AN ESTIMATED DSGE MODEL FOR THE KYRGYZ REPUBLIC: POLICY IMPLICATIONS

by

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A THESIS
SUBMITTED TO THE GRADUATE SCHOOL OF PUBLIC POLICY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF PUBLIC POLICY

IN

MASTER OF PUBLIC POLICY, INTERNATIONAL PROGRAM

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MAY 2016

ABSTRACT

This paper studies the effects of fiscal and monetary policy shocks on economic performance in the Kyrgyz Republic using a dynamic stochastic general equilibrium model. Using Bayesian estimation methods, I estimate the model. This allows me to estimate important structural parameters, the unobservable shocks, and examine their transmission mechanism. The study finds that a fiscal stimulus boosts output with an increase in hours of work and a decline in consumption and investment while a contractionary monetary shock leads to decrease in all of those variables. I also examine the effect of fiscal and monetary policy on Kyrgyz economy using a structural VAR model and find most of the theoretical model's prediction to be empirically consistent.

Keywords: *Econometric Modeling, DSGE, the Kyrgyz Republic, Monetary Policy, Fiscal Policy, Bayesian Estimation, IRFs, Structural VAR*

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1. Introduction

Recently, a dynamic stochastic general equilibrium (DSGE) modeling has become a standard framework in macroeconomics. In fact, DSGE models are firmly grounded on economic theory and offer a formal econometric and mathematical apparatus for business cycle factors study and economic policy analysis, which, undoubtedly, distinguish them from other economical models, such as, for instance, vector auto-regressions. Practical value of that framework has been appraised by rights. Both economists and policymakers use it to analyze the effects of macroeconomic policies on an economy. However, most of them focus on advanced countries and less is known for developing countries. Moreover, it is important and necessary to develop a DSGE analysis for the Kyrgyz Republic. A thorny path of Kyrgyz economic transition has raised the role of its central bank to promote sustainable economic development and low inflation; however, due to the shortage of in-depth empirical research, its practical aspects still remain open-ended.

The purpose of this thesis is to study the effects of fiscal and monetary policy shocks on economic performance in the Kyrgyz Republic using a dynamic stochastic general equilibrium model. To answer the research question I've developed and estimated DSGE model with staggered prices for the Kyrgyz economy. The model is estimated by using Bayesian method. This allows me to estimate important structural parameters, the unobservable shocks, and examine their transmission mechanism. In order to assess the empirical consistency of the model, I also examine the effect of fiscal and monetary policy on Kyrgyz economy using a structural VAR analysis.

An estimate of the main behavioral parameter, a degree of price stickiness, is estimated to be considerably high in the Kyrgyz Republic and thus empirically important for the model. Quantitatively, it implies that on the average firms change the prices every three quarters. As for the fiscal policy, the low coefficient of the lagged bonds in the model's tax rule shows that taxes alone are not a panacea in financing of permanent issuance of government bonds. However, they are still used commonly due to the blurred horizon of fiscal forecasting. Budget deficit and growing social liabilities nudge the government to search for alternative ways of financing. Unlike that, the parameters of monetary policy reaction function are found to be important. Since the mean of autoregressive parameter on the lagged interest rate is estimated to be 0.9900, there is a noticeable degree of interest rate smoothing. Estimation reveals that the monetary policy reacts more tightly to the change in inflation rather than to the change in output. Stochastic processes for the exogenous shocks of evolution of technology, government expenditures, and interest rate are found to be very similar to their priors and estimated to be very persistent.

The study finds that in short run a fiscal stimulus boosts output with an increase in hours of work and a decline in consumption and investment while a contractionary monetary policy leads to decrease in all of those variables. The results also reveal that tax and government bonds increase in response to the fiscal shock. It is accompanied by the growth of nominal interest rate and decline in money supply. As the analysis shows, the effect of government spending shock on investment is determined by the response of consumption and government spending. This, in turn, explains the observed decrease in capital that is generated by investments. Contractionary monetary policy negatively affects output and a level of unemployment through investment depression. The policy of “expensive” money, which aimed to curb an increase of the price level, is also found to be associated with shrink in consumption. In addition, the structural VAR analysis finds most of theoretical model's predictions to be empirically consistent.

The DSGE model for the Kyrgyz economy in this study is based, to the large extent, on the model of Smets and Wouters (2003) developed and estimated for the Eurozone. For simplicity, the model for the Kyrgyz Republic employs just a limited number of frictions incorporated into the parent model. For instance, the model for the Kyrgyz economy does not address wage rigidity or internal habit formation in consumption. The model estimated by Smets and Wouters for the euro area exploits seven observable variables indicating that the same number of shocks is applied. In turn, the structural shocks in estimated DSGE model for the Kyrgyz Republic are represented by deviations of total factor productivity, government spending, and interest rate. The major reason of having a smaller number of shocks to economy is a noticeably higher level of data limitation.

Despite rapid development and noticeable achievements of DSGE framework, it still remains quite new for Kyrgyz scholars due to complexity in the model settings, a lack of reliable and sufficient time series, identification problems, and so forth. To my knowledge, the DSGE modeling for domestic economy is limited to the study conducted by Nurbek Jenish and Asel Kyrgyzbaeva (2012). The authors attempted to integrate specific features of the Kyrgyz economy, such as dependence on external money transfers and vulnerability on external shocks, into the standard DSGE model for small open economy. Besides that, it explicitly models the fiscal part, and employs assumptions on distorted steady state and incomplete assets markets. The model distinguishes foreign sector although it is not specified directly. Jenish and Kyrgyzbaeva use calibration method to estimate parameters of their model.

The reminder of this paper is organized as follows. Section 2 presents a simple DSGE model for the Kyrgyz Republic. Section 3 estimates the model by using Bayesian methods. Section 4 presents the effect of fiscal and monetary policy shocks on the economy under estimated model. Section 5 concludes.

2. A DSGE Model for the Kyrgyz Republic

In essence, a DSGE model for the Kyrgyz Republic is a small closed economy model consisting of five different domestic economic agents - (i) representative household, (ii) firms that produce intermediate goods, (iii) firms that produce final goods for consumption, (iv) the government, and (v) the central bank [Figure 1].

Following the assumption of Keynesian economic theory, the representative household own main factors of production - labor and capital, which in turn allow them to make decisions on how much labor to supply for the market. A workforce provided by the household to firms for goods production is considered as a differentiated good. It is assumed that the owners of this production factor have a monopolistic power over the size of wages.

Besides that, the representative household faces persistent choice between consumption of goods and accumulation of a liquid assets stock. It also owns all firms in the economy and, respectively, is supposed to manage them by making decisions regarding their activities.

Final good firms use intermediate goods as inputs to produce goods, which is subsequently being converted into domestic consumption and investment. Thus, an additional capital is created from some fraction of a final goods flow. The latter transforms into investment with one period lag, and gets involved into the goods production again. Herewith, the process of capital creation is associated with some losses. To capture that assumption, the model is incorporated with a mechanism of defining capital costs function as the capital adjustment costs.

The DSGE model in this paper defines a state budget as a budget with zero deficit. Government spending policy incurred by the country is following the dynamics of first order autoregressive process (AR(1)) and domestic demand shocks.

2.1. The Household Sector

There is a representative household in the model. The instantaneous utility function of the household is addictive and separable in three arguments increasing with rise of consumption c_t and real money balances $\left(\frac{M_t}{P_t}\right)$, and decreasing with growth of working hours n_t.

Each period of time the representative household solves the following utility maximization problem specified on infinite time interval

$$\max_{c_t,\ n_t, M_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t \left[\frac{c_t^{1-\theta}}{1-\theta} - \frac{n_t^{1+\varphi}}{1+\varphi} + \frac{1}{1-\xi}\left(\frac{M_t}{P_t}\right)^{1-\xi}\right],$$

where $\mathbb{E}_0$ is an initial expectation of the variable or conditional expectation operator based on information available at time t_0, β is a subjective discount factor, which is strictly between 0 and 1, θ is a coefficient of relative risk aversion or the reciprocal of the inter-temporal elasticity of substitution ($\theta \in (0,1)$), φ is the inverse of Frisch elasticity of labor supply ($\varphi \geq 0$), and ξ is a preference parameter that sets up demand function for real money.

The representative household holds two types of financial instruments: money (M_t) and bonds denominated in national currency (B_t). It earns money from using factors of production – labor and capital, and has an income in form of dividends (D_t) from activities undertaken by firms that belong to the households. According to the model, representative household owns some stock of the capital and gives it for rent to firms. It is assumed that the revenue that has been earned by the household in current period and wealth accumulated before are spent for consumption (c_t), investments to the capital of firms belonging to households (i_t), and taxes to the government (τ_t). Thus, capital stock that is rented by firms might be changed by respective investment decision or due to intensity of the physical capital loading. In turn, the latter is associated with some real costs in terms of the final output.

Accordingly, the representative household maximizes its utility under the following budget constraint

$$c_t + i_t + m_t + b_t = w_t n_t + r_t^k k_{t-1} + \frac{R_{t-1}}{\Pi_t} b_{t-1} + \frac{m_{t-1}}{\Pi_t} + d_t - \tau_t,$$

where r_t^k is a rent fee for using the capital, k_{t-1} is a capital stock held by the household at time (t-1), and w_t is a wage in real terms.

On the other hand, the last equation shows that the household fully spends its income on consumption, investments to firms they own, money stock, and government bonds.

Second limitation of the household utility maximization task is a physical capital accumulation equation

$$k_t = (1-\delta)k_{t-1} + i_t - S\left(\frac{i_t}{i_{t-1}}\right) i_t,$$

where δ stands for the norm of capital amortization ($0 < \delta < 1$) and S is a capital adjustment cost.

From above, it is assumed that the process of capital launching is associated with one period lag and entails some adjustment costs. For this research, the capital cost function is set through the capital adjustment cost.

Here, it is assumed that $S(1) = S'(1) = 0$ and $S''(1) = \kappa$.

It means that in equilibrium when the previous level of investment is equal to the current level or, in other words, remains unchanged, the function of changes in investment equals to zero. Another assumption is that the first derivative of the capital adjustment cost is also equals to zero in equilibrium.

The modern DSGE model specifications like, for instance, in Erceg et al. (2000), Christiano et al. (2001, 2005) and Smets and Wouters (2003, 2007) imply some certain inertial dynamics of investments in response to economic shocks. So, one might find that the capital adjustment cost directly depends on the pace of investment change.

Finally, the first-order conditions yield

$$c_t \; : \; c_t^{-\theta} = \lambda_t$$

$$n_t \; : \; n_t^{\varphi} = \lambda_t w_t$$

$$m_t \; : \; m_t^{-\xi} = \lambda_t - \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\Pi_{t+1}}$$

$$k_t \; : \; \mu_t = \beta \mathbb{E}_t \left[\lambda_{t+1} r_{t+1}^k + \mu_{t+1}(1-\delta)\right]$$

$$b_t \; : \; \lambda_t = \beta \mathbb{E}_t \left(\frac{R_t}{\Pi_{t+1}} \lambda_t\right)$$

$$i_t \; : \; \lambda_t = \mu_t \left(1 - S\left(\frac{i_t}{i_{t-1}}\right) - S'\left(\frac{i_t}{i_{t-1}}\right) \frac{i_t}{i_{t-1}}\right) + \mathbb{E}\mu_{t+1} S'\left(\frac{i_{t+1}}{i_t}\right) \left(\frac{i_{t+1}}{i_t}\right)^2.$$

Let $q_t \equiv \frac{\mu_t}{\lambda_t}$. When, from the FOC with respect to i_t, we have

$$q_t \left[1 - S\left(\frac{i_t}{i_{t-1}}\right) - S'\left(\frac{i_t}{i_{t-1}}\right) \frac{i_t}{i_{t-1}}\right] = 1 - \mathbb{E}_t \left[\frac{\Pi_{t+1}}{R_t} q_{t+1} S'\left(\frac{i_{t+1}}{i_t}\right) \left(\frac{i_{t+1}}{i_t}\right)^2\right].$$

Thence, the first-order conditions derived while solving for the problem of utility maximization by the household i_t defines the function of investment demand.

The FOC with respect to k_t also can be rewritten likewise as

$$q_t = \beta \mathbb{E}_t \left[\frac{\Pi_{t+1}}{R_t} \{r_{t+1}^k + q_{t+1}(1-\delta)\}\right].$$

2.2. Technologies and Firms

2.2.1. Final Goods Producers

Final good firms use differentiated intermediate goods and act on the perfectly competitive market.

The final good is produced using the intermediate goods in the following technology

$$y_t = \left[\int_0^1 y_{jt}^{\frac{\psi-1}{\psi}} dj\right]^{\frac{\psi}{\psi-1}}.$$

Profit maximization yields a following demand function for intermediate goods of j firm

$$y_{jt} = \left(\frac{P_{tj}}{P_t}\right)^{-\psi} y_t.$$

Subsequently, the price index is determined by the following expression

$$P_t = \left[\int_0^1 p_{jt}^{1-\psi} dj\right]^{\frac{1}{1-\psi}}.$$

2.2.2. Intermediate Good Producers

Continuum of intermediate good firms operates in monopolistically competitive market. The technology of each firm is described by Cobb-Douglas production function as follows:

$$y_{jt} = z_t k_{jt-1}^{a} n_{jt}^{1-\propto},$$

where coefficient α represents the capital share (0<α<1), and z_t is a common technology shock.

Common technology shock is assumed to follow a first-order autoregressive process with i.i.d. normal error term

$$\log z_t = \rho_z \log z_{t-1} + \varepsilon_{zt}.$$

The (real) profit is

$$\left(\frac{p_{tj}^*}{P_t}\right) y_{jt} - r_t^k k_{jt-1} - w_t n_t,$$

where p_{tj}^* is the optimal price set by firm j.

Each period of time t the firm solves the following profit maximization problem

$$\max E_t \sum_{k=0}^{\infty} \beta^k \eta^k \left[\left(\frac{p_{tj}^*}{P_{t+k}}\right) y_{jt+k} - r_{t+k}^k k_{jt+k-1} - w_{t+k} n_{t+k}\right],$$

where the output is restricted by production function

$$y_{jt} = \left(\frac{P_{tj}}{P_t}\right)^{-\psi} y_t = z_t k_{jt-1}^{a} n_{jt}^{1-\propto}.$$

Solving the problem yields the following optimal condition

$$\sum_{k=0}^{\infty} (\beta\eta)^k E_t \left[\left(\frac{p_{tj}^*}{P_{t+k}}\right) - \frac{\psi}{\psi-1} mc_{t+k}\right] y_{jt+k} = 0,$$

where

$$mc_t = \frac{w_t}{(1-\propto) z_t}\left[\frac{r_t^k (1-\propto)^{\propto}}{\psi - 1 \propto w_t}\right].$$

The aggregate optimal price of domestic intermediate goods is obtained by

$$p_{jt}^{*} = \frac{\psi}{\psi-1}\frac{\sum_{k=0}^{\infty}(\beta\eta)^{k}\, y_{jt+k}\, mc_{t+k}}{\sum_{k=0}^{\infty}(\beta\eta)^{k}\frac{y_{jt+k}}{P_{t+k}}}.$$

2.3. Price Dynamics

We assume that prices are staggered as in Calvo meaning that each period of time domestic firms with exogenously given probability get the signal under which the firms arrange the price based on maximization of expected discounted sum of revenues.

Let $1-\eta$ be the probability a firm adjusts its price. When, the price of final good would be given by

$$P_t = \left[\eta\, p_{t-1}^{1-\psi} + (1-\eta)\, p_{jt}^{*1-\psi}\right]^{\frac{1}{1-\psi}}.$$

2.4. Fiscal Authority

The government budget constraint is given by

$$B_t = R_{t-1}B_{t-1} + P_t g_t - P_t \tau_t.$$

In other words, the government spending g_t is being financed by issuing government bonds B_t and imposing the lump-sum tax τ_t.

The government consumption is assumed to follow an exogenous stochastic process as follows

$$\log g_t = \rho_g \log g_{t-1} + \varepsilon_{gt},$$

where $\rho_g \in (0,1)$ is a persistency of government consumption, and $\varepsilon_{gt} \sim N(0,\sigma_x^2)$ is a standard deviation (shock) of the government spending.

2.5. Monetary Authority

Although a "real world" monetary policy can be represented by several monetary instruments, a large number of DSGE studies employ just a single independent rule of monetary policy. For simplify, the latter is also a case for this thesis. It means that there is only single condition, Taylor rule, defining behavior of the Central Bank.

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + \varepsilon_{rt},$$

where $\phi_\pi > 1$ is an inflation coefficient in the monetary policy rule, ρ_r is an autoregressive parameter on the lagged interest rate ($\rho_r \in (0,1)$), ϕ_y is an output coefficient in the monetary policy rule, and ε_{rt} is an interest rate shock.

2.6. Aggregation

Labor

$$n_t = \int_0^1 n_{jt}\, dj = \frac{1}{z_t}\left[\frac{r_t^k\,(1-\propto)^{\propto}}{\propto w_t}\right]^a \int_0^1 y_{jt}\, dj.$$

Capital

$$k_{t-1} = \int_0^1 k_{jt-1}\, dj = \frac{1}{z_t}\left[\frac{r_t^k\,(1-\propto)^{\propto}}{\propto w_t}\right]^{a-1} \int_0^1 y_{jt}\, dj.$$

These equations yield

$$\frac{n_t}{k_{t-1}} = \frac{r_t^k\,(1-\propto)^{\propto}}{\propto w_t}$$

$$\int_0^1 y_{jt}\, dj = z_t k_{t-1}^a n_t^{1-\propto}.$$

2.7. Market equilibrium

We aware that in equilibrium the demand for goods from the representative household is equal to supply of goods by a representative firm, and such market equilibrium might be represented through a resource constraint formula

$$y_t = c_t + i_t + g_t,$$

where nominal values are deflated to the aggregate price level for the final consumption goods P_t.

Since all economic agents in the model are representative by their nature, the equation above might be interpreted as an equality of aggregate demand and supply. According to that logic, all equations derived earlier can also be considered from the standpoint of the economy as a whole.

On the other hand, a resource constraint formula is an equilibrium equation in the market of final good consumption, when the amount of goods produced is equivalent to household consumption, investment, and government procurement.

3. Parameter Estimates

The model is estimated by using Bayesian methods. I first log-linearized my model around the steady state. Then, I solve my model and apply the Kalman filter to evaluate the likelihood function of observables. The procedure of parameter estimation is split into the two stages. At first, a log posterior function, which combines preliminary information about parameters with the likelihood of the data, is being maximazed to assess a mode of posterior distribution. After that, the Metropolis-Hastings algorithm gets involved in order to find «a complete picture of the posterior distribution and to evaluate the marginal likelihood of the model»[1].

3.1. Calibration

In order to determine a stationary value of real variables, the DSGE model is being calibrated to bring the structural properties of the model to the real indicators of the Kyrgyz economy in considering period of time.

At first, I set some target values, which become a base for the other model parameters estimate, particularly, a fraction of government spending in Kyrgyz gross domestic product ($\frac{g}{y} = 0.31$) and an actual value of the government bonds-to-GDP ratio ($\frac{b}{y} = 0.08$).

The calibrated parameter of subjective discount rate β for the model with time period of a quarter is set up to 0.99, which is considered as a "standard" calibration in the latest DSGE literature.

Other parameters of the model have been estimated.

3.2. Data

Suggested DSGE model for the Kyrgyz Republic employs statistical data of 61 periods from the first quarter of 2000 to the first quarter of 2015 for three observable macroeconomic variables: (i) real gross domestic product; (ii) government spending; and (iii) monetary aggregate M2X (or broad money), where the first variable is endogenous, and the rest are assumed to be given exogenously.

All nominal values of observable variables in this study are expressed in som, a Kyrgyz national currency.

The time series for the real GDP and government expenditures are based on the information of the National Statistical Committee of the Kyrgyz Republic[2], a broad money data is retrieved from databases of the National Bank of the Kyrgyz Republic (NBKR)[3]. The time series used are seasonally adjusted, logged, and

[1] Smets and Wouters (2007), p.592

[2] The official website of the National Statistical Committee of the Kyrgyz Republic http://www.stat.kg/

[3] The official website of the National bank of the Kyrgyz Republic http://www.nbkr.kg/

when de-trended. Seasonal adjustment was carried out using Census Bureau's X-12 filter. This mechanism can only be used for positive numbers, therefore seasonal adjustment is applied to original data. The data is de-trended using Hodrick-Prescott filter. The smoothing parameter λ was set to 1600, a default value for quarterly data.

3.3. Prior Distribution of the Parameters

Numerical values of prior distributions of parameters are shown in tables 1A and 1B.

Preference, Rigidity, and Technology Parameters A degree of price stickiness aka a coefficient of prices flexibility is assumed to be beta distributed around mean 0.655 with standard deviation 0.0100. Coefficient of relative risk aversion of households, the inverse of the elasticity of work effort with respect to the real wage, preference parameter, the inverse of the second-order derivative of capital adjustment costs, stochastic parameter that determines the time-varying markup in the goods market, the coefficient of the lagged bonds in log-linearized tax equation are described by gamma distribution.

Monetary Policy Reaction Function Parameters Two parameters of the monetary policy rule, inflation and output coefficients, are assumed to follow gamma distribution with means of 0.574 and 0.188, and standard errors of 0.2000 and 0.0500, respectively. Coefficient on the lagged interest rate, a parameter which is also included into equation describing the monetary policy rule, is assumed to follow beta ditribution, with mean 0.990 and standard deviation 0.0010.

Shocks The standard errors (shocks) of the total factor productivity are assumed to follow an inverse-gamma distribution with a mean of 0.007. The standard deviation of the shock has been set to infinity in order to keep staying within its substance. Same distribution and its standard deviation have been assigned for the shocks of government expenditures with mean assumed to be 0.148, and interest rate with mean 0.043. The persistence of the AR(1) processes in evolution of the total factor productivity and government expenditures is beta distributed with mean 0.774 and 0.842, respectively. Standard deviations for latter have been defined at the level of 0.1000 and 0.0500 (see Table 1B for details).

3.4. Posterior Estimates of the Parameters

On the basis of prior information about parameters and using Metropolis-Hastings mechanisms I got posterior parameter means, and the 5 and 95 percentiles of the posteriors, which are reported in the last three columns of tables 1A and 1B.

Preference, Rigidity, and Technology Parameters A price stickiness is estimated to be 0.6551. The posterior mean of the inverse of Frisch elasticity of labor supply is 2.5343. Regarding the inter-temporal elasticity of substitution, the posterior estimate of θ is 0.0041. Preference parameter that sets up demand function for real money is estimated to be 0.3049. The parameter of capital adjustment costs, stochastic parameter that determines the time-varying markup in the goods market, and the coefficient of the lagged bonds in log-linearized tax equation are estimated around 6.0763, 10.7441 and 0.1026, respectively.

Monetary Policy Reaction Function Parameters Inflation and output coefficients in the monetary policy rule are estimated to be around 0.39 and 0.21, respectively. The posterior mean of the lagged interest rate coefficient is estimated to match the prior 0.99 with its 5th percentile at 0.9884 and 95th percentile at 0.9917.

Shocks Stochastic processes for the exogenous shocks are estimated to be highly persistent. Autoregressive parameters (also known as AR(1) coefficients) on evolution of the total factor productivity, government expenditures, and the lagged interest rate are found to be very similar to their priors with the values of 0.7783, 0.8089, and 0.9900, respectively (see also Figure1A and Figure1B on the estimated parameter distribution). The means of the standard deviation of technology and interest rate are 0.0048 and 0.0328, respectively. Posterior mean of standard deviation (shock) of the government expenditures is estimated to be 0.1470.

4. Impulse Response Functions and Analysis

4.1. Fiscal Shock

I now examine the dynamic response of the economy to fiscal and monetary policy shocks. Figures 5.1.1.A, B and 5.1.2.A, B plot the impulse response functions of relevant variables to the one standard deviation shocks.

In short term, the major indicator of economic activity responds positively to the fiscal shock although, such reaction remains almost unnoticed in quantitative terms. But as time passes, its downward trend wipes out observed positive effect by diverting the output into the negative side of the graph. According to the impulse responses received, an apparent impact of such a government policy lasts about 15 quarters gradually returning to a steady state in a longer run. In this case, output increase is not driven by consumption. Generally saying the shock depresses consumption, which when gradually gets back to its equilibrium level by 20th period from the moment of shock impact.

The labor market reaction to the fiscal shock was predictably positive and skimpy. By sixth-seventh quarter from the onset of shock, the labor market indicator returns to its “normal” condition. The corresponding graph shows that the value of investments, in quantitative terms, falls in comparison with those available at the time of the shock. The process of reclamation that takes part from 9th to 20th quarter is characterized by barely noticeable deviation in the direction of growth.

Expansionary fiscal policy is expectedly carried out by dint of increase in issuance of government securities (government bonds). However, due to limited demand for the latter that process is often accompanied by the growth of nominal interest rate. Herewith, the money supply does not increase but rather decreases until the interest rate is at its unusually high level. As the analysis shows, the households react to the fiscal shock with consumption reduction.

The effect of government spending shock on investment is determined by the response of consumption and government spending. The impulse response graph shows that investments are falling. It also reveals a negative feedback from the money supply to estimated increase in government spending. Since money supply equals to money demand on the aggregate level in proposed DSGE model, the market should respond by raising of the interest rate that takes place to be. Investments are become crowded out. This also explains the observed decrease in capital that is generated by investments.

Figure 4.1.1.A. Impulse Responses to the Positive Fiscal Shock

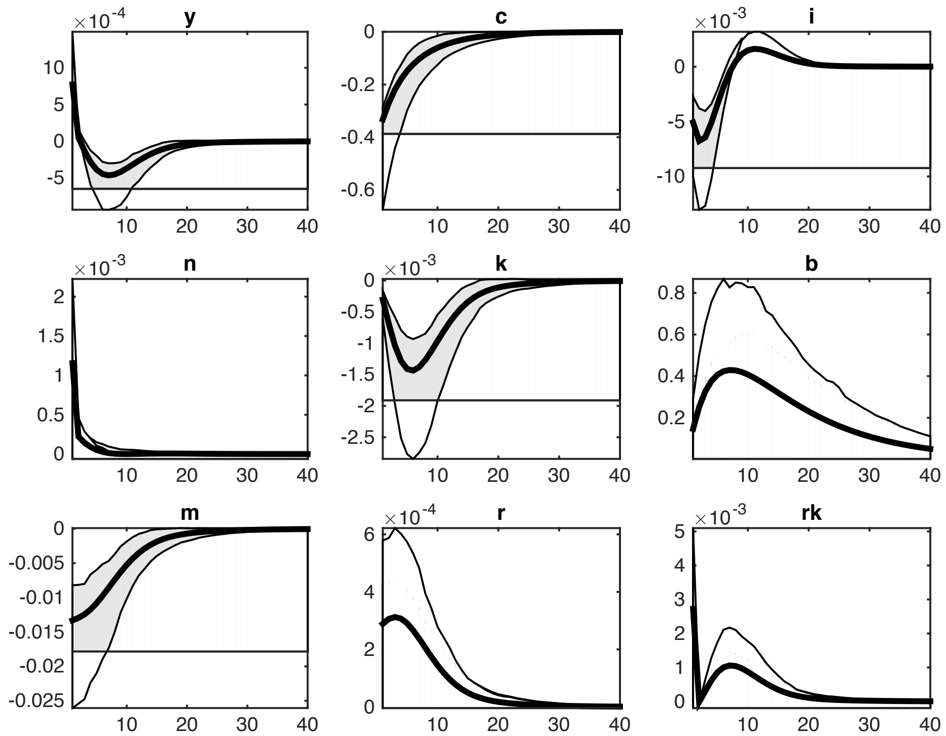
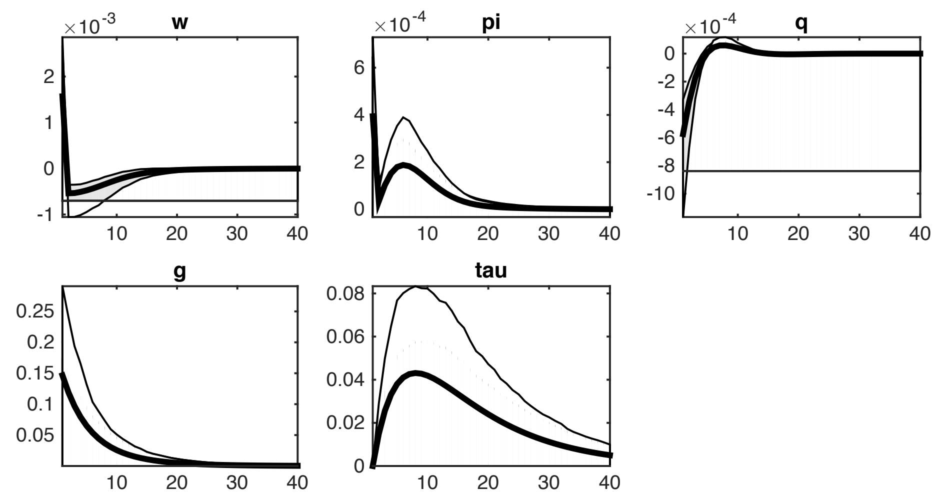


Figure 4.1.1.B. Impulse Responses to the Positive Fiscal Shock



4.2. Monetary Shock

Next part of the impulse response analysis introduces the response of the same bunch of macroeconomic variables: output, consumption, investment, hours of work, money demand, and nominal interest rate to contractionary monetary policy shock. Impulse responses under the figure 4.2.1.A. and 4.2.1.B. have also been derived by the same means as for the fiscal shock.

In Chapter 2, the model describes monetary policy in terms of the Taylor rule. According to the monetary rule, the monetary shock is basically an increase in interest rate associated with contractionary monetary policy.

Pursuant to the Keynesian interpretation, an economy is not dichotomous and money is not neutral. Thus, there is a specific transmission mechanism through which money affects real sector. In short term, an interest rate is that element linking real and monetary spheres. In other words, a change in interest rate affects money demand and investment meaning it affects real market (or market of goods and services).

From theory, an interest rate hike is caused by decrease in money supply. Figure 4.2.1. shows that the interest rate gets back to its steady state level by tenth period from the moment of shock impact. Almost same time is needed for the money supply, which graph has similar but “mirrored” shape as for the interest rate, to overcome the consequences of negative monetary shock.

An interest rate also affects firms’ investments because so called a policy of “expensive” money narrows accessibility of a credit. The higher an interest rate, the lower firms’ demand on loans, and thus investments. According to the graph, it takes around four periods for investment to return to pre-shock level. As a result, there is a fall in aggregate demand and, accordingly, in output. Nonetheless, the result shows a very short-lived effect of contractionary monetary policy on output, which lasts no longer then one period.

Figure 4.2.1.A. Impulse Responses to the Negative Monetary Shock

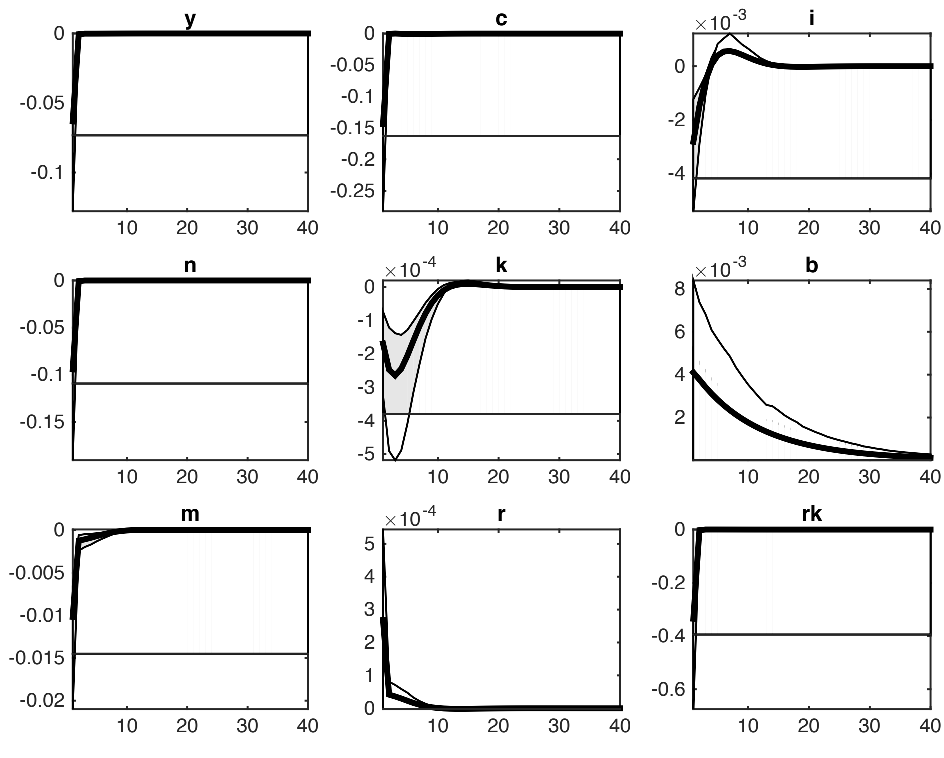
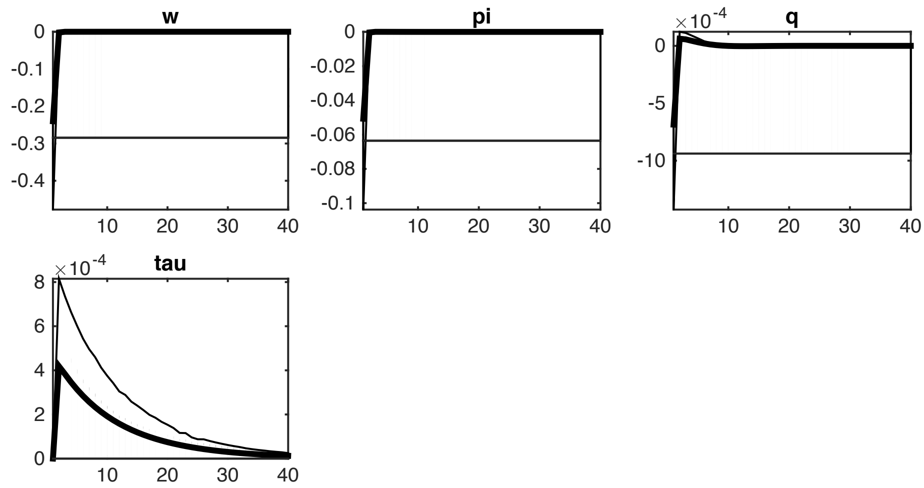


Figure 4.2.1.B. Impulse Responses to the Negative Monetary Shock



Herewith, the price falls down. In other words, contractionary monetary policy diminishes inflation. However, price level decrease in turn leads to the slow down of economic activity. As a result, contractionary monetary policy increases unemployment although it also has one period effect only. Since higher interest rate stimulates households to save more rather then consume, consumption decreases.

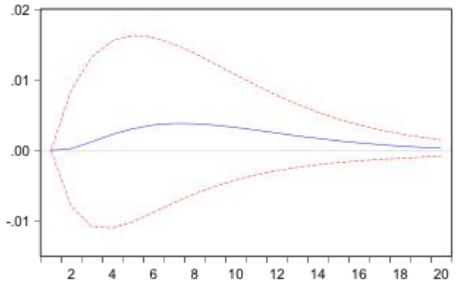
In order to evaluate the empirical consistency of the model, I developed and examined an alternative structural vector autoregression model assessing a response of output to money supply.

4.3. Empirical Consistency of an Estimated DSGE Model

This paper employs structural vector autoregression for empirical consistency assessment of an estimated DSGE model of the Kyrgyz Republic. This alternative is chosen because in spite of the fact that it offers a non-theoretical quantitative approach, VARs are successfully and widely used to describe and summarize macroeconomic data as well as for the implementation of macroeconomic forecasting (Stock and Watson, 2001). For all its simplicity, VARs provide with relatively systematic approach in capturing the rich dynamics of the time series. There are three different types of VAR: reduced, recursive, and structural; however, the latter is believed to be fit most adequately for the purpose of policy analysis. Here, the structural VAR model is developed for the same statistical data set as for the DSGE model. For the purpose of this paper, SVAR is realized using an approach of recovering from reduced VAR.

Since statistical data should meet some rigid requirements for VAR modeling, the time series used, except year-on-year inflation, are seasonally adjusted and de-trended. Seasonal adjustment is carried out using Census Bureau's X-12 filter. Time series are also cleared of their cyclical component by using filtering methods, particularly, Hodrick-Prescott filter with smoothing parameter λ = 1600. Based on the value of t-statistics, the constant term is judged to be not statistically significant and thus dropped.

Figure 4.3.1. Impulse Response of Output to the Monetary Shock



According to the graph above, expansionary monetary policy eventually boosts output, which gets back to its steady state after 20 periods from the onset of the shock. However, the confidence interval visuals show that the results of SVAR modeling are not statistically significant.

5. Conclusion

Since the attainment of independence, the Kyrgyz Republic faced many economic challenges, such as inflation, destruction of existing economic ties, economic disorientation, and others inherent to a sudden change of economic platform. The turbulence of the world economy along with internal political crises of 2005 and 2010 had a negative impact on the national economy characterized by its low level of diversification, permanent budget deficit, rising public debt, and high dependence on imports. As a result, the importance of the central bank's tasks together with consistent measures of fiscal authorities to promote sustainable economic development and low inflation has significantly increased.

There is a long practice of contractionary monetary policy in Kyrgyzstan against the background of ongoing high inflation risks. In fact, its implementation is complicated by growing government expenditures, high level of budget deficit, and random and irregular distribution of the government spending within fiscal year. Permanent budget deficit, which is predominantly financed through credits and grants from international donors, leaves no room for the fiscal maneuvers and fiscal capacity extension to contribute to economic growth. The fiscal authority actions invariably lead to an increase in the money supply putting additional pressure on the price level in the country. To curb the monetary factor, the central bank is bounded with the policy of upbuilding in sterilization operations to eliminate the negative impact of excessive money supply on economy.

The research employs cutting edge DSGE modeling framework for analysis of the impact of expansionary fiscal and monetary policies on economic performance in the Kyrgyz Republic. Since the practical evidence remains scanty, this study contributes to empirical analysis of Kyrgyz economy and extents theoretical insights for its further research. This paper is a first empirical attempt to estimate parameters of DSGE model for the Kyrgyz economy and to use impulse responses for the policy analysis. It is based on contemporary DSGE modeling framework. Dynamic system of the model non-linear equations is log-linearized around long-term equilibrium. The research employs Bayesian estimation techniques with Metropolis-Hastings mechanism, a version of Markov Chain Monte-Carlo (MCMC) algorithm, to get parameter estimates. All estimates have been done in MatLab using Dynare econometric software package.

The main finding of the paper is a beneficial effect of the government spending shock to output, whereas contractionary monetary policy is shown to have an opposite result for the Kyrgyz economy. As for the fiscal stimulus, the observed influence has a short and unstable nature, which turns opposite in a longer perspective. This is also accompanied by an increase in working hours and government securities in circulation, as well as interest rate hike. It is found that economic performance improvement in not driven by consumption, which is declined along with investment and money supply after the fiscal shock hits the economy.

In turn, the outcomes of modeling show that simplified DSGE framework can provide with consistent results for the further analysis of the monetary policy impact on economy. In addition to existing believes among analysts and findings of other studies on the weakness of monetary transmission mechanism in the Kyrgyz Republic, this paper clearly reveals that contractionary monetary policy negatively affects output and a level of unemployment through investment depression. The policy of "expensive" money, which aimed to curb an increase of the price level, is also associated with shrink in consumption. Thus, it can be concluded that DSGE framework with a limited number of actual data used is proved to be useful to explain the effect of monetary policy in Kyrgyzstan.

An estimated DSGE model for the Kyrgyz Republic might be elaborated further to make the results of estimation to be more consistent with reality through implementation of habit formation, wage rigidity, external sector etc. in order to capture the rich dynamics of domestic economy. Seemingly, the model can benefit greatly from expansion of observable variables list and a larger number of actual statistics using, for instance, monthly data. It is assumed that there is a problem of scarcity and quality of statistical time series, which might influence the results received and their further interpretation. In general, the suggested framework contributes as one of the first cut in in-depth empirical analysis of the Kyrgyz economy, and the results of modeling might be used in further process of study on its interrelations.

Tables

Table 1A. Prior and Posterior Distribution of Structural Parameters

			Prior distribution			Posterior distribution			
			Distr.	Mean	St. Dev.	Mode	Mean	5 percent	95 percent
η	eta	Degree of price stickiness	beta	0.655	0.0100	0.6555	0.6551	0.6387	0.6715
θ	theta	Inter-temporal elasticity of substitution	gamma	0.005	0.0010	0.0040	0.0041	0.0029	0.0053
φ	varphi	The inverse of Frisch elasticity of labor supply	gamma	2.554	0.2000	2.5136	2.5343	2.2072	2.8596
ξ	xi	Preference parameter that sets up demand function for real money	gamma	0.294	0.1000	0.2945	0.3049	0.1874	0.4184
κ	kappa	The parameter of capital adjustment costs	gamma	6.501	2.0000	5.4487	6.0763	2.9754	9.0260
ψ	psi	Stochastic parameter that determines the time-varying markup in the goods market	gamma	10.891	2.0000	10.3976	10.7441	7.4569	13.9654
ϕ_b	phib	The coefficient of the lagged bonds in log-linearized tax equation	gamma	0.102	0.0200	0.0986	0.1026	0.0695	0.1346
ϕ_π	phipi	Inflation coefficient in the monetary policy rule	gamma	0.574	0.2000	0.3143	0.3863	0.1932	0.5720
ϕ_y	phiy	Output coefficient in the monetary policy rule	gamma	0.188	0.0500	0.1897	0.2061	0.1291	0.2814

Note: The posterior distribution is obtained using the Metropolis-Hastings algorithm.

Table 1B. Prior and Posterior Distribution of Shock Processes

			Prior distribution			Posterior distribution			
			Distr.	Mean	St. Dev.	Mode	Mean	5 percent	95 percent
ε_z	ez	Standard deviation (shock) of the total factor productivity (technology)	invg	0.007	Inf	0.0041	0.0048	0.0025	0.0070
ε_g	eg	Standard deviation (shock) of the government spending	invg	0.148	Inf	0.1441	0.1470	0.1250	0.1688
ε_r	er	Standard deviation (shock) of the interest rate	invg	0.043	Inf	0.0273	0.0328	0.0196	0.0456
ρ_z	rhoz	Autoregressive parameter on evolution of the total factor productivity (technology)	beta	0.774	0.1000	0.7943	0.7783	0.6780	0.8805
ρ_g	rhog	Autoregressive parameter on government expenditures process	beta	0.842	0.0500	0.8143	0.8089	0.7212	0.8984
ρ_r	rhor	Autoregressive parameter on the lagged interest rate	beta	0.990	0.0010	0.9901	0.9900	0.9884	0.9917

Note: The posterior distribution is obtained using the Metropolis-Hastings algorithm.

Figures

Figure 1. A Small Closed Economy Model

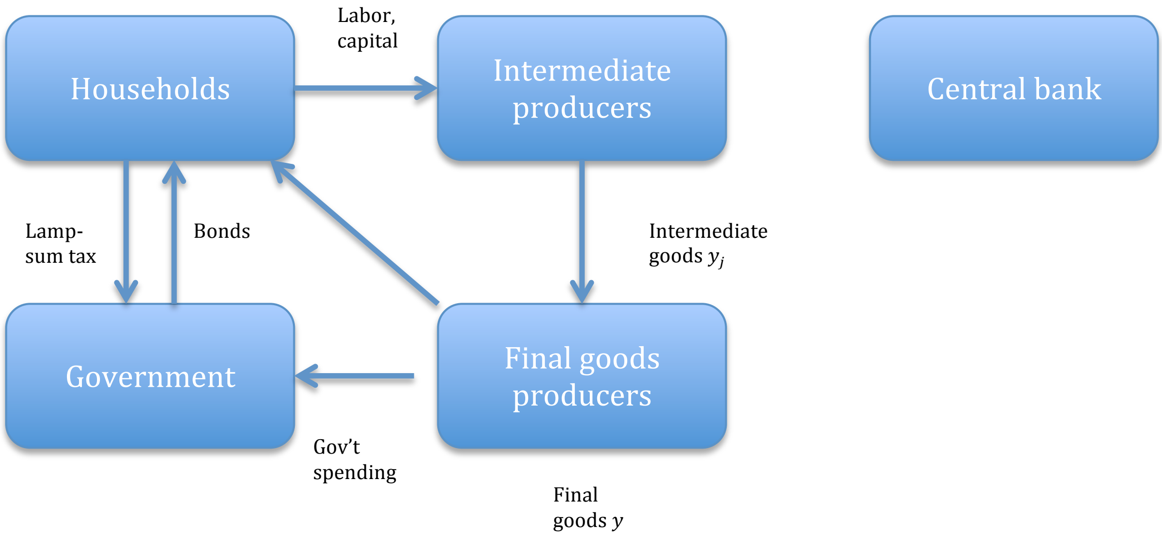


Figure 2A. Estimated Parameter Distribution

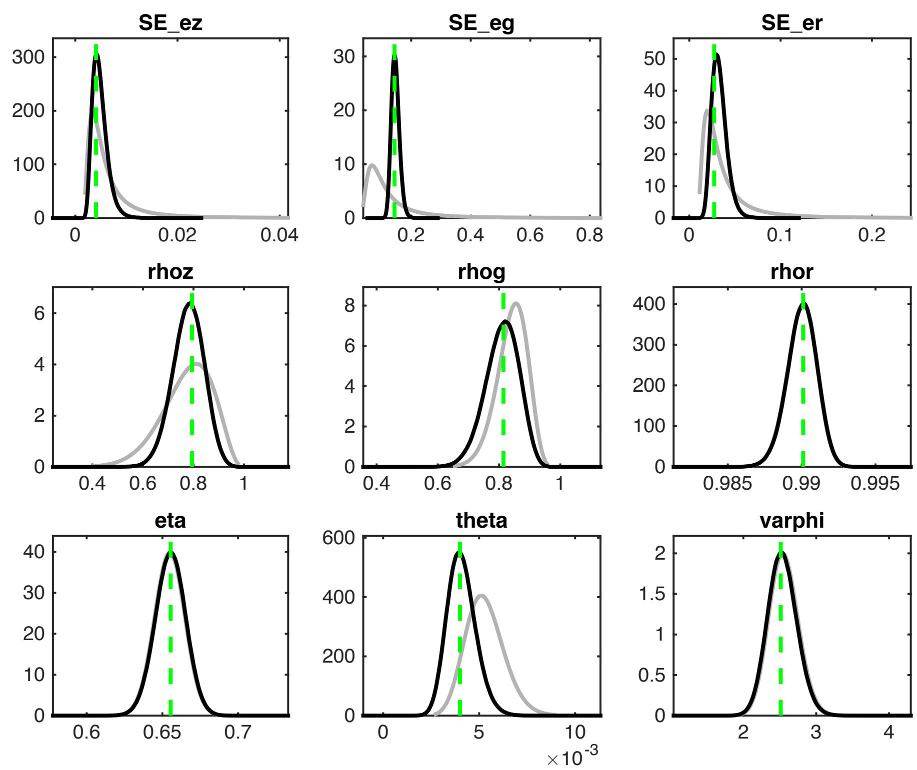
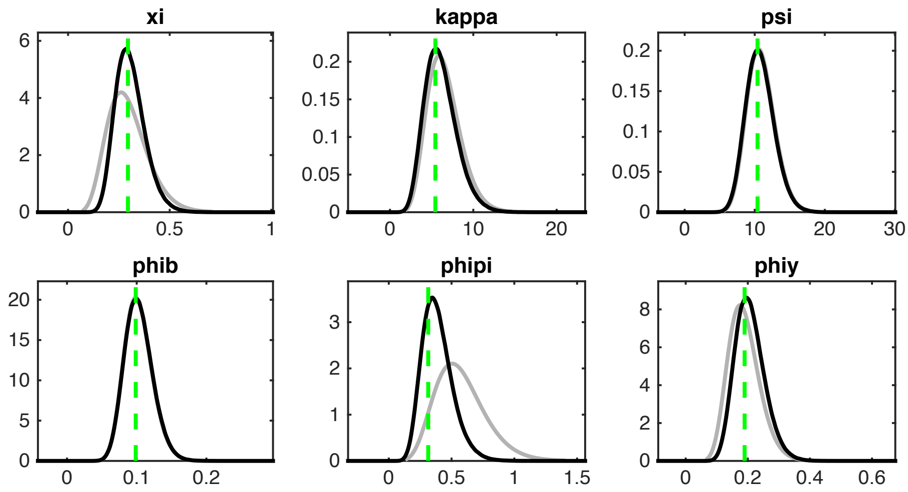


Figure 2B. Estimated Parameter Distribution



Appendices

Appendix 1. Log-Linear Equilibrium Conditions

$$\hat{c}_t = E_t\hat{c}_{t+1} - \frac{1}{\theta}(\hat{r}_t - E_t\hat{\pi}_{t+1})$$

$$\hat{n}_t = \frac{1}{\varphi}\widehat{w}_t - \frac{\theta}{\varphi}\hat{c}_t$$

$$\widehat{m}_t = \frac{\theta}{\xi}\hat{c}_t - \frac{1}{\xi(R-1)}\hat{r}_t$$

$$\hat{\imath}_t = \frac{1}{1+\beta}\hat{\imath}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{\imath}_{t+1} + \frac{\kappa}{1+\beta}\hat{q}_t$$

$$\hat{q}_t = E_t\hat{\pi}_{t+1} - \hat{r}_t + \frac{r^k}{1+r^k-\delta}E_t\hat{r}^k_{t+1} + \frac{1-\delta}{1+r^k-\delta}E_t\hat{q}_{t+1}$$

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \frac{(1-\eta)(1-\beta\eta)}{\beta}[(1-\propto)\widehat{w}_t + \propto \hat{r}^k_t - \hat{z}_t]$$

$$\hat{y}_t = \hat{z}_t + \propto \hat{k}_{t-1} + (1-\propto)\hat{n}_t$$

$$\hat{n}_t - \hat{k}_{t-1} = \hat{r}^k_t - \widehat{w}_t$$

$$k_t = (1-\delta)\hat{k}_{t-1} + \delta\hat{\imath}_t$$

$$\hat{b}_t = R\hat{b}_{t-1} + \frac{Rb}{y}\hat{r}_{t-1} - \frac{Rb}{y}\hat{\pi}_t + \hat{g}_t - \hat{\tau}_t$$

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{i}{y}\hat{\imath}_t + \hat{g}_t$$

$$\hat{\tau}_t = \phi_b\hat{b}_{t-1}$$

$$\hat{g}_t = \rho_g\hat{g}_{t-1} + \varepsilon_{gt}$$

$$\hat{z}_t = \rho_g\hat{z}_{t-1} + \varepsilon_{zt}$$

$$\hat{r}_t = \rho_r\hat{r}_{t-1} + \phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + \varepsilon_{rt}$$

References

1. Adjemian, Stéphane, Houtan Bastani, Michel Juillard, Frédéric Karamé, Junior Maih, Ferhat Mihoubi, George Perendia, Johannes Pfeifer, Marco Ratto and Sébastien Villemot (2011), "Dynare: Reference Manual, Version 4", Dynare Working Papers, 1, CEPREMAP.
2. Adolfson, M., S. Laseen, J. Linde and M. Villani (2007). "Bayesian estimation of an open economy DSGE model with incomplete pass-through". Journal of International Economics 72 (2), 481-511.
3. Adolfson, M., S. Laseen, J. Linde and M. Villani (2008). "Evaluating an estimated new Keynesian small open economy model". Journal of Economic Dynamics and Control 32 (8), 2690-2721.
4. Aguiar, M. and G. Gopinath (2007). "Emerging Market Business Cycles: The Cycle Is the Trend". Journal of Political Economy. Vol. 115. № 1. P. 69-102.
5. Aiyagari, S. R., L.J. Christiano and M. Eichenbaum (1992). "The output, employment, and interest rate effects of government consumption". Journal of Monetary Economics. Vol. 30. № 1. P. 73-86.
6. An, Sungbae and Frank Schorfheide (2007). "Bayesian Analysis of DSGE Models". Econometric Reviews, 26 (2-4), 113-172.
7. Ashimov, A.A., Y.V. Borovskii, B.A. Aisakova, B.T. Sultanov and M.A. Onalbekov (2007). "Parametric Regulation of Economic Indicators Volatility on the Basis of a Dynamic Stochastic General Equilibrium Model" (Parametricheskoe regulirovanie volatilnosti ekonomicheskih pokazatelei na baze odnoi dinamicheskoi stohasticheskoi modeli obshego ravnovesiya). Econometric Reviews, 26 (2-4), 113-172.
8. Atabaev, Nurlan and Junus Ganiyev (2013). "VAR Analysis of the Monetary Transmission Mechanism in Kyrgyzstan". May. *Eurasian Journal of Business and Economics, 6*(11), pp. 121-134.
9. Blanchard, O.J. and C.M. Kahn (1980). "The Solution of Linear Difference Models under Rational Expectations". Econometrica, 48, 5, P. 1305-1311.
10. Calvo, Guillermo A. and Carmen M. Reinhart (2002). "Fear of Floating". Quarterly Journal of Economics. Vol. 2. No. 117. P. 379–408.
11. Calvo, Guillermo A. (1983). "Staggered Prices in a Utility-Maximizing Framework". Journal of Monetary Economics, September, vol. 12 (3), P. 383-398.
12. Chari, V.V., Patrick J. Kehoe and Ellen R. McGrattan (2005). "A critique of structural VARs using business cycle theory". Federal Reserve Bank of Minneapolis, Research Department Working Paper 631.
13. Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy". Journal of Political Economy, Vol. 113(1). P. 1-45.
14. Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy". Journal of Political Economy, Vol. 113(1). P. 1-45.
15. Christiano, Lawrence J., M. Eichenbaum and R. Vigfusson (2006). "Assessing structural VARs". NBER Macroeconomics Annual, 21, P. 1-72.
16. Christiano, Lawrence J., M. Trabandt and K. Walentin (2010). "DSGE Models for Monetary Policy Analysis". NBER Working Paper Series, 16074.

17. De Walque, G., Franc Smets and Raf Wouters (2006). "Firm-specific production factors in a DSGE model with Taylor price setting". International Journal of Central Banking. Vol. 2. № 3. P. 107–154.
18. DeJong, D.N., B.F. Ingam and C.H. Whiteman (2000). "A Bayesian approach to dynamic macroeconomics". Journal of Econometrics 98 (2), P. 203-223.
19. Del Negro, M. and F. Schorfheide (2008). "Forming priors for DSGE models (and how it affects the assessment of nominal rigidities)". Journal of Monetary Economics 55 (7), P. 1191-1208.
20. Dib, A. (2001). "An estimated Canadian DSGE model with nominal and real rigidities". Bank of Canada. Working Paper. 26 p.
21. Fernández-Villaverde, J. and J.F. Rubio-Ramirez (2004). "Comparing dynamic equilibrium models to data: a Bayesian approach". Journal of Econometrics. Vol. 123 (1), P. 153-187.
22. Fernández-Villaverde, J. and J.F. Rubio-Ramirez (2005). "Estimating dynamic equilibrium economies: linear versus nonlinear likelihood". Journal of Applied Econometrics. 20. P. 891-910.
23. Fernández-Villaverde, Jesus, Juan F. Rubio-Ramirez, Thomas J. Sargent and Mark W. Watson (2007). "The ABC and (D's) of understanding VARs". American Economic Review, June, 97(3), P. 1021-1026.
24. Fernández-Villaverde, Jesus (2009). "The Econometrics of DSGE Models". National Bureau of Economic Research. Working Paper. No. 14677. January.
25. Gali, J., J.D. Lopez-Salido and J. Valles (2003). "Technology shocks and monetary policy: assessing the Fed's performance". Journal of Monetary Economics, 50(4), P. 723-743.
26. Galí, J. and M. Gertler (2007). "Macroeconomic Modeling for Monetary Policy Evaluation". Journal of Economic Perspectives, 21, 4, P. 25-45.
27. Galí J., López-Salido J. D., Vallés J. (2007). "Understanding the effects of government spending on consumption". Journal of the European Economic Association. Vol. 5. № 1. P. 227-270.
28. Galí, Jordi (2008). "Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework", Princeton: Princeton University Press, 203 p.
29. Galí, Jordi (2008). "The New Keynesian Approach to Monetary Policy Analysis: Lessons and New Directions". CREI and Universitat Pompeu Fabra, February. 16 p.
30. Geweke, J. (1999). "Using simulation methods for Bayesian econometric models: inference, development and communication". Econometric Reviews. Vol. 18 (1). P. 1–73.
31. Griffoli, Tommaso Mancini (2007-2008). "Dynare User Guide: An Introduction to the solution and estimation of DSGE models". Public beta version.
32. Hamilton, J.D. (1994). "Time Series Analysis", Princeton: Princeton University Press, 820 p.
33. Heer, B. and A. Maußner (2009). "Dynamic General Equilibrium Modeling: Computational Methods and Applications", 2nd ed., Berlin: Springer, 704 p.
34. Ivashenko S.M. (2010). "The application of dynamic stochastic model of general economic equilibrium for the analysis of inflation in Russia and the US" ("Primenenie dinamicheskoi stohasticheskoi modeli obshego ekonomicheskogo ravnovesiya dlya analiza inflyatcionnyh protcessov v

Rossii I S.SH.A.”). Peter the Great St.Petersburg polytechnic University Press. No. 6. P. 305-309.

35. Jenish, Nurbek and Asel Kyrgyzbaeva (2012). “On the Possibility of Inflation Targeting in Kyrgyzstan". University of Central Asia, Graduate School of Development, Institute of Public Policy and Administration. Working Paper No.8., 60 p.
36. Jones Callum and Mariano Kulish (2014). “A practical Introduction to DSGE Modeling with Dynare". Quantile, February No.12, P. 23-44.
37. Juselius, K. and M. Franchi (2007). “Taking a DSGE Model to the Data Meaningfully", Economics: The Open-Access, Open-Assessment E-Journal, 1, 4, 1-38.
38. Kim, J. (2000). “Constructing and estimating a realistic optimizing model of monetary policy”. Journal of Monetary Economics 45 (2), P. 329-359.
39. Kuo, Chun-Hung and Hiroaki Miyamoto “An Estimated DSGE Model with Unemployment and Wage Rigidity for Japan’s Economy” (forthcoming).
40. Lucas, R.E. (1976). “Econometric Policy Evaluation: A Critique”, Carnegie-Rochester Conference Series on Public Policy, 1, 1, P. 19-46.
41. Mankiw, N. Gregory (2016). “Macroeconomics”, 9th International Edition. Worth Publishers. 642 p.
42. Medina J.P., and C. Soto (2005). “Oil Shocks and Monetary Policy in an Estimated DSGE Model for a Small Open Economy”. Central Bank of Chile. 40 p.
43. Medina J.P., and C. Soto (2006). “Model for Analysis and Simulations: A Small Open Economy DSGE for Chile”. Central Bank of Chile. 47 p.
44. Medina J.P., and C. Soto (2007). “The Chilean business cycle through the lens of a stochastic general equilibrium model”. Central Bank of Chile. Working Papers. No. 457.
45. Mikusheva Anna (2014). “Estimation of dynamic Stochastic General Equilibrium Models". Quantile, February No.12, P. 1-21.
46. Mukhamediev B.M. and T.I. Kakizhanova (2014). “Modeling of oil revenues impact to the dynamics of main macroeconomic indicators of Kazakhstan”. Al-Farabi Kazakh National University. KazNU Bulletin, Economics series № 1 (101). P. 3-12.
47. Murchison, S. and A. Rennison (2006). “ToTEM: The Bank of Canada's new quarterly projection model”. Bank of Canada.
48. Oshchepkov Ivan (2006). “The Review of Russian Experience in Macroeconomic Modeling using DSGE Models”. Bank of Canada.
49. Rabanal, P. and J. Rubio-Ramirez (2005). “Comparing new Keynesian models of the business cycle: a Bayesian approach”. Journal of Monetary Economics 52, P. 1151-1166.
50. Rotemberg, J., and M. Woodford (1997). “An optimization-based econometric framework for the evaluation of monetary policy”. National Bureau of Economic Research. Macroeconomics annual, 12, 297.
51. Ruge-Murcia, F.J. (2007). “Methods to Estimate Dynamic Stochastic General Equilibrium Models”. Journal of Economic Dynamics and Control, 31, 8, P. 2599-2636.
52. Schmitt-Grohé, Stephanie and Martin Uribe (2003). “Closing small open economy models”. Journal of International Economics, 61 (1), P. 163–185.

53. Smets, Franc and Rafael Wouters (2003). “An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area”. Journal of the European Economic Association, September. Vol. 1(5). P. 1123-1175.
54. Smets, Franc and Rafael Wouters (2005). “Comparing shocks and frictions in US and euro area business cycles: a Bayesian DSGE approach”. Journal of Applied Econometrics 20 (2), P. 161-183.
55. Smets, Franc and Rafael Wouters (2007). “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach”. The American Economic Review, American Economic Association. June. Vol. 97 (3). P. 586–606.
56. Stock, James H. and Mark W. Watson (2001). “Vector Autoregressions”. The Journal of Economic Perspectives, Fall, Volume 15, Number 4: P. 101–115.