificial trick, but the assumption that as consumers become wealthier they become less patient (implying $\beta'(B_t) < 0$) seems not to be out of line. An informal anecdote in favor of such an assumption could be the observation that once the Ministry of Finance of Russia accumulated a large stabilization fund by 2005, the public pressure to spend this money on large national projects intensified. Yet another alternative would be to assume that the interest rate faced by the economy depends negatively on the net assets of the economy; the more in debt the country is, the higher world interest rate it faces. Such a specification would yield exact same equations in log-linear form as the endogenous rate of time preference.

The budget constraint for the permanent income consumers is standard:

$$B_{t+1} = (1+r)B_t + W_t L_t^o + P_t^{oil} X - R_t + \Pi_t - C_{M,t}^o - \frac{P_{N,t}}{P_{M,t}} C_{N,t}^o, \tag{3}$$

where r is the exogenous world real interest rate, W_t is the real wage in terms of tradables, P_t^{oil} is the world price of oil, which will later be assigned an AR(1) process in logs, X is the endowment of oil, R_t is the reserves purchased by the central bank, Π_t is profit from ownership of firms, while $P_{M,t}, P_{N,t}$ are prices of imports and domestic goods.

The problem of the optimizing consumer is solved by inserting the constraint (3) into the maximization problem (1), performing the maximization and applying the standard envelope condition $V'(B_t) = U'(C_{M,t})$. The first-order conditions are

$$W \partial U / \partial C_{M,t}^o = v'(L_t^o), \tag{4}$$

$$\frac{C_{N,t}^o}{C_{M,t}^o} = \frac{1-\alpha}{\alpha} \left(\frac{P_{N,t}}{P_{M,t}} \right)^{-\eta}, \tag{5}$$

$$\partial U / \partial C_{M_t}^o = (1+r)\beta(B_t) E_t \partial U / \partial C_{M,t+1}^o. \tag{6}$$

Here, the first equation is labor supply. The second equation is the intratemporal choice between two types of consumption goods. The Euler equation (6) shows how endogenous rate of time preference leads to a unique steady state. If consumption is constant, then the equation reduces to $(1+r)\beta(\bar{B}) = 1$, where bar denotes steady state value. The steady state value of B_t is thus pinned down by the function for $\beta(.)$. It is perhaps most natural to take $\bar{B} = 0$, although in principle any other value is just as good. If we assume that $\beta'(B_t) < 0$, then, whenever the assets B_t fall below the steady state level (the economy goes into debt), $\beta(B_t)$ increases and consumers become more patient. They start to consume less, and debt goes down. Correspondingly, when B_t increases above the steady state level, so that the economy is a net lender, then $\beta(B_t)$ falls, consumers become impatient and spend the extra assets they have, again driving B_t back to the steady state level. Thus, condition $\beta'(B_t) < 0$ makes the steady state not only unique, but also stationary.

Now let us turn towards rule-of-thumb consumers. All of the intratemporal conditions are the same for them (choice between the two consumption goods and leisure in each period). The only difference is that they simply maximize one-period felicity (2) subject to the constraint that their consumption must equal labor earnings plus the oil transfers in that period and the profits from firm ownership:

$$P_{M,t}C^r_{M,t} + P_{N,t}C^r_{N,t} = P_{M,t}(W_t L^r_t + P^{oil}_t X - R_t + \Pi_t),$$

and the constraint that their consumption of imports is simply equal to their share of the oil revenues:

$$C^r_{M,t} = P^{oil}_t X - R_t.$$

Note that together these two constraints imply that the non-tradable consumption equals labor earnings and profits.

Individual demand for both types of consumption in each period is given by expressions

$$C^i_N = (1-\alpha)\left(\frac{P_N}{P}\right)^{-\eta} C^i, \tag{7}$$

$$C^i_M = \alpha\left(\frac{P_M}{P}\right)^{-\eta} C^i, \tag{8}$$

where $P \equiv \left[(1-\alpha)P_N^{1-\eta} + \alpha P_M^{1-\eta}\right]^{\frac{1}{1-\eta}}$ is the CPI.

Aggregation implies that the overall levels of consumption and labor in the economy equal to the weighted average of the two types, with weights λ and $(1-\lambda)$:

$$C_M = \lambda C^o_M + (1-\lambda)C^r_M, \tag{9}$$

$$C_N = \lambda C^o_N + (1-\lambda)C^r_N, \tag{10}$$

$$L = \lambda L^o + (1-\lambda)L^r. \tag{11}$$

Production of nontradables is given by

$$C_N = L^\gamma/\gamma, \tag{12}$$

where we implicitly impose a condition that production and consumption of nontradables must be equal. In further analysis, we will often take $\gamma = 1$ for simplicity, which gives us constant returns to scale technology.

Monetary policy, in terms of accumulation of reserves, consists of taking out a fraction μ_t of all export revenues in each period:

$$R_t = \mu_t P_{oil,t} X, \tag{13}$$

where $P_{oil,t}$ is the world price of the natural resource (oil), X is the constant endowment of oil, and R_t is the amount of foreign reserves purchased by the central bank. In further analysis, we normalize the endowment of exports to unity, $X^* = 1$.

Money demand is given by a simple consumption-based quantity equation

$$M_t = P_{M,t} C_{M,t} + P_{N,t} C_{N,t}, \tag{14}$$

and money is introduced into the economy via purchases of foreign exchange:

$$\Delta M_t = R_t P_{M,t}. \tag{15}$$

This set-up completes the model, with exception of price behavior of nontradables, which will be introduced later as in Calvo (1983).

2.2 Linearization around the steady state

Since the model is characterized by a unique steady state, it is possible to derive a system of linearized equations, which approximate the behavior close to the steady state. It makes sense to make the following normalizations, in order to simplify the solution: $\bar{B}, \bar{R} = 0, \frac{\bar{P}_N}{\bar{P}_M} = 1, \bar{C}_M = 1, X = 1$. Then we arrive to the following system:

1. Dynamic equations

The material balance condition

$$B_{t+1} = (1+r)\left[B_t + (1-\mu_t) P_t^{oil} X - C_{M,t}\right]$$

is linearized trivially to

$$b_{t+1} = (1+r)[b_t + p_t^{oil} - \mu_t - c_{M,t}] \tag{16}$$

Here, small letters denote log deviations of the corresponding variables from the steady state. Since $\bar{B} = 0$, the deviation of assets is defined as $b_t \equiv dB_t/\bar{C}_M$, that is, in percent to steady state export revenue.

The Euler equation (6) for optimizers is linearized to be:

$$(1-\eta)(1-\alpha)(p_{N,t} - p_{M,t}) + C^o_{M,t} = -\frac{\beta'(0)}{\beta(0)} b_t + E_t\left[(1-\eta)(1-\alpha)(p_{N,t+1} - p_{M,t+1}) + c^o_{M,t+1}\right], \tag{17}$$

where we used the upcoming equation (21) to express relative consumption through the RER.

The terms of trade are assumed to follow a persistent AR(1) process

$$p_t^{oil} = \rho p_{t-1}^{oil} + \varepsilon_t. \tag{18}$$

For now, we assume that the shocks to terms of trade ε_t are the only source of uncertainty in the economy, since the goal of this paper is to derive the optimal policy in response to such shocks.

2. Household intratemporal behaviour

Within one period, consumers maximize utility by choosing between two types of consumption and leisure. The corresponding rules are equivalent for both types of households. The labor supply is given by

$$w_t - (1 + \eta\alpha - \alpha)(p_{N,t} - p_{M,t}) - c_{N,t}^o = \kappa l_t^o, \tag{19}$$

$$w_t - (1 + \eta\alpha - \alpha)(p_{N,t} - p_{M,t}) - c_{N,t}^r = \kappa l_t^r. \tag{20}$$

The intratemporal choice between the two types of goods is given by

$$c_{N,t}^o - c_{M,t}^o = -\eta(p_N - p_M), \tag{21}$$

$$c_{N,t}^r - c_{M,t}^r = -\eta(p_N - p_M). \tag{22}$$

Finally, the rule-of-thumb consumers have their tradable consumption equal to the available resources in each period:

$$c_{M,t}^r = p_t^{oil} - \mu_t. \tag{23}$$

Non-tradable consumption is then equal to the labor income and profit from firm ownership, and the amount is already determined here by the rest of the first order condition.

The CPI (for purposes of estimating consumer price inflation) is defined as

$$p_t = (1 - \alpha)p_{N,t} + \alpha p_{M,t} \tag{24}$$

where $\alpha = \frac{P_M^* C_M^*}{P^* C^*}$ is the parameter in the utility function corresponding to the steady-state expenditure share of the imported good in consumption.

3. Aggregation

Since at the steady state $\bar{C}_N^o = \bar{C}_N^r = \bar{C}_N$, $\bar{C}_M^o = \bar{C}_M^r = \bar{C}_M$, $\bar{L}^o = \bar{L}^r = \bar{L}$, equations (9)-(11) are linearized trivially to

$$c_{M,t} = \lambda c_{M,t}^o + (1 - \lambda)c_{M,t}^r, \tag{25}$$

$$c_{N,t} = \lambda c_{N,t}^o + (1 - \lambda)c_{N,t}^r, \tag{26}$$

$$l_t = \lambda l_t^o + (1 - \lambda)l_t^r. \tag{27}$$

4. Production and pricing

Export of oil is once again defined as endowment, hence, the only production takes place in the non-tradable sector, where output is a simple function of labor supply:

$$c_{N,t} = \gamma l_t, \tag{28}$$

where $\gamma = 1$ is the degree of returns to scale. Assuming constant returns to scale in what follows, pricing is determined as in Calvo (1983) and is defined by the following system of dynamic equations:

$$p_{N,t} = \theta x_t + (1-\theta)p_{N,t-1}, \tag{29}$$

$$x_t = \theta_1(w_t + p_{M,t}) + (1-\theta_1)E_t x_{t+1}, \tag{30}$$

where θ is the share of non-tradable firms adjusting the price at time t, and $\theta_1 \equiv 1 - \beta(0)(1-\theta)$ and $\beta(0)$ is the discount factor of the price-setting firm.

5. Money market

Money supply is governed by the following rule derived from log-linearized versions of (13) and (15):

$$m_t = m_{t-1} + \alpha\mu_t. \tag{31}$$

Note that to the first-order approximation, changes in the oil price and the exchange rate do not influence money creation. This is due to the fact that in the steady state, there is no reserve accumulation and hence $\mu^* = 0$. Such a result may be worrysome, and gives rise to the question of whether first-order approximation is sufficient for the oil price, which ranged from about 10 dollars per barrel in 1998 to about 70 dollars in 2005.

The linearized quantity equation (money demand) is

$$m_t - p_t = (1-\alpha)c_{N,t} + \alpha c_{M,t} \tag{32}$$

The final equation needed to close the model is the monetary policy. We consider three types of univariate policy rules: inflation targeting $\pi_t = 0$, real exchange rate targeting $p_{N,t} - p_{M,t} = 0$, and constant money supply (no intervention) $\mu_t = 0$, as well as two hybrid rules, where the money instrument responds to inflation and the RER, or to inflation and the output gap.

2.3 Calibration of parameters

The parameters picked for the model are shown in Table 1, and are meant for the Russian case. The most important parameter is perhaps the elasticity of substitution between the domestic and imported goods η. For the benchmark value, we take $\eta = 0.67$, which means that production is complementary to imports. This parameter comes from Belomestnova (2002) and New Economic School (2005), who estimate the elasticities of demand for Russian imports with respect to the real exchange rate and income. At the same time, we also look at the hypothetical situation that domestic product is a substitute to imports. Afterall, import substitution is often named the driving force of the Russian growth after the double devaluation of the Russian ruble in 1998. Besides, this experiment can be justified by a hypothesis that the central bank cares not so much for the service sector, but rather for a however small emerging tradable goods production.

Parameter ρ is taken to equal 0.91. This number was obtained from a first-order autoregression of the real international oil price. In such regressions, the exact coefficient is very sensitive to the time period of estimation and varies between 0.90 and 0.97, but qualitative results of our paper are not sensitive to the exact choice of value within this range (and even outside it).

Table 1: Baseline parameter values.

Parameter	Description	Value
η	Elasticity of substitution between domestic and imported good	0.67 or 1.5
κ	Inverse of elasticity of labor supply w.r.t. real wage	1
γ	Labor share in production of domestic goods	1
ρ	First order autocorrelation of oil price process	0.91 p.q.
A	Share of domestic goods in total consumption	0.7
θ	Probability of price adjustment	0.25 p.q.
$\beta(0)$	Discount factor at steady state	0.97 p.a.
$\beta'(0)$	Semi-elasticity of discount factor	-0.0001

2.4 Results of simulations with one-variable rules: impulse responses

The system of equations presented above is solved using numerical methods. We present the results of simulations as impulse response functions of both types of consumption, aggregate consumption, and inflation under the three types of univariate monetary policy rules, associated with targeting of one variable. For purposes of demonstration, we show the impulse response graphs for the case when all of the consumers follow rule-of thumb behavior ($\lambda = 0$), since it is easier to see the intuition when one assumes no consumption smoothing. The impulse responses were simulated using the techniques and Matlab programs developed by Uhlig (1999) and are demonstrated in Figures 1-3.

2.4.1 No reaction policy

The results for monetary targeting (no intervention) are shown in Figure 1. Two graphs are given, demonstrating the case when the two types of goods are complements ($\eta = 0.67$) and substitutes ($\eta = 1.5$). These results demonstrate a benchmark case, and give logical results. Thus, in both cases consumption of tradables (imports) increase one-for-one with the oil price increase. Correspondingly, the amount of non-tradable production grows or falls depending on whether these goods are complementary to imports. Inflation is negative at the time of shock, as imports become cheaper in the sense that the nominal exchange rate P_M falls. Consequently, as the oil price returns to the long-run level, the nominal exchange rate gradually grows back, which means that inflation is positive, although very small. Inflation of non-tradables prices is minimal, since money supply does not change.

2.4.2 Real exchange rate targeting

Corresponding graphs for RER targeting are shown in Figure 2. Two things are immediately apparent. First, graphs for the cases of substitutable goods and complementary goods are identical. This makes sense, because with constant RER there is no relative consumption change. Likewise, we observe only two lines on the graphs, because all types of consumption respond identically. Thus, we see only responses of inflation and output. What we see is an immediate positive response of inflation: in order to bring the RER back to parity, the central bank buys reserves and issues money, which causes prices of both types of goods to start growing. At the same time, it is clear that the central bank does not buy up all of the windfall gain of "petrodollars": consumption still increases on impact.

It is noteworthy that with this type of policy *temporary* oil price shocks have a *permanent* effect on nominal variables: the central bank continues to buy up the reserves until the shock dies out, and the money supply ends up at a new, higher level. Correspondingly, prices also end up higher than at the initial steady state.

An interesting observation is that the response of consumption is non-monotonic. The intuition is easiest to see thinking about non-tradable consumption. At first, consumption jumps up fueled by an increase in the money supply, while prices remain stuck at the initial level. Further, the central bank continues to buy the reserves and adding extra money into the system, while prices still remain low. Eventually, however, the oil price shock dies out, and each period smaller and smaller amount of extra money is added, while prices continue to rise. At some point the growth in money supply falls below the growth in prices, and consumption starts to fall.

2.4.3 Inflation targeting

Next, we show the graphs for inflation targeting in Figure 3. These graphs vividly show that in response to an oil shock, both types of consumption jump up. Tradable consumption grows for obvious reasons: there is extra export revenue. However, this increase is not proportional to the shock, since in order to prevent the cheapening of the foreign currency, the central bank adds money to the economy by buying some of the extra dollars, which could potentially be spent on imports. This extra money stimulates production of non-tradables as well, since their prices are sticky. The RER appreciates. After the increase of the money supply, prices of non-tradables want to grow, which forces the central bank to start decreasing the money supply back to fight the inflation. The resultant sales of foreign reserves temporarily increase tradable consumption even further, and to the extent that non-tradables are complementary, their production grows as well.

2.5 Hybrid rules

The rules presented above are all overly simplistic in the sense that each of them uses just one variable. At the same time, it has been acknowledged in the literature that targeting only one variable frequently leads to extreme volatility in other variables (Clarida, Gali and Gertler 1999). Hence, we now turn to the situation when the central bank follows a hybrid rule, responding simultaneously to two variables. Of particular interest are two rules: the rules allegedly followed by the Bank of Russia, which claims to respond to inflation and the real exchange rate, and the analogue of the Taylor rule with monetary base on the left-hand side.

We for now concentrate on a particular form of monetary policy rule:

$$\mu_t = -\omega_1 \pi_t + \omega_2 (p_{N,t} - p_{M,t}), \tag{33}$$

$$\mu_t = -\omega_1 \pi_t + \omega_2 c_N, \tag{34}$$

where $\omega_1 > 0$ and $\omega_2 \gtrless 0$ are some coefficients to be determined endogenously. In these two rules, monetary authority responds with a certain weight to changes in inflation, and with a certain weight - to changes either in the real exchange rate or to domestic output. The exact weights are chosen so that they minimize the loss function

$$L = Var(c_N) + Var(\pi), \tag{35}$$

that is, the sum of unconditional variance of output and inflation. Such a loss function is frequently used in the literature (Rudebusch and Svensson 1999, Williams 2003), although is not derived from an exact welfare criterion, as is also possible to do (see Woodford (2003), Chapter 6). The reason why we do not use the exact criterion is that welfare as specified by the utility function depends heavily on consumption, rather than output, and in our case, much of this consumption is imported. Instead we posit that the monetary authority cares about stability of output, for reasons that go beyond simple consumption smoothing. Thus, Aghion and Banerjee (2005) argue that output volatility hampers long-run growth, especially in countries with poorly developed financial markets.

Minimization of variance gives different values for the coefficients for different values of η and λ, but generally the coefficients are both positive and the the one in front of inflation ω_1 is much bigger in absolute value than ω_2. We now turn to comparison of the relative performance of these different rules.

2.6 Volatility of variables and discussion

Following the impulse response analysis, the next step is to take a look at the estimated standard deviations of the variables of interest under different policy rules. Table 2 shows these figures for all six of the discussed policy rules. These figures represent the exact unconditional standard deviations, derived from the VAR(1) representation of the whole system[2], with standard deviation of the shock ε_t normalized to unity. Minimization of the loss (35) was achieved by grid search for the values for ω_1 and ω_2, which minimize the objective function. The value for the loss function is shown in the last column of Table 2.

The table shows the results for two values of η, which correspond to the cases when imports are substitutable and complementary to domestic product. Likewise, to study the effect of rule-of-thumb behavior, we look at the standard situation of consumption depending completely on

[2] The formula for the second moments of the variables in a VAR(p) can be found, for example, in Hamilton (1994), pp.264-266.

permanent income ($\lambda = 1$), as well as the case when most of consumer respond to current income ($\lambda = 0.30$).

It is especially interesting to look at the standard deviations of output and inflation, since a weighted average of these variables normally enters the objective function of the monetary authority. However, we also report the volatility of imported goods consumption and the real exchange rate, since arguments can be made that these variable need to be stabilized as well. It is easy to see in the table that both tradable consumption and the real exchange rate are much more volatile overall than inflation and output.

Not surprisingly, given our conclusions from the impulse responses, money targeting gives smaller volatility of both non-tradable output and inflation than RER targeting, with baseline parameter values. In all cases, money targeting gives smaller values for the loss function. Inflation targeting comes close to money targeting, but still falls a bit behind for baseline parameter values.

Turning to the hybryd rules, the striking result is that the inflation-RER rules allegedly used by the Bank of Russia turns out to be superior in terms of overall loss for all combinations of the parameters, especially when consumers are mostly naive. In the base-case scenario ($\eta = 0.67, \lambda = 0.30$), the improvement over money targeting is achieved at the cost of higher output variability, but the benefit is significant reduction in inflation volatility. However, it should be noted that the optimal weight on the RER with this type of rule turns out to be rather small, and the optimal rule is $\mu_t = 0.12(p_{N,t} - p_{M,t}) - 2.4\pi_t$.

An important result is that the inflation-output rule turns out to be about as good, more frequently slightly worse, in spite of the fact that it is precisely inflation and output, not the RER, which appear in the loss function. Hence, the inflation-RER rules can be argued to be superior on the grounds of practical simplicity: the RER is much more easy to observe and react to than the output gap. In this sense, the RER can be regarded as a useful indicator of the overall economic activity, even in an economy, in which there is no import-competing sector.

We see that in the case when consumers follow the permanent income hypothesis, the dominance of the inflation-RER rule over the univariate ones seems to be weak. Inflation targeting and money targeting do about as well in terms of overall loss as the hybrid rule. An introduction of rule-of-thumb consumers makes the case for heeding RER much stronger in terms of overall loss. This result is quite intuitive: the case for an active stabilization policy is especially strong when consumers fail to do their consumption smoothing themselves. If they behave as perfect permanent income consumers, on the other hand, they store all of the windfall gains from temporary oil price increases abroad, without destabilizing domestic demand.

3 Extensions to the model

3.1 Import substitution sector

One criticism of the above model is the lack of any sector that competes with imports - an introduction of such a sector is standard practice in such models and seems logical. After all, an important argument in favor of stabilization of the real exchange rate is precisely the stabilization of import-competing sector. If one keeps the example of Russia in mind, it is frequently believed that the 1998 devaluation of the ruble stimulated domestic production, and thus pulled the country out of the slump.

Hence, here we extend the basic model to see how the introduction of such a sector would change the results. We proceed by assuming that what was regarded to be the manufactured import C_M is now a composite of imported foreign good C_F and a domestic imperfect substitute C_H:

$$C_M = \left[(1-\phi)^{\frac{1}{\nu}} (C_H)^{\frac{\nu-1}{\nu}} + \phi^{\frac{1}{\nu}} (C_F)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \tag{36}$$

where it is assumed that $\nu > 1$ so that the two goods are substitutes. Hence, households consume services C_N and manufactured goods C_M, produced both domestically (C_H) and abroad (C_F).

Following the paradigm that domestic exports consist solely of raw materials, it is assumed that domestic manufactured goods is non-tradable internationally, so its production equals consumption, and the production function is identical to that of C_N:

$$C_H = {L_H}^{\gamma}/\gamma,$$

where L_H is the share of labor that goes towards the manufactured good. Correspondingly, the service sector now employs only L_N, and $L = L_N + L_H$ is the total labor supply. Labor flows freely across sectors, providing for a common wage rate. The sticky price processes for the services and manufactured goods are also assumed identical and described by equations (29-30).

Such assumptions about identical cost and price adjustment structure in the two sectors greatly simplifies the model, because the price levels in the two sectors must be equal to each other. The prices at the steady state are determined by the same mark-up over the marginal cost (the wage), while between the steady states they move according to the same law of motion. Hence, $P_H = P_N$ at all times. It is then sensible to define the real exchange rate as P_N/P_F. It should be noted that since

$$P_M = \left[(1-\phi) P_H^{1-\nu} + \phi P_F^{1-\nu} \right]^{\frac{1}{1-\nu}},$$

P_N/P_M can be easily expressed via P_N/P_F. In log-linear form (now normalizing $\bar{P}_N/\bar{P}_F = 1$ at the steady state)

$$p_N - p_M = \phi(p_N - p_F).$$

Hence, all relative prices can be expressed via $p_N - p_F$.

All of the first-order conditions are derived analogously to the baseline model, and specifically, consumption of different types of goods relate to each other via expressions

$$c_N^i - c_M^i = -\eta\phi(p_N - p_F), \tag{37}$$

$$c_H^i - c_F^i = -\nu(p_N - p_F), \tag{38}$$

$$c_M^i = (1-\phi)c_H^i + \phi c_F^i. \tag{39}$$

and the material balance conditions now become:

$$b_{t+1} = (1+r)[b_t + p_t^{oil} - \mu_t - c_{M,t}], \tag{40}$$

$$c_{F,t}^r = p_t^{oil} - \mu_t. \tag{41}$$

Calibration of parameters is similar to that given in Table 1, with the exception that $\alpha = 0.5$, $\phi = 0.5$, $\eta = 0.4$, $\nu = 2$. Thus, it is assumed that manufactured goods are about half of the whole consumption aggregate and about half of the manufactured goods are foreign.

Note that the baseline model is a special limiting case of the model with the substitution sector described here. Thus, if one sets $\phi = 1$ then $C_M = C_F$ and we are back to the model we had before - the import substitution sector vanishes.

Let us now compare the results with different monetary policy rules, which are given in Table 3. In the table, output is defined as $\frac{1-\alpha}{1-\alpha\phi}c_N + \frac{\alpha(1-\phi)}{1-\alpha\phi}c_H$, where $\frac{1-\alpha}{1-\alpha\phi}$ and $\frac{\alpha(1-\phi)}{1-\alpha\phi}$ are the steady-state shares of the corresponding sectors in total production.

A remarkable observation from Table 3 is that the case for reacting to the real exchange rate is actually weakened, not strengthened, in presence of import substitution sector. Thus, losses from rigid targeting of the real exchange rate seem to be much higher in this case, while losses from any other policy seem lower than in the Table 2. The rule of reacting to both inflation and the RER seems to bring the lowest value of the loss function still, but the optimal weight on the RER is the same as before. In fact, for the baseline case with $\lambda = 0.3$ the optimal rule is $\mu_t = 0.12(p_{N,t} - p_{F,t}) - 3.0\pi_t$, whereas in the baseline model of Section 2 the optimal rule was $\mu_t = 0.12(p_{N,t} - p_{M,t}) - 2.4\pi_t$. Even though the optimal reaction to the RER is very weak, it is positive in both cases.

This result may seems striking because the presence of a substitution sector may seem to be a good reason for paying attention to the RER in the first place. However, the intuition for this result is straight-forward. The presence of two production sectors acts as a stabilizer, because a real appreciation leads to an expansion in the nontradable service sector and a contraction in the import-substituting manufacturing sector. These two effects balance each other out. However, if the monetary authorities fix the real exchange rate, then the two production sectors have to move exactly together by equations (37-39). Therefore, any shock becomes exacerbated by policy, which forces the two production sectors to either both contract or both expand, instead of counter-balancing each other.

3.2 Money demand shocks

Although oil price shocks can be regarded as the primary shock for economies heavily dependent on exports of oil, it is also interesting to consider what the optimal policy is in the case of demand shocks. Table 4 summarizes results for different policy rules in face of this kind of shocks. Here, it is assumed that a random shock is added to the money demand equation (32), and the shock also follows an AR(1) process with the root 0.91. The economy is the one with an import substitution sector, and the share of naive consumers is $\lambda = 0.3$.

From the table we see an interesting result that the winner among univariate rules seems to be inflation targeting. The inflation-RER rules effectively reduces to inflation targeting, since the optimal weight on RER is found to be zero, and the weight on inflation converges to negative infinity. Adding output in the policy rule can improve things significantly, although this results holds only in presence of an import substitution sector – without such a sector the output-inflation rule is about as good as inflation targeting. Hence, the nature of monetary shocks seems to be entirely different from oil shocks, and hence the optimality of the inflation-RER rule followed by the Bank of Russia hinges upon the economy being resource-based and being subject to volatile world prices for the raw materials the country sells.

The intuition for the optimality of inflation targeting in case of money demand shocks is the following. Consider an economy without an import substitution sector. In the case of no response to a positive money demand shock, domestic output takes a drop, according to the money demand equation. Imports, on the other hand, remain close to the initial level (since flow of "petrodollars" remains unchanged, as well as expectations of future flows). In order to make relatively lower nontradable consumption an equilibrium, the real exchange rate needs to go up, that is, the domestic currency (which is more demanded now) needs to appreciate. This happens via a fall in the nominal exchange rate, corresponding to a short period of deflation.

Thus, any rule targeting the RER, inflation, or output improve the situation, because with such a rule the central bank immediately issues extra money by buying up some international reserves. As a result, import goes down, output goes down by not as much as with no reaction, the exchange rates (both nominal and real) do not jump. In order to stabilize domestic output, it turns out to be optimal to target inflation, so that prices of domestic goods do not change as much. This result is similar to that in Parrado (2004).

Note that in this case it is not possible to offset money demand shock completely, as is common in standard models. The reason is that an increase in money supply to offset the money demand also leads to a build up of reserves with a corresponding drop in tradable goods consumption.

3.3 Stabilization fund

Another important extension to be considered is the interplay of monetary policy with fiscal policy. Specifically, one can add to this model a stabilization fund, which would accumulate export revenues at times of high oil prices, and decumulate whenever oil prices drop below a certain threshold.

In the above setting, the easiest way to introduce such a fund is simply tax 100% of all revenues above the average oil price, and return this money as transfers when oil price falls below average. Such a tax is completely neutral, because it taxes a pure resource rent. At the same time, it removes all of the stochastics coming from the oil price side, and the economy becomes identical to one with a constant price of oil. Therefore, in combination with a stabilization fund, inflation targeting may be chosen as the optimal strategy.

Note that such a policy is immune to a standard critique that fiscal policy is inappropriate for stabilization purposes due to long implementations lags. Here, stabilization is achieved automatically and the tax rate depends on the level of oil price. Such a policy to a large extent has been adopted in Norway, and is being structured in Russia currently.

A perfect stabilization fund of this kind, however, is probably infeasible in practice, at a minimum due to uncertainty about stochastic properties of oil prices. Therefore, keeping in mind the optimal monetary policy is necessary for a country in similar situation.

3.4 Interest rate based rules

So far, we have studied the optimal monetary policy when the only instrument available to monetary authorities is purchases of foreign reserves. Here we demonstrate that this policy tool may be optimal for all resource-dependent countries hit by terms of trade shocks, mostly due to the fiscal nature of the instrument — purchases of foreign reserves replace the stabilization fund when a proper stabilization fund is lacking.

To demonstrate the optimality of the international reserve management, we now consider a more conventional monetary policy instrument, namely, a nominal interest rate.

The interest rate is introduced via the following interest rate parity condition:

$$i_t = E_t p_{F,t+1} - p_{F,t}, \tag{42}$$

which says that, given constant foreign interest rate, the domestic interest rate is simply the rate of nominal depreciation. Note that a constant interest rate rule corresponds to a fixed nominal exchange rate. Equation (42) replaces equations (31) and (32) and we set $\mu = 0$ in the remaining equations.

We repeat the exercise in this paper with this interest rate as a policy tool. That is, we search for the optimal rules of the form (33) and (34). Turns out that for a wide range of parameters η, ν, λ, α, and ϕ the rule that maximizes the sum of variances of inflation and output is

$$i_t = 0.2\pi_t. \tag{43}$$

That is, it is optimal to respond only to inflation, and the coefficient on inflation is very small. The only situation, in which it is optimal to respond to the real exchange rate as well, is if the non-tradable sector of the economy is made small. This is understandable — in that case, stabilization of output is achieved by stabilization of the import-substitution sector. But even in that case, the coefficient on the RER is a small -0.1.

The most important finding, however, is that usage of the interest rate as a policy instrument leads to a higher overall loss. For the benchmark case with $\lambda = 0.30$ in the import-substitution model the loss is 0.0089. This is higher than the 0.0049 that can be achieved using the purchases of reserves (see Table 3). Hence, international reserve management can be justified as a superior policy tool even for countries with developed financial markets, in the case that these countries are suffering from the Dutch disease.

4 Relation to the Russian experience in 2005

The Bank of Russia clearly responds to the real exchange rate much more strongly than is prescribed in the above analysis. For example, the Bank has failed to meet the inflation target for 2005: the initial target of 8% was later changed to 10%, but the CPI grew by almost 11% according to the official statistics. The common explanation has been the unusually high oil prices, which forced the Central Bank to buy an unusually large amount of foreign reserves, in order to fend off the appreciation. If such behavior is optimal, this means that an optimal policy implies an increase in inflation after an oil price shock. However, the optimal rule derived above implies only a modest, hardly noticeable, response to the RER. The comparative impulse responses with the optimal rule and a rule that assigns an extra weight to the RER is given in Figure 4. The case is shown for the model with import substitution sector of Section 3.1. In the upper panel the picture, the rule is the one found is Section 2.6, which is the one that minimizes the loss. In the lower panel, the weight on the real exchanger rate is increased to 1.

One can easily see that with the optimal rule, inflation still goes down for one period following the oil shock, and then is back to around zero. The share of purchases reserves is about 0.25 of the extra shock. If one increases the weight on the RER, however, then the share of purchased reserves increases to about 0.35, and inflation rises in response to the shock by about 0.1%. GDP is clearly less stable in this case as well. The only variable that benefits from such an extra weight on the RER is the production in the import substitution sector C_H. Hence, such policy can be justified only if we think that the Bank of Russia cares specifically about the import-substitution sector, or about the RER itself, for example, due to reasons outlined in Aghion, Bacchetta, Ranciere and Rogoff (2006).

5 Conclusion

In this paper, we considered an economy sick with Dutch disease, i.e., an economy, in which all of the tradable goods are purchased from abroad in exchange for revenues from raw material export, and the primary shock to economic activity comes from the fluctuations in the terms of trade.

We have shown that in such an economy it makes sense to use international reserve management as a tool to stabilize the economy, to a great extent because this tool has a fiscal feature, in the sense that purchases of international reserves remove real resources from the economy. However, usage of this instrument makes sense only when a true fiscal stabilization fund is not available.

In case the international reserve management is used, the monetary authority should respond primarily to inflation, but also to the real exchange rate. In such countries, the real exchange rate serves not so much as a measure of the competitiveness of domestic good, but rather an indicator of the level of aggregate demand.

Using an example of Russia as a country sick with Dutch disease, we have argued that the optimal rule derived in our calibrated model is similar to the one allegedly used by the Bank of Russia, which reacts to inflation and to the real exchange rate. However, our calibration indicates that the Bank of Russia probably assigns too much weight to the real exchange rate in its policy.

References

Aghion, Philippe, Philippe Bacchetta, Romain Ranciere, and Kenneth Rogoff, "Exchange Rate Volatility and Productivity Growth: The Role of Financial Development," Working Paper 12117, National Bureau of Economic Research May 2006.

Aghion, Phillipe and Abhijit Banerjee, *Volatility and Growth*, Oxford: Oxford University Press, 2005.

Aizenman, Joshua, "International Reserve Managment and the Current Account," Working Paper 12734, National Bureau of Economic Research December 2006.

Belomestnova, Anna, "Estimation of Demand Functions for Import into Russia," 2002. NES Master's dissertation.

Bruno, Michael and Jeffrey Sachs, "Energy and Resource Allocation: A Dynamic Model of the "Dutch Disease"," *Review of Economic Studies*, 1982, *49* (5), 845–59.

Calvo, Guillermo A., "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 1983, *12*, 383–98.

___, C.M. Reinhart, and Carlos Vegh, "Targeting the Real Exchange Rate: Theory and Evidence," *Journal of Development Economics*, 1995, *47*, 97–133.

Campbell, John and N. Gregory Mankiw, "Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence," in Olivier Blanchard and Stanley Fischer, eds., *NBER Macroeconomic Annual*, MIT Press, 1989, pp. 185–216.

Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan, "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?," *Review of Economic Studies*, July 2002, *69* (3), 533–64.

Clarida, Richard, Jordi Gali, and Mark Gertler, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, December 1999, *37*, 1661–707.

Esanov, Akram, Christian Merkl, and Lucio Vinhas de Souza, "Monetary Policy Rules for Russia," *Journal of Comparative Economics*, September 2005, *33* (3), 484–99.

Gali, Jordi and Tommaso Monacelli, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 2005, *72*, 707–34.

____ **, J. David Lopez-Salido, and Javier Voiles**, "Rule-of-Thumb Consumers and the Design of Interest Rate Rules," *Journal of Money, Credit, and Banking*, August 2004, *36* (5), 739–64.

Gelb, Alan H., *Oil Windfalls: Blessing or Curse?*, A World Bank Research Publication, 1988.

Hamilton, James D., *Time Series Analysis*, Princeton University Press, 1994.

Krugman, Paul, "The Narrow Moving Band, the Dutch Disease, and the Economic Consequences of Mrs. Thatcher: Notes on Trade in the Presence of Dynamic Economies of Scale," *Journal of Development Economics*, October 1987, *27* (1-2), 41–55.

Mendoza, Enrique G., "Real Business Cycles in a Small Open Economy," *American Economic Review*, September 1991, *81* (4), 797–818.

New Economic School, "Analysis of the Monetary Policy Impact on the Banking Sector Development," Report for the Non-commercial Foundation for Enterprise Restructuring and Financial Institutions Development 2005.

Obstfeld, Maurice, "Macroeconomic Policy, Exchange-Rate Dynamics, and Optimal Asset Accumulation," *Journal of Political Economy*, December 1981, *89* (6), 1142–61.

Parrado, Eric, "Inflation Targeting and Exchange Rate Rules in an Open Economy," Working Paper WP/04/21, International Monetary Fund 2004.

Rudebusch, Glenn D. and Lars E.O. Svensson, "Policy Rules for Inflation Targeting," in John B. Taylor, ed., *Monetary Policy Rules*, The University of Chicago Press, 1999, chapter 5, pp. 203–262.

Uhlig, Harald, "A Toolkit for Analyzing Nonlinear Dynamic Stochastic Models Easily," in Ramon Marimon and Andrew Scott, eds., *Computational Methods for the Study of Dynamic Economies*, Oxford University Press, 1999, chapter 3.

Uribe, Martin, "Real Exchange Rate Targeting And Macroeconomic Instability," *Journal of International Economics*, January 2003, *59* (1), 137–59.

Uzawa, Hirofumi, "Time Preference, the Consumption Function, and Optimal Asset Holdings," in J.N.Wolfe, ed., *Value, Capital, and Growth: Pepers in Honor of Sir John Hicks*, Chicago: Aldine, 1968.

Vdovichenko, Anna and Victoria Voronina, "Monetary Policy Rules and their Applications in Russia," Working Paper 04/09, Economic Education and Research Consortium 2004.

Williams, John C., "Simple Rules for Monetary Policy," *Federal Reserve Bank of San Francisco Economic Rewiew*, 2003, pp. 1–12.

Woodford, Michael, *Interest and Prices*, Princeton University Press, 2003.

Figure 1: Response to an oil price shock with money targeting

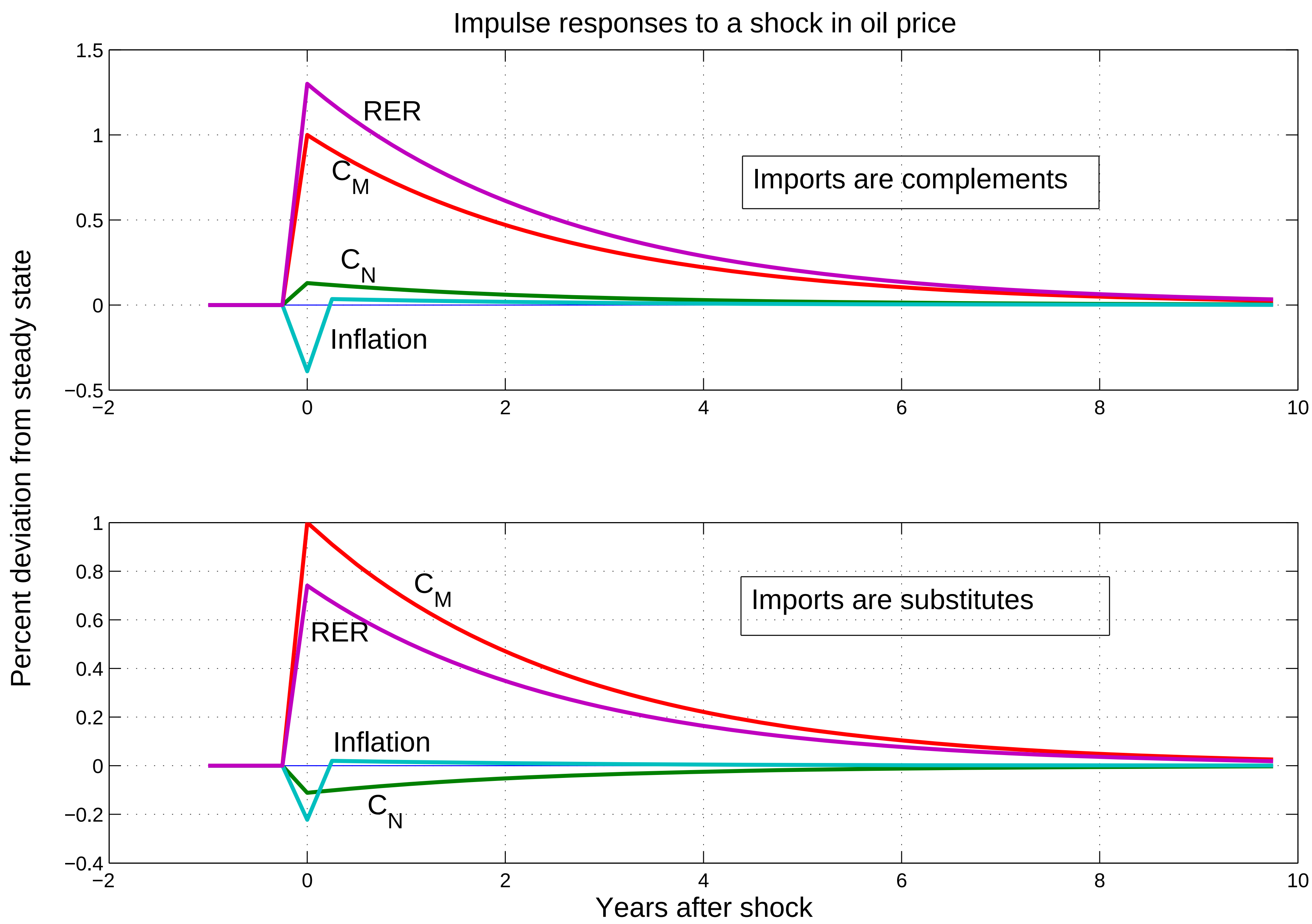

Figure 2: Response to an oil price shock with RER targeting

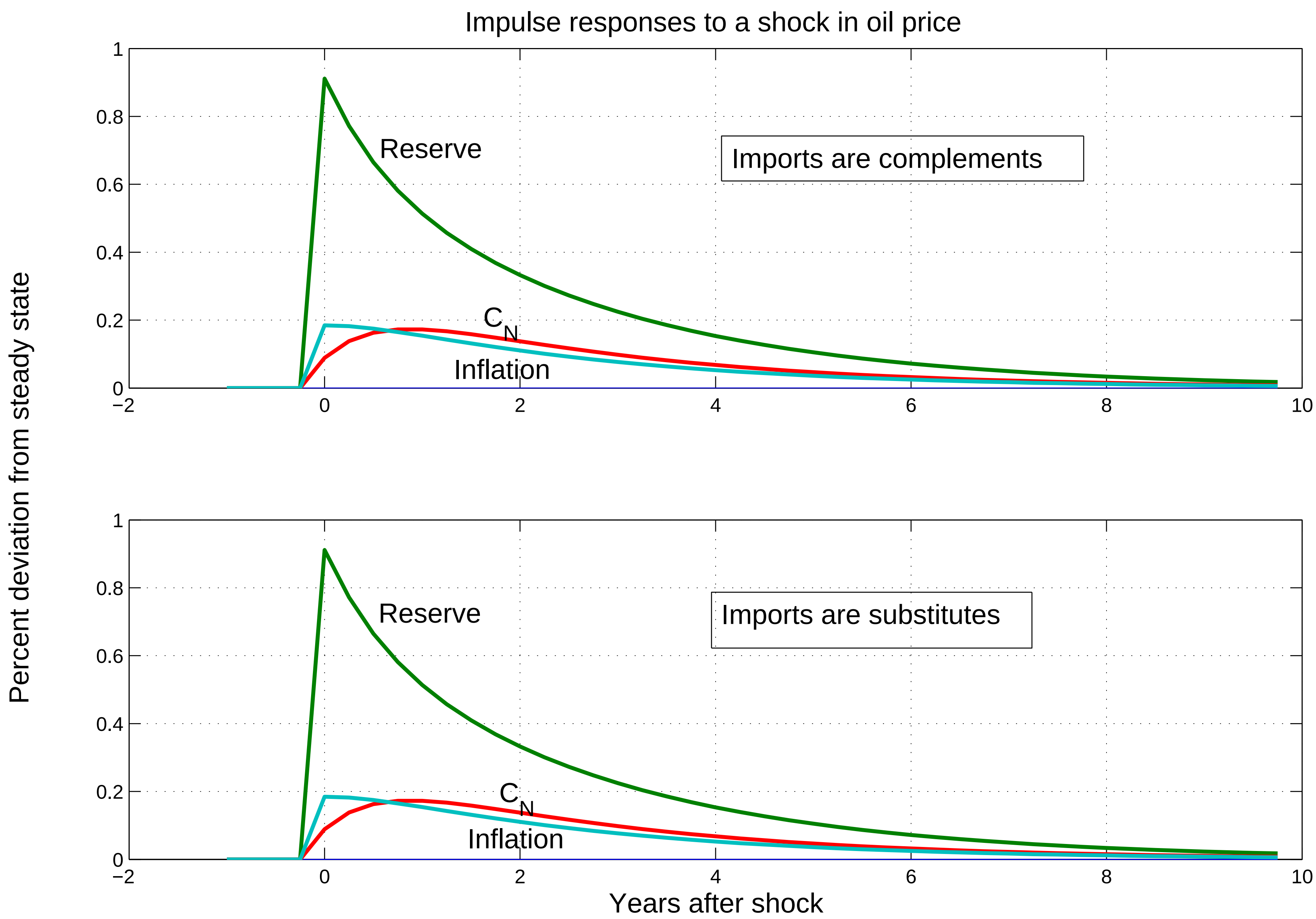

Figure 3: Response to an oil price shock with inflation targeting

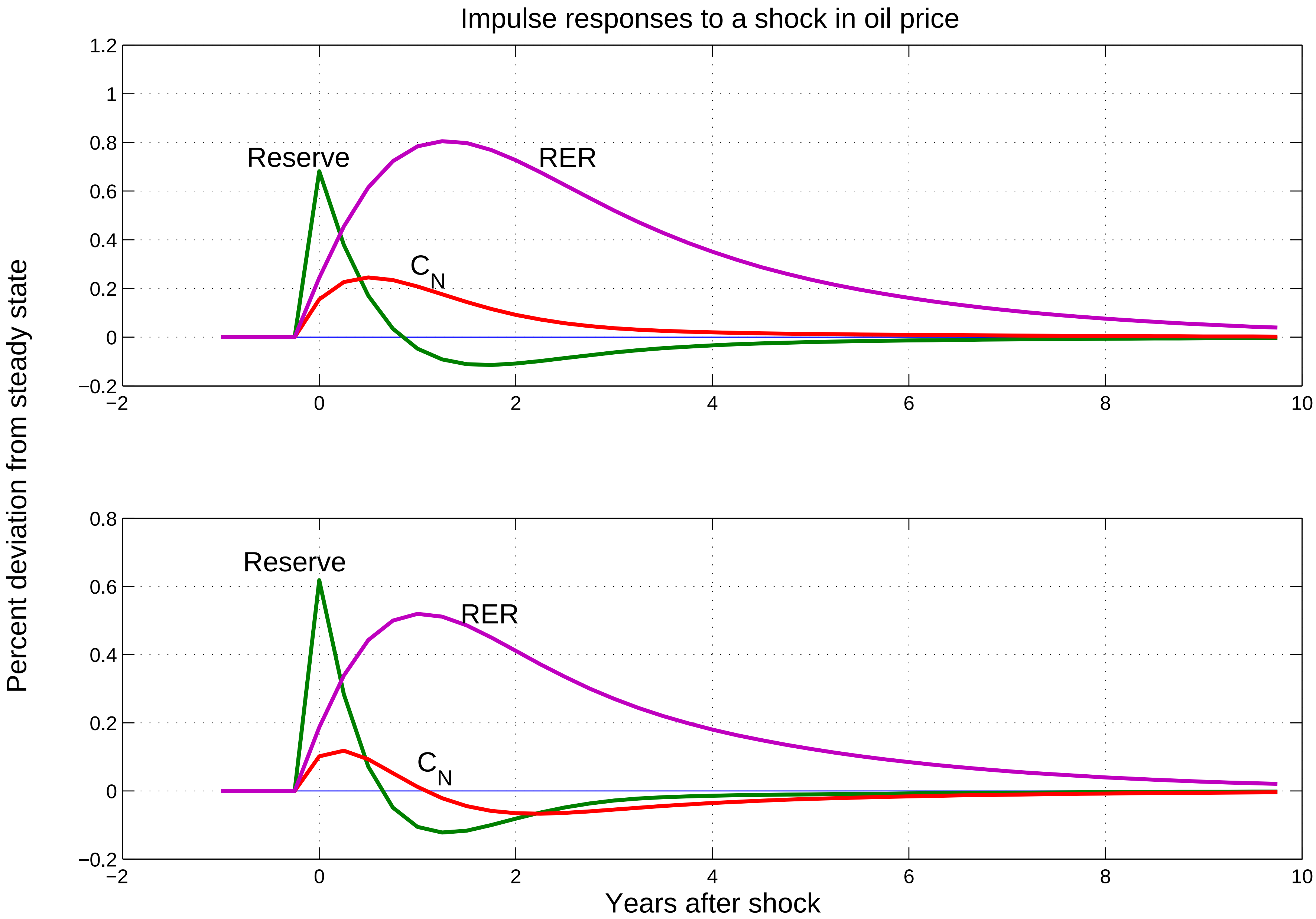

Table 2: Standard deviation of variables under different policy rules

		Standard deviation of				
η	λ	Output	Imports	Inflation	RER	Loss
Money targeting						
0.67	0.30	0.09	1.28	0.05	1.78	0.0053
1.50	1.00	0.07	1.27	0.04	0.89	0.0031
0.67	0.30	0.15	1.78	0.26	2.44	0.0460
1.50	0.30	0.14	1.97	0.19	1.40	0.0267
RER targeting						
0.67	1.00	0.10	0.10	0.45	0.00	0.1082
1.50	1.00	0.10	0.10	0.45	0.00	0.1082
0.67	0.30	0.28	0.28	0.59	0.00	0.2150
1.50	0.30	0.28	0.28	0.59	0.00	0.2150
Inflation targeting						
0.67	1.00	0.14	1.27	0.00	1.75	0.0092
1.50	1.00	0.08	1.26	0.00	0.88	0.0035
0.67	0.30	0.31	1.73	0.00	2.22	0.0472
1.50	0.30	0.15	1.89	0.00	1.26	0.0117
Inflation-RER rule with optimal weights						
0.67	1.00	0.09	1.20	0.05	1.67	0.0050
1.50	1.00	0.06	1.21	0.03	0.84	0.0022
0.67	0.30	0.21	1.63	0.13	2.14	0.0311
1.50	0.30	0.07	1.79	0.07	1.21	0.0049
Inflation-output rule with optimal weights						
0.67	1.00	0.09	1.21	0.05	1.68	0.0051
1.50	1.00	0.06	1.21	0.02	0.85	0.0022
0.67	0.30	0.22	1.67	0.13	2.19	0.0316
1.50	0.30	0.09	1.94	0.06	1.31	0.0059

Table 3: Standard deviation of variables in the model with import-substitution sector

	Standard deviation of				
λ	Output	Imports	Inflation	RER	Loss
Money targeting					
1.00	0.05	1.27	0.03	0.90	0.0019
0.30	0.11	1.97	0.16	1.41	0.0178
RER targeting					
1.00	0.13	0.13	0.70	0.00	0.2546
0.30	0.44	0.44	0.89	0.00	0.4890
Inflation targeting					
1.00	0.07	1.27	0.00	0.89	0.0025
0.30	0.18	1.92	0.00	1.29	0.0164
Inflation-RER rule with optimal weights					
1.00	0.05	1.25	0.02	0.88	0.0014
0.30	0.06	1.88	0.08	1.29	0.0049
Inflation-output rule with optimal weights					
1.00	0.05	1.25	0.02	0.89	0.0015
0.30	0.07	1.94	0.07	1.33	0.0053

Table 4: Standard deviation with money demand shocks

Standard deviation of				
Output	Imports	Inflation	RER	Loss
Money targeting				
1.00	0.08	0.47	0.73	0.6106
RER targeting				
0.58	0.58	0.16	0.00	0.1821
Inflation targeting				
0.41	0.88	0.00	0.37	0.0847
Inflation-RER rule with optimal weights *(Optimal weight on RER is zero)*				
0.41	0.88	0.00	0.36	0.0850
Inflation-output rule with optimal weights				
0.15	1.18	0.19	0.71	0.0300

Figure 4: Responses to oil price shock with inflation-RER rules