MODELLING THE IMPACT OF EXTERNAL SHOCKS ON ECONOMY OF UKRAINE: DSGE APPROACH

Olena Bazhenova*, Yuliya Bazhenova
Taras Shevchenko National University of Kyiv, Ukraine

Abstract. *The paper explores the dynamic stochastic general equilibrium model to study the impact of external shocks on the economy of Ukraine. The dynamic stochastic general equilibrium model is constructed for a small open economy that includes households, firms (domestic manufacturers and importers), government, the National Bank and external sector. The model assumes the new-Keynesian approach that includes the so-called "rigidities" of prices and wages, the existence of the households' consumption habits and investments with adjustment costs. Also, it takes into account the country's significant dependence on mineral products imports. All goods in the economy are divided into the domestic ones (that are exported and consumed in the country), imports and mineral products. So the purpose of the model is to study the impact of external shocks on the economy of Ukraine, such as a positive shock in world output, a positive shock in the world aggregate demand, a positive shock in the world interest rate, and a positive shock in world prices.*

Key words: *DSGE model, small open economy, nominal rigidities, external sustainability, external economic shocks*

Introduction

The econometric toolset had been playing the leading role in the economic models construction before the mid of 1970s. As mentioned in (Cantore and others, 2013), it was common to evaluate the "Keynesian reduced form behavioural equations" that along with the basic macroeconomic identities formed a "large" model.

The article "Econometric Policy Evaluation: A Critique" by Robert E. Lucas (Lucas, 1976) published in 1976 was a powerful spur to further the development of methods of economic and mathematical modelling, as it explored the failure to forecast macroeconomic trends based on econometric models, given the change of economic policy. According to Lukas, predictions based on macroeconomic models that rely on past relationships between variables are not reliable. He believed that if structure econometric model is conditioned by "optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models" (Lucas, 1976).

* *Corresponding author:*
Faculty of Economics, Department of Economic Cybernetics, Taras Shevchenko National University of Kyiv, Vasylkivska str. 90A, Kyiv, 03022, Ukraine
E-mail: bazhenova_elena@univ.kiev.ua

Also, the appearance of the so-called "theory of rational expectations" played a key role in the development of economic and mathematical modelling methods. This theory represents a set of assumptions about the economic agents' way of using all available information to predict. For example, according to one of the theory of rational expectations founders John F. Muth, "expectations of firms (or, more generally, the subjective probability distribution of outcomes) tend to be distributed, for the same information set, about the prediction of the theory (or the "objective" probability distributions of outcomes)" (Muth, 1961).

Thus, the appearance of Lukas' Critique and the theory of rational expectations were the impetus for the development of the so-called dynamic stochastic general equilibrium models (DSGE models). These models are based on microeconomic interactions of rational agents such as households, firms and government (Vasylenko, Bazhenova, 2014). Forerunner of DSGE models was the theory of real economic cycles developed by Finn Kydland and Edward Prescott (Kydland, Prescott, 1977).

Literature review

There is a large amount of publications devoted to the construction of dynamic stochastic general equilibrium (DSGE) models. It is worth noting the papers of F.Kydland and E.Prescott (Kydland, Prescott, 1982), L.J.Cristiano, M.Eichenbaum and C.Evans (Christiano, Eichenbaum, Evans, 2005), B.Bernanke, M.Gertler, S.Gilhrist (Bernanke, Gertler, Gilhrist (1998), F.Smets and R.Wouters (Smets, Wouters, 2002), J.Rotemberg and M.Woodford (Rotemberg, Woodford, 1997), M.Del Negro and F.Schorfheide (Del Negro, Schorfheide, 2002, 2008), G. Calvo (Calvo, 1983), R.Clarida, J.Gali and M.Gertler (Clarida, Gali, Gertler, 1999, 2001), J.Gali and T.Monachelli (Gali, Monacelli, 2005), J.Fernández-Villaverde (Fernández-Villaverde, 2009) and many others.

However, one of the most cited publications devoted to constructing of DSGE models is paper of F.Smets and R.Wouters (Smets, Wouters, 2002). The authors constructed new-Keynesian dynamic stochastic general equilibrium model for the euro area and assessed it using Bayesian methods. The results of simulations witnessed a significant level of price rigidity in the euro area.

Among the achievements of Ukrainian scientists, it should be noted the papers of Yu.Bazhenova (Bazhenova, 2009), I.Lukianenko and R.Semko (Lukianenko, Semko, 2010; Lukianenko, Semko, 2015) devoted to the construction of DSGE models for the economy of Ukraine to determine the effects of monetary and fiscal policy, fluctuations in the stock market and other financial researches. Thus, the DSGE models have not been used to model the external shocks impact on Ukraine's economy.

DSGE models have often been used to study the impact of different external economic shocks on the country's economy. In particular, most models are devoted to studying the effect of oil price shock caused by the oil crisis in the 1970s-1980s.

In (Gali, Monacelli, 2005) authors used the new-Keynesian model of a small open economy to analyse the effects of monetary policy regimes. Unlike other DSGE models, this one most fully represents the relationship of a country with the outside world including international trade and capital flows. In particular, the model covers the following variables of outside world: world output, consumption of imported commodities from partner countries, consumer price indices of partner countries, world price index, bilateral and effective terms of trade, bilateral and effective nominal and real exchange rates, uncovered interest rate parity.

A.Barnett and R.Straub (Barnett, Straub, 2008) explores the driving forces of the current account balance in the US as a country that imports oil and uses this resource in the production of intermediate and final goods. Along with the internal shocks, external disturbances are modelled in the form of oil price shock, given its exogenous nature. It is shown that a positive shock of oil prices results in GDP growth and inflation decrease.

O.Blanchard and J.Gali (Blanchard, Gali, 2008) analysed the impact of oil price shock on the economy during the 1970s–2000s and explained different responses to this shock during this period by the means of constructing the DSGE model of the economy that imports oil and uses it in production and consumption subject to the real wage rigidity.

J.Jaaskela and D.Jennings (Jaaskela, Jennings, 2010) built a dynamic stochastic general equilibrium model of a small open economy for Australia. This model considers separately the external sector (in the form of a large economy – the USA) described by Phillips curve, IS curve and Taylor rule that determines the foreign monetary policy and by the equation depicting the GDP gap. The external sector also contains aggregate foreign demand shock and foreign monetary policy shock. In the domestic sector, unlike many models, it presented the terms of trade that are proportionate to the real exchange rate.

The model in (Polbin, 2013) investigates an open economy that depends on oil and gas exports (energy commodities) that are used in domestic production and are exported. The focus is to research the impact of the shock in world oil prices, disregarding other shocks, for example, the exchange rate shock. The author also examines the impact of a 10-percent increase in world oil prices on macroeconomic indicators. It is shown that this shock leads to real GDP growth in the short run at 0.5%, total exports – by 6% and the current account in the initial period – by 1.8%. However, there is a decline of production and exports in the sector of traded goods production.

Shulgin (Shulgin, 2013) estimates the DSGE model for a small open economy of oil exporting country (Russia) to study the impact of currency and monetary policy rules on the economy. The author analyses the response function of “real” and “financial” economy on the oil shock, the external interest rate shock and foreign exchange rate policy shock.

Thus, **the aim** of the article is to model the impact of external shocks on Ukraine’s economy by estimating the dynamic stochastic general equilibrium (DSGE) model as a small open economy model with a significant dependence on energy imports.

Constructing the DSGE model for Ukraine's economy

The paper explores dynamic stochastic general equilibrium model of a small open economy that includes households, firms (domestic manufacturers and importers), government, the National Bank and the external sector. The model is constructed according to the new-Keynesian approach that includes the so-called "rigidities" of prices and wages, the existence of the households' consumption habits and investments with adjustment costs. The significant country's dependence on mineral products imports is also taken into account. All goods in the economy are divided into the domestic ones (that are exported and consumed in the country), imports and mineral products.

The households. The households are considered to be homogeneous in the context of goods and services consumption and assets' ownership and heterogeneous on wage and worked hours in equilibrium (Christiano, Eichenbaum, Evans, 2005). Although there are other assumptions concerning the identity of households and identical decisions made by them "regarding the managed variables" (Polbin, 2013).

Therefore, we consider a representative household that consumes goods and services, accumulates capital assets that are invested, owns domestic and foreign bonds, payment of which can be considered as savings of prior period, saves in the form of cash balances and supplies some amount of labour to firms. In addition, households receive salaries according to worked hours, income from invested capital, social transfers, payments on bonds, income from deposited money in the previous period. The representative household maximizes expected utility that is determined by the consumption of goods and services, labour supply and real balances.

Thus, the representative household maximizes instantaneous expected utility function that is a modification of functions proposed in (Smets, Wouters, 2002), (Christiano, Eichenbaum, Evans, 2005), (Fernández-Villaverde, 2009), (Polbin, 2013), (Lukianenko, Semko, 2010), (Shulgin, 2013), where utility at time t defines as

$$U_t = \varepsilon_t^c \frac{(c_t - h_t)^{1-\sigma_c}}{1-\sigma_c} - \varepsilon_t^l \frac{l_t^{1+\sigma_l}}{1+\sigma_l} + \varepsilon_t^m \frac{\left(\frac{M_t}{P_t}\right)^{1-\sigma_m}}{1-\sigma_m}. \quad (1)$$

Here c_t represents consumption at time t, h_t – variable that defines consumption habits at time t, l_t – labour supply at time t, $\frac{M_t}{P_t}$ – real balances at time t, ρ – discount rate, ε_t^c – consumption shock at time t, ε_t^l – shock to labour supply at time t, ε_t^m – money demand shock at time t, σ_c – coefficient of relative risk aversion of household, σ_l – inverse of the elasticity of labour efforts with respect to real wage, σ_m – inverse of the real balances elasticity with respect to the interest rate.

Following (Smets, Wouters, 2002) we assume that consumption habits at time t depend on consumption in previous period (t – 1):

$$h_t = hc_{t-1}. \quad (2)$$

Thus, the utility of households depends positively on consumption (less variable that characterises the sustainability of habits in consumption) and real money balances, negatively – from labour supply measured by the number of worked hours.

The household maximizes the expected utility function subject to its budget constraint as in (Bernanke, Gertler, Gilhrist, 1998), (Bazhenova, 2009), (Christiano, Eichenbaum, Evans, 2005), (Smets, Wouters, 2002) and other authors:

$$\begin{aligned} m_t + c_t(1+\tau_t^c) + inv_t + \frac{b_t^h}{1+E_t i_{t+1}^h} + \frac{S_t b_t^f}{1+E_t i_{t+1}^f} = \\ = w_t l_t (1-\tau_t^l) + r_t^K k_t (1-\tau_t^K) + tr_t + \frac{b_{t-1}^h}{\pi_t} + \\ + \frac{S_{t-1} b_{t-1}^f}{\pi_t} + r_t^{DEP} dep_t (1-\tau_t^{dep}) + \frac{m_{t-1}}{\pi_t}, \end{aligned} \quad (3)$$

where m_t – real money demand at time t that defines as $\frac{M_t}{P_t}$, τ_t^c – consumption tax at time t, inv_t – real investments at time t, b_t^h – real demand for domestic bonds at time t, S_t – nominal exchange rate at time t, b_t^f – real demand for foreign bonds denominated in foreign currency at time t, i_{t+1}^h – nominal interest rate on domestic bonds at time $t + 1$, i_{t+1}^f – nominal interest rate on foreign bonds denominated in foreign currency at time $t + 1$, w_t – real wage at time t, τ_t^l – wage tax rate at time t, r_t^K – price for renting the capital at time t, k_t – capital stock at time t, τ_t^K – capital tax rate at time t, tr_t – social transfers from central budget at time t, π_t – inflation rate at time t, r_t^{DEP} – interest rate on deposits at time t, dep_t – real demand for deposits at time t, τ_t^{dep} – deposits tax rate at time t. Also it may be used price level instead of inflation rate π_t.

Thus, a household holds its savings in the form of real balances, one-period domestic bonds and foreign currency denominated bonds bought at foreign markets with interest rates i_t^h and i_t^f accordingly.

Solving the first-order conditions of maximization problem of expected utility function (1) subject to budget constraint (3) yields:

$$m_t = \left(\frac{\varepsilon_t^m}{\varepsilon_t^c} \left(1+\tau_t^c\right) (c_t - h_t)^{\sigma_c} \frac{1+E_t i_{t+1}^h}{E_t i_{t+1}^h} \right)^{\frac{1}{\sigma_m}} \quad (4)$$

$$w_t = \frac{\varepsilon_t^l}{\varepsilon_t^c} \frac{1+\tau_t^c}{1-\tau_t^l} l_t^{\sigma_l} (c_t - h_t)^{\sigma_c} \quad (5)$$

$$1 = \rho\left[\frac{E_t\lambda_{t+1}}{\lambda_t} \cdot \frac{1 + E_t i_{t+1}^h}{E_t \pi_{t+2}}\right] \tag{6}$$

$$\lambda_t = \varepsilon_t^c \frac{(c_t - h_t)^{-\sigma_c}}{1 + \tau_t^c} \tag{7}$$

Here equation (4) represents money demand equation, equation (5) is the labour supply function, equation (6) is Euler equation and equation (7) shows the consumption marginal utility. And inflation in time *t* equals

$$\pi_t = \frac{P_t}{P_{t-1}} \tag{8}$$

Assuming the existence of wages and prices rigidities, we use Calvo model (Calvo, 1983) that implies an alteration in wages and prices in every moment of time by some households and firms. As mentioned in (Polbin, 2013) other pricing mechanisms (for example, one of Rotemberg) lead to the same model equations after its log-linearization.

So, following (Erceg, Henderson, Levin, 2000), (Smets, Wouters, 2002), (Bazhenova, 2009) we assume the existence of wage setting according to Calvo (Calvo, 1983). Provided by this wage setting mechanism let household *i* sets the wage at the level $\widetilde{W}_t^i$ with the probability $(1 - \xi_w)$ and with probability ξ_w – $W_t^i = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_w} W_{t-1}^i$, where γ_w is a degree of wage indexation that varies from zero to one (Smets, Wouters, 2002), (Bazhenova, 2009).

In an aggregated form due to the principle of Dixit-Stiglitz (Dixit, Stiglitz, 1977) we have:

$$W_t = \left[(1 - \xi_w)(\widetilde{W}_t)^{1-\chi_w} + \xi_w \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{t-1} \right)^{1-\chi_w} \right]^{\frac{1}{1-\chi_w}}, \tag{9}$$

where χ_w is an elasticity of substitution between households.

At the same time households set nominal wage maximizing expected utility subject to budget constraints and labour demand function:

$$l_t^i = \left(\frac{W_t^i}{W_t}\right)^{-\chi_w} l_t \tag{10}$$

Hence solving the maximization problem it yields:

$$\widetilde{w}_t = \left(-\frac{\chi_w \sigma_c}{(1+\sigma_l \chi_w)} \frac{E_t \sum_{k=0}^{\infty} (\rho \xi_w)^k \left(\varepsilon_{t+k}^l l_{t+k}^{\sigma_l + 1} w_{t+k}^{\chi_w (\sigma_l + 1)} \right)}{E_t \sum_{k=0}^{\infty} (\rho \xi_w)^k \left(\varepsilon_{t+k}^c (c_{t+k} - h_{t+k})^{1-\sigma_c} \right)} \right)^{1/\chi_w (1+\sigma_l)} \tag{11}$$

Thus the equation (9) can be modified in the following way:

$$W_t = \left[(1-\xi_w)(\widetilde{w}_t)^{1-\chi_w} + \xi_w \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{t-1} \right)^{1-\chi_w} \right]^{\frac{1}{1-\chi_w}} \tag{12}$$

Domestic goods manufacturers. The model assumes the presence of domestic firms that produce intermediate consumption goods and operate at the market of monopolistic competition.

Production function of a representative domestic firm *m* that produces a differentiated good *m* is a function with a technological progress that augments labour (neutral by Harrod):

$$y_t^m = (k_t^m)^{\alpha} (\varepsilon_t^z l_t^m)^{\beta}, \tag{13}$$

where y_t^m represents output of domestic good *m* at time *t*, k_t^m represents capital costs for the production of domestic good *m* at time *t*, l_t^m denotes labour costs for the production of domestic good *m* at time *t*, ε_t^z is a technological shock at time *t*, α is an elasticity of output with respect to capital and β is an elasticity of output with respect to labour.

At the same time demand for good *m* from firms that use it to produce final goods equals

$$y_t^m = \left(\frac{P_t^m}{P_t} \right)^{-\chi_p} y_t, \tag{14}$$

where P_t^m – price of the product *m*, χ_p – elasticity of substitution between goods and y_t – aggregate output of goods in real terms at time *t*.

Setting prices for intermediate goods as in the case of wage setting follows Calvo pricing mechanism.

So for good *m* firm sets the price $\widetilde{P}_t^m$ with probability $1-\xi_p$ and price $\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} P_{t-1}^m$ with ξ_p probability where γ_p is a degree of indexation that alters from zero to one (Smets, Wouters, 2002).

The optimal price is based on the solution of the maximization problem of the net present value of the firm's profit relative to the good *m*:

$$\widetilde{P}_t^m = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{E_t \sum_{k=0}^{\infty} (\rho \xi_p)^k \frac{P_{t+k}^{\varepsilon_p + 1} y_{t+k} mc_{t+k}}{\prod_{s=1}^{k} (1 + i_{t+s})}}{E_t \sum_{k=0}^{\infty} (\rho \xi_p)^k \frac{P_{t+k}^{\varepsilon_p} y_{t+k}}{\prod_{s=1}^{k} (1 + i_{t+s})}} \tag{15}$$

Accordingly, the aggregate price level is defined as follows:

$$P_t = \left[(1 - \xi_p)(\widetilde{P}_t^m)^{1-\varepsilon_p} + \xi_p \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} P_{t-1} \right)^{1-\varepsilon_p} \right]^{\frac{1}{1-\varepsilon_p}} \tag{16}$$

Importers of goods and services. The economy also imports goods with prices that are set, as according to Calvo pricing mechanism. Thus, the importer of good *m* sets the price $\widetilde{P}_t^{mf}$ with probability $1 - \xi_p^f$ and $\left(\frac{P_{t-1}^f}{P_{t-2}^f} \right)^{\gamma_p^f} P_{t-1}^{m\,f}$ with probability ξ_p^f, where γ_p^f is the level of indexation and varies from zero to one.

The optimal price in this case is based on maximizing the net present value of net cash flow (Bazhenova, 2009):

$$\widetilde{P}_t^{mf} = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{E_t \sum_{k=0}^{\infty} (\rho \xi_p^f)^k \left(\frac{P_{t+k}^{f\ \varepsilon_p + 1} c_{t+k}^f \psi_{t+k}}{\prod_{s=1}^{k} (1 + i_{t+s})} \right)}{E_t \sum_{k=0}^{\infty} (\rho \xi_p^f)^k \left(\frac{P_{t+k}^{f\ \varepsilon_p} c_{t+k}^f}{\prod_{s=1}^{k} (1 + i_{t+s})} \right)}, \tag{17}$$

where c_t^f is a real consumption demand for imports in domestic economy at time *t* and ψ_t represents one price gap at time *t*.

Accordingly, the aggregate price level for imported goods is determined as follows:

$$P_t^f = \left[(1 - \xi_p^f)(\widetilde{P}_t^f)^{1-\varepsilon_p} + \xi_p^f \left(\left(\frac{P_{t-1}^f}{P_{t-2}^f} \right)^{\gamma_p^f} P_{t-1}^f \right)^{1-\varepsilon_p} \right]^{\frac{1}{1-\varepsilon_p}} \tag{18}$$

Thus, the aggregate price level in the economy equals:

$$P_t^T = \left[\left(1-\alpha_p\right)\left(P_t\right)^{1-\eta} + \alpha_p \left(P_t^f\right)^{1-\eta} \right]^{\frac{1}{1-\eta}}. \tag{19}$$

Investments. The model assumes that households own the firms that attract additional funding increasing the authorised capital by additional issue of shares. Although, it should be noted that according to the Modigliani-Miller theorem provided perfect financial markets and the absence of taxes "capital market valuation does not depend on the method of financing investment" (Polbin, 2013). However, as taxable income from invested capital is given by $r_t^K k_t(1-\tau_t^K)$ in our model the theorem is not satisfied.

Simulating the behaviour of households, we suggest that they invest to optimise capital and to benefit from the firms' ownership, that is, to maximize the difference between the value of the firm and the cost of its capital in current prices. The firms are not able to provide the optimal level of capital immediately due to the presence of the so-called "adjustment costs" (costs that occur when the firm alters the size of the fixed assets).

Thus, capital dynamics equation with adjustment costs is given by:

$$K_t = (1-\delta)K_{t-1} + I_t(1 - s^I(\varepsilon_t^I I_t)) \tag{20}$$

or in real terms:

$$k_t = (1-\delta)k_{t-1} + inv_t(1 - s^I(\varepsilon_t^I inv_t)), \tag{21}$$

where ε_t^I – investment shock at time t, $s^I(\varepsilon_t^I\, inv_t)$ – a positive function that represents adjustment costs for the unit of capital at time t[1] and equals $\frac{s^I}{2}(\varepsilon_t^I inv_t)^2$, δ – depreciation rate.

Thus, the problem of maximizing the expected utility of a household subject to budget constraint should also include the capital dynamics equation. Finding the first order conditions for I_t / P_t and K_{t+1} / P_{t+1} gives the following equalities:

$$\frac{\lambda_t^K}{\lambda_t} = \frac{1}{1 - \frac{s^I}{2}(\varepsilon_t^I inv_t)^2}, \tag{22}$$

$$\frac{\lambda_t^K}{\lambda_t} = \frac{E_t \lambda_{t+1}}{\lambda_t} \rho \left(\left(1 - E_t \tau_{t+1}^K\right) E_t r_{t+1}^K + E_t \frac{\lambda_{t+1}^K}{\lambda_{t+1}} (1-\delta) \right). \tag{23}$$

[1] It is also common in DSGE models to specify adjustment costs determined by the rate of change of investment (Christiano, Eichenbaum, Evans, 2005), (Smets, Wouters, 2002)

As $\frac{\lambda_t^K}{\lambda_t}$ is considered to be value of an additional unit of capital in the case of firms' optimal behaviour, equations (22) and (23) are determined by:

$$Q_t = \frac{1}{1 - \frac{s^I}{2}(\varepsilon_t^I inv_t)^2} \tag{24}$$

$$Q_t = \frac{E_t \lambda_{t+1}}{\lambda_t} \rho \left(\left(1 - E_t \tau_{t+1}^K \right) E_t r_{t+1}^K + E_t Q_{t+1} (1 - \delta) \right). \tag{25}$$

The next step is to find the optimal values of the interest rate on capital and wages based on solving the problem of minimizing the costs of the firm that include capital ($r_t^K k_t$) and labour ($w_t l_t$) costs. Thus we have:

$$r_t^K = mc_t (\varepsilon_t^z)^\beta \alpha k_t^{\alpha-1} l_t^\beta \tag{26}$$

$$w_t = mc_t (\varepsilon_t^z)^\beta \beta k_t^\alpha l_t^{\beta-1} \tag{27}$$

Aggregate demand. Output of goods and services in economy y_t is determined by domestic demand for manufactured goods and services E_t and demand from foreign customers E_t^* (export of domestic goods and services):

$$y_t = E_t + E_t^* \tag{28}$$

The demand from foreign consumers for domestic products is given by:

$$E_t^* = \alpha_p \left(\frac{S_t P_t}{\varepsilon_t^{P*} P_t^*} \right)^{-\eta} (\varepsilon_t^{E*} E_t^{*T}), \tag{29}$$

where P_t^* represents price level abroad at time t, ε_t^{P*} is a shock of price level abroad at time t, E_t^{*T} shows aggregate demand of foreign consumers at time t and ε_t^{E*} is a shock in aggregate demand of foreign consumers at time t.

Domestic demand of households for domestic and imported goods and services is found by solving the problem of minimizing the costs on consumption (Bazhenova, 2009):

$$\min_{E_t^T} P_t^T E_t^T = \min_{\{E_t, E_t^f\}} \left(P_t E_t + P_t^f E_t^f \right), \tag{30}$$

Hence, domestic demand for domestic goods and services at the moment t is given by:

$$E_t = \left(1 - \alpha_p\right) \left(\frac{P_t}{P_t^T} \right)^{-\eta} E_t^T, \tag{31}$$

73

where E_t^T is an aggregate demand for domestic goods and services at domestic and foreign markets at time t, α_p is a propensity to consume foreign goods, η represents elasticity of substitution between consumption of foreign and domestic goods.

Demand for imported goods and services at time t E_t^f equals to:

$$E_t^f = \alpha_p \left(\frac{P_t^f}{P_t} \right)^{-\eta} E_t^T \tag{32}$$

On the other hand, aggregate demand is based on the aggregation of demand for domestic and imported goods and services by households with constant elasticity of substitution:

$$E_t^T = \left[(1-\alpha_p)^{\frac{1}{\eta}} E_t^{\frac{\eta-1}{\eta}} + \alpha_p^{\frac{1}{\eta}} E_t^{f\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{33}$$

To determine the impact of energy resources on the economy Ukraine we consider minerals as a single imported good taking into account shock in its price.

Consequently, imports are divided into imports of goods and services $P_t^f E_t^f$ and imports of energy resource $P_t^o O_t$:

$$\mathrm{Im}_t = P_t^f E_t^f + \varepsilon_t^{P^o} P_t^o O_t, \tag{34}$$

where $\varepsilon_t^{P^o}$ represents shock in the price of mineral products imports at time t.

Similar to the results of (Polbin, 2013) when modelling the economy of Ukraine mineral fuel, oil, petroleum products and natural gas are considered as one energy resource and therefore a single good due to its high proportion in imports and large spending on it. Thus, the equation of the dynamics of energy resources prices P_t^o and its consumption O_t at time t (variables are considered in logarithms) suggesting that the economy consumes only imported energy resource given its high price in foreign currency and devaluation trends observed recently:

$$\ln O_t = (1-\rho_o)\ln \overline{O} + \rho_o \ln O_{t-1} + \eta_t^o \tag{35}$$

$$\ln P_t^o = (1-\rho_{P^o})\ln \overline{P^o} + \rho_{P^o} \ln P_{t-1}^o + \eta_t^{P^o}, \tag{36}$$

where $\overline{O}$ and $\overline{P^o}$ are consumption (import) and energy prices in the steady state, η_t^o, $\eta_t^{P^o}$ are disturbances in energy consumption (import) and it price, ρ_o and ρ_{P^o} – parameters.

Equations (35) and (36) are simplifications of processes that occur in the real economy, particularly taking into account the non-stationarity of energy prices. However, they are widely used in the construction of dynamic stochastic general equilibrium models as in (Polbyn, 2013), (Lama, Medina, 2012), (Leduc, Sill, 2012).

Aggregate demand consists of consumption c_t^T, investment inv_t^T and government spending g_t^T:

$$E_t^T = c_t^T + inv_t^T + g_t^T \tag{37}$$

Moreover, the internal demand for domestic goods and services E_t consists of consumption c_t, investment inv_t and government expenditures g_t:

$$E_t = c_t + inv_t + g_t \tag{38}$$

Domestic demand for imported goods and services E_t^f accordingly is given by:

$$E_t^f = c_t^f + inv_t^f + g_t^f. \tag{39}$$

The aggregate consumption demand, investment demand and demand from the government sector are determined due to the principle of Dixit-Stiglitz using functions with constant elasticity of substitution:

$$c_t^T = \left[(1-\alpha_p)^{\frac{1}{\eta}} c_t^{\frac{\eta-1}{\eta}} + \alpha_p^{\frac{1}{\eta}} c_t^{f\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{40}$$

$$inv_t^T = \left[(1-\alpha_p)^{\frac{1}{\eta}} inv_t^{\frac{\eta-1}{\eta}} + \alpha_p^{\frac{1}{\eta}} inv_t^{f\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{41}$$

$$g_t^T = \left[(1-\alpha_p)^{\frac{1}{\eta}} g_t^{\frac{\eta-1}{\eta}} + \alpha_p^{\frac{1}{\eta}} g_t^{f\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{42}$$

External sector. Exploring the trade channel of external disturbances transmission, it seems urgent to consider the terms of trade effects on the economy of Ukraine, taking into account the openness of our economy and dependence on opportunities at commodity markets. As the most important factors of the economic downturn in Ukraine are declining terms of trade due to unfavourable price conditions for domestic exports of goods, especially for metal and agricultural products.

The terms of trade TT_t are determined as the ratio of export prices deflator P_t to import prices deflator P_t^f multiplied by the terms of trade shock ε_t^{TT}:

$$TT_t = \varepsilon_t^{TT} \frac{P_t}{P_t^f}. \tag{43}$$

The terms of trade shock ε_t^{TT} is simulated on the basis of the first order autoregression process.

The real exchange rate s_t is based on the nominal exchange rate S_t and the ratio of price indices in the country P_t and abroad P_t^* including the nominal exchange rate shock ε_t^s, given its significant impact on the behaviour of the economic system of Ukraine:

$$s_t = \frac{\varepsilon_t^S S_t P_t^*}{P_t}. \qquad (44)$$

The nominal exchange rate shock ε_t^s also is simulated as the first order autoregression process.

As known, the basis of purchasing power parity is the law of one price, i.e., "at the efficient market identical goods should have the same price" (Polovnyov, 2008). However, due to various objective reasons in the real economy, it is mostly not traced. Therefore following (Bazhenova, 2009) the model contains one price gap ψ_t that is defined as follows:

$$\psi_t = \frac{S_t P_t^*}{P_t^f}. \qquad (45)$$

Current account balance ca_t (the flow of goods and services pca_t and primary and secondary income between residents and non-residents nfa_t by (Methodological comment to the statistics of the external sector in Ukraine, 2009)) including shock in primary current account ε_t^{PCA} and shock in net foreign assets or "income from foreign investments" (Burda,Wyplosh, 1997) ε_t^{NFA} is given by:

$$ca_t = \varepsilon_t^{PCA} pca_t + \varepsilon_t^{NFA} nfa_t \qquad (46)$$

The primary current account equals the difference between exports E_t^* and imports of goods and services Im_t:

$$pca_t = E_t^* - \mathrm{Im}_t \qquad (47)$$

Following (Polbin, 2013) net foreign assets equal:

$$nfa_t = i_{t-1}^f b_{t-1}^f - b_{t-1}^f - r_{t-1}^* d_{t-1}^* + d_{t-1}^*, \qquad (48)$$

where d_t^* – foreign government debt at time t, r_t^* – interest rate on foreign government loans at time t.

Given the presence of risk associated with investments in domestic assets and restrictions on the movement of capital in Ukraine, the model takes into account both the existence of risk premiums and restrictions on the movement of capital (e.g., restrictions imposed by decree of National Bank of Ukraine №354 "On regulation of the situation at money and foreign exchange markets of Ukraine" dated 3.06.2015). Thus, the equation that describes the uncovered interest rate parity includes risk premium μ_t^P and restrictions on movement of capital φ_t^C:

$$\left((1 + i_t) - (1 + i_t^*) - \frac{E_t S_{t+1} - S_t}{S_t} + \mu_t^P + \varphi_t^C \right) = 0, \qquad (49)$$

Further we assume that μ_t^P and φ_t^C are constant for all t.

Government sector. Government budget constraint is determined by:

$$\frac{d_t^D + S_t d_t^*}{y_t} - \frac{(d_{t-1}^D + S_{t-1} d_{t-1}^*)}{y_t} + \frac{m_{t-1}}{\pi_t y_t} - \frac{m_t}{y_t} = \tag{50}$$
$$= \frac{g_t}{y_t} + \frac{tr_t}{y_t} - \frac{tax_t}{y_t} + (r_t - \gamma_t)\frac{d_{t-1}^D}{\pi_t y_t} + (r_t^* - \gamma_t)\frac{S_t d_{t-1}^*}{\pi_t y_t} + BD_{O,t}$$

Here tax_t are total taxes in real terms at time t, d_t^D – internal public debt at time t, g_t – budget expenditures at time t, r_t – interest rate on domestic government loans at time t, γ_t – growth rate of gross domestic product at time t, $BD_{O,t}$ – part of the budget deficit due to imports of minerals products at time t, $m_t - \frac{m_{t-1}}{\pi_t}$ – income from seigniorage.

In turn, tax revenues to the state budget are made up of consumption taxes $c_t\tau_t^c$, taxes on wages $w_t l_t \tau_t^l$, capital taxes $r_t^K k_t \tau_t^K$ and lump sum taxes τ_t^{ls} as to (Kumhof, Laxton, Muir, Mursula, 2010):

$$tax_t = c_t\tau_t^c + w_t l_t \tau_t^l + r_t^K k_t \tau_t^K + \tau_t^{ls} \tag{51}$$

Total public sector debt is the sum of the internal and external public debts:

$$d_t = d_t^D + d_t^* \tag{52}$$

Given the increasing share of foreign debt and devaluation processes in Ukraine, we calculate the fiscal policy rule as follows:

$$\frac{g_t}{\overline{g}} = \left(\frac{tax_t}{\overline{\overline{tax}}}\right)^{1/\alpha_{tax}} \left(\frac{tr_t}{\overline{\overline{tr}}}\right)^{1/\alpha_{TR}} \left(\frac{d_t^*/E_t^*}{\overline{d^*}/\overline{E^*}}\right)^{1/\alpha_B}, \tag{53}$$

where α_{tax} represents the coefficient that characterizes the propensity of government to finance public expenditures by increasing the tax burden, α_{TR} represents coefficient that characterizes the propensity of government to finance public spending by cutting social transfers and α_B represents the coefficient that characterizes the propensity of government to finance public spending by increasing the debt burden on the economy.

National Bank. Monetary policy rule in this model is specified as follow:

$$\frac{i_t}{\overline{i}} = \left(\frac{\pi_t}{\overline{\pi}}\right)^{\alpha_\pi} \left(\frac{y_t}{\overline{y}}\right)^{\alpha_y} \left(\frac{s_t}{\overline{s}}\right)^{\alpha_S} \left(\frac{i_{t-1}}{\overline{i}}\right)^{\alpha_i} \left(\frac{ir_t}{\overline{\overline{ir}}}\right)^{\alpha_{ir}} \left(\frac{m_t}{\overline{\overline{m}}}\right)^{\alpha_m} \left(\frac{P_t/P_t^f}{\overline{P}/\overline{P^f}}\right)^{\alpha_P}, \tag{54}$$

where $\left. P_t \middle/ P_t^f \right.$ is the ratio of the price level of domestic products to the price level of imported goods at time t. In equations (53) and (54) variables with horizontal lines denotes the variables in steady state.

The shocks and variables that characterise the world economy are modelled as the AR(1) processes.

The model is realised in Dynare 4.4.3 based on Matlab R2010a. For this purpose, it was linearized and calibrated.

Parameter estimates. The results of the parameter estimation that determine the basic characteristics of Ukraine's economy are shown in Table 1. These parameters have been estimated by combining the model calibration and parameter estimation of the model. The calibration is the analytical procedure of selection parameters of the model that reflects the characteristics of Ukraine's economy, estimates of (Smets, Wouters, 2002) and (Bazhenova, 2009) and estimates based on statistical data of IMF. Also to find the model parameters it was used the econometric methods.

TABLE 1. **Parameters that determine the basic characteristics of Ukraine's economy**

Parameter	Value	Parameter	Value	Parameter	Value
ρ	0,99	γ_w	0,408	χ_w	0,9
σ_l	1,1	ξ_w	0,5	α_p	0,62
ε_w	0,9	ξ_p^f	0,44	η	1,01
σ_c	0,8	γ_p^f	0,5	χ_p	0,5
σ_m	10	φ_t^C	0,8	ξ_p	0.64
h	0,7	$\hat{\mu}^P$	0,29	γ_p	0,5
α_π	0,04	α_{TR}	0,05	α_m	-0,030
α_S	0,18	α_A	1,80	α_{tax}	0,74
α_{ir}	-0,003	α_y	-0,001	α_D	-0,04
α_{TT}	0,18	α_i	0,81		

Source: author's calculations according to the data of IMF, (Smets, Wouters, 2002), (Bazhenova, 2009).

Results

In the paper we are focusing on the following four disturbances that impact economy: a positive shock in world output, a positive shock in the world aggregate demand, a positive shock in the world interest rate and a positive shock in world prices.

A positive shock in world output. The growth of world output gives rise to the growth of domestic output due to the growth of demand for traditional Ukrainian exports. This, in turn, increases the demand for production factors (labour and capital) that leads to an increase in real wages and, as a result of income effect, to reducing labour supply of households usually accompanied by rising marginal costs of the domestic firms. However, the decrease in growth rate of prices of domestic goods and services is observed. At the same time, the increase in real wages has a positive effect on household consumption of final goods and services.

On the other hand, the expansion of demand for domestic products stimulates an increase of the domestic firms' attractiveness that encourages the inflow of investment to the economy. It exerts pressure on the interest rate towards its reduction and further intensification of investment and innovation. This, in turn, stimulates the growth of tax revenues to the government budget and a further increase in government spending. Moreover, the impact of the world output growth has long-lasting effect that observes for more than 40 quarters.

A positive shock in the world aggregate demand. The growth of world aggregate demand leads to the growth of aggregate demand for domestic goods and services and, in particular, the investment demand for goods (but decrease in consumer demand and demand from the government sector) in order to increase the country's exports of goods and services. The demand for imported goods and services as a whole decreases, although, growth in consumer demand for imported goods and services is seen. First of all, it may be associated with a significant share of imported raw materials in the output of Ukrainian export (including products of mineral origin). Thus, in the short run there is a switching demand from consumer goods to the investment one. In the short run, a fall in the aggregate demand is observed, then – we see its growth and stabilization in the long run.

Nevertheless, in the short run, an increase in the primary current account and in the current account is seen (exports growth is accompanied by an increase in imports). In the long term, the results of simulations suggest the returning of the current account balance to its equilibrium level.

A positive shock in the world interest rate. Increase in interest rates abroad provokes a rise in interest rates in the country, indicating the dependence of the Ukrainian banking system from foreign capital (particularly in the context of external sustainability the attraction of short-term bank capital is considered to be a negative factor (Bazhenova, 2014)). First of all, it has the effect of reducing the inflow of foreign capital to the country and increasing payments for using it. In this respect, the high probability of the so-called "sudden stops" in capital inflows into the country that can be caused by crises in capital donor countries, associated with rising interest rates and problems of access to finance resources, should be noted. However, the net foreign assets, according to the results of simulations, show a rising tendency with subsequent stabilization.

So, in the short run, increase in interest rates abroad leads to a drop in household consumption, due to the large part of consumption lending and reducing the demand for real money balances.

The aggregate demand for goods and services by results of simulations shows the instantaneous inertial growth accompanied by a further fall, which, in the long run, does not reach the previous level. In addition, a decrease in demand for imported investment goods of firms, due to the increasing cost of capital and reducing the attractiveness of domestic firms, is observed. Ultimately, it provokes a drop in production, reduction of real wages and unemployment that leads to the falling of imports and the deterioration of the current account balance. At the same time, an increase in domestic inflation in the country and reducing imported inflation cause deterioration of terms of trade. Finally, in the long run, interest rate abroad falls have not reached the previous level. Internal interest rate shows a similar trajectory.

A positive shock in world prices. The rising of world prices (essentially, a transfer of wealth to the national economy) primarily causes an increase in the consumption of goods and services by households (the desire of households to save part of the resulting wealth to smooth consumption over time should be taken into account) that increases an aggregate demand in the economy.

This, in turn, triggers the growth of output, increasing the attractiveness of domestic firms and the corresponding rise of demand for inputs that leads to an increase in real wages and, therefore, the marginal costs of firms. However, this is accompanied by a decrease in labour supply from households due to the effect of income.

The marginal costs growth provokes instant price increases despite the pricing mechanism by Calvo that provides a gradual increase in prices. Together these factors lead to a decrease in production of domestic firms and accordingly reduce the demand for inputs. Thus, the effect of the world prices shock is short term and is graded in two years.

Conclusions

This research deals with the DSGE model of Ukraine as a small open economy that includes households, firms (domestic manufacturers and importers), government, the National Bank and the external sector. The model is constructed according to the new-Keynesian approach that includes the so-called “rigidities” of prices and wages, the existence of the households’ consumption habits and investments with adjustment costs. Also, it takes into account the significant country’s dependence on mineral products imports.

The purpose of the model is to study the impact of external shocks on the economy of Ukraine, such as a positive shock in world output, a positive shock in the world aggregate demand, a positive shock in the world interest rate and a positive shock in world prices.

A rise in world output provokes the growth of domestic output, due to the growth of demand for traditional Ukrainian exports, an increase of the attractiveness of domestic firms that encourages the inflow of investment to the economy and exerts pressure on the interest rate towards its reduction and further intensification of investment and innovation. The overall impact of the world output growth has long-lasting effect that observes for more than 40 quarters.

The growth of the world aggregate demand leads to the growth of aggregate demand for domestic goods and services, especially the investment demand for goods. In the short run, there is a switching demand from consumer goods to the investment one. As a result, a fall in the overall aggregate demand is observed, then - its growth and stabilization in the long run.

Increase in interest rates abroad provokes a rise in interest rates in the country, indicating the dependence of the Ukrainian banking system from foreign capital. In the short term, increase in interest rates abroad leads to a drop in household consumption, due to the large part of consumption lending, and reduces the demand for real money balances. The aggregate demand for goods and services, as illustrated by the results of simulations, shows the instantaneous inertial growth accompanied by a further fall, which in the long run does not reach the previous level.

Rising of world prices primarily causes an increase in the consumption of goods and services by households that increases an aggregate demand in the economy. The effect of the world prices shock is short term and is graded in two years.

REFERENCES

Barnett, A., Straub, R. (2008). What drives U.S. Current Account Fluctuations? European Central Bank. Working Paper Series №959. Retrieved from: https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp959.pdf?95304f44ec997b65b9926870e18c376d

Bazhenova, O. (2014). Teoretychni ta praktychni aspekty vplyvu inozemnogo kapitalu na volatylnist ekonomichnogo zrostannya v Ukrayni. Ekonomika ta derzhava, №11, p. 36–40.

Bazhenova, Yu. (2009). Modeluvannya vplyviv monetarnoyi ta fiskalnoyi polityk na makro-ekonomichnu stabilnist derzhavy. PhD thesis.

Bernanke, B., Gertler, M., S.Gilhrist (1998). The Financial Accelerator in a Quantitative Business Cycle Framework. NBER Working Paper Series №6455. Retrieved from: http://www.nber.org/papers/w6455.

Blanchard, O.J., Gali J. (2010). The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so different from the 1970s? Retrieved from: http://www.nber.org/chapters/c0517.pdf

Burda, M., Wyplosh C. (1997). Makroekonomika: Evropeyskiy Tekst. SPetersburg, Sudostroyenie, 544 p.

Calvo G. (1983). Staggered Prices in a Utility Maximizing Framework. Journal of Monetary Economics, Vol. 12 (3), p. 383–398.

Cantore C., Vasco J.G., Levine P., Pearlman J., Yang B. (2013). The Science and Art of DSGE Modelling: I – Construction and Bayesian Estimation. In Handbook of Research Methods and Applications in Empirical Macroeconomics edited by N.Hashimzade and M.A.Thornton, 614 p.

Christiano, L.J., Eichenbaum, M., Evans, C. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. Journal of Political Economy, 2005, vol. 113, no. 1. p. 1–45.

Clarida, R., Gali J., Gertler M. (1999). The Science of Monetary Policy: A New Keynesian Perspective. Journal of Economic Literature, Vol. XXXVII (December 1999), p. 1661–1707.

Clarida, R., Gali J., Gertler M. (2001). Optimal Monetary Policy in Closed Versus Open Economies: An Integrated Approach. NBER Working Paper Series №8604. Retrieved from: http://www.nber.org/papers/w8604.

Del Negro, M., Schorfheide, F. (2002). Priors from General Equilibrium Models for VARs: Forecasting and Identification, mimeo, Federal Reserve Bank of Atlanta and University of Pennsylvania.

Del Negro, M., Schorfheide, F. (2008). Forming Proirs to DSGE Models (And How It Affects the Assessment of Nominal Rigidities). NBER Working Paper Series №13741. Retrieved from: http://www.nber.org/papers/w13741.

Dixit, A., Stiglitz, J. (1977). Monopolistic competition and optimum product diversity. The American Economic Review, № 67 (3), p. 297–308.

Erceg, C.J., Henderson, D.W., Levin A.T. (2000). Optimal monetary policy with staggered wage and price contracts. Journal of Monetary Economics, 46, p. 281–313.

Fernández-Villaverde, J. (2009). The Econometrics of DSGE Models. NBER Working Paper Series №14677. Retrieved from: http://www.nber.org/papers/w14677.

Gali, J., Monacelli, T. (2005). Monetary Policy and Exchange Rate Volatility in a Small Open Economy. Review of Economic Studies, 72, p. 707–734.

IMF eLibrary Data. Retrieved from: http://data.imf.org/TimeSeries?key=61017699

Jaaskela, J., Jennings, D. (2010). Monetary Policy and the Exchange Rate: Evaluation of VAR Models. Retrieved from: http://www.rba.gov.au/publications/rdp/2010/pdf/rdp2010-07.pdf

Kumhof, M., Laxton, D., Muir, D., Mursula, S. (2010). The Global Integrated Monetary and Fiscal Model (GIMF) – Theoretical Structure. IMF Working Paper WP 10/34. Retrieved from: http://web.stanford.edu/~kumhof/gimfwp1034.pdf

Kydland, F.E., Prescott, E.C. (1977). Rules rather than Discretion: the Inconsistency of Optimal Plans. Journal of Political Economy, Vol.85, p. 473–491.

Kydland, F.E., Prescott, E.C. (1982). Time to Build and Aggregate Fluctuations. Econometrica, Volume 50, Issue 6, p.1345–1370. Retrieved from: https://www.minneapolisfed.org/research/prescott/papers/timetobuild.pdf

Lama, R., Medina, J.P. (2012). Is Exchange Rate Stabilization an Appropriate Cure for the Dutch Disease? International Journal of Central Banking, № 8 (1), p. 5–46.

Leduc, S., Sill, K. (2004). A Quantitative Analysis of Oil-price Shocks, Systematic Monetary Policy and Economic Downturns. Journal of Monetary Economics, 51(4), p.781–808.

Lucas, R. (1976). Econometric Policy Evaluation: A Critique. The Phillips Curve and Labour Markets, Brunner K., Meltzer A., New York, American Elsevier, vol.1, p. 19–46. Retrieved from: http://people.sabanciuniv.edu/atilgan/FE500_Fall2013/2Nov2013_CevdetAkcay/LucasCritique_1976.pdf

Lukianenko, I., Semko, R. (2010). Osoblyvosti Pobudovy Dynamichnoyi Stohastychnoyi Modeli Zagalnoiy Rivnovagy dlya Analizu Ekonomiky Ukrayny. Ekonomichna Kibernetyka, №4, 6 (64–66), p. 48–59.

Lukianenko, I., Semko, R. (2015). Dynamichni Stohastychni Modeli Zagalnoiy Rivnovagy: Teoriya Pobudovy ta Praktyka Vykorystannya u Finansivyh Doslidzhennyah. Kyiv, NAUKMA, 246 p.

Marion, N.P. (1981). Anticipated and Unanticipated Oil Price Increases and the Current Account. NBER Working Paper 759. Retrieved from: http://www.nber.org/papers/w0759.pdf

Methodological Comment to the Statistics of the External Sector in Ukraine (2009). Retrieved from: http://www.bank.gov.ua/doccatalog/document?id=4703286

Muth, J.F. (1961). Rational Expectations and the Theory of Price Movements. Econometrica, Vol.29, No.3, p. 315–335.

Polbin, A. (2013). Postroenie Dinamicheskoy Stohasticheskoy Modeli Obschego Ravnovesiya dlya Ekonomiki s Vysokoy Zavisimostuy ot Eksporta Nefti. Retrieved from: http://library.hse.ru/e-resources/HSE_economic_journal/articles/17_02_07.pdf

Polovnyov, Yu., Andruschenkov, A. (2008). Vyznachennya Chynnykiv Dynamiky Realnogo Obminnogo Kursu Hryvni. Visnyk Natsionalnogo banku Ukrayny, № 5, p. 24–27.

Rotemberg, J.J., Woodford, M. (1997) An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy. Retrieved from: http://www.nber.org/chapters/c11041.pdf

Semko, R. (2011). Bayesian Estimation of Small-scale DSGE Model of the Ukrainian Economy Retrieved from: http://mpra.ub.uni-muenchen.de/35215/1/MPRA_paper_35215.pdf

Shulgin, A. (2013). Otsenka pravil monetarnoy politiki v ramkah DSGE modeli ekonomiki Rossii. Retrieved from: http://www.iep.ru/files/news/Shulgin.pdf

Smets, F., Wouters, R. (2002) An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area. European Central Bank, Working Paper 171. Retrieved from: https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp171.pdf

Vasylenko, Yu., Bazhenova, O. (2014). A Causal Macroeconomic Model of Devaluation and Inflation Impact on the Economy of Ukraine. Ekonomika, 93(1), p. 57–73.