

ІНФОРМАЦІЙНЕ ТА МАТЕМАТИЧНЕ ЗАБЕЗПЕЧЕННЯ ЕКОНОМІЧНИХ ПРОЦЕСІВ

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RESEARCH ON THE MODELS OF THE GDP GROWTH STIMULATION. CASE OF DEVELOPED COUNTRIES

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Чугунов А.А., Ткачова О.С. Дослідження моделі стимулювання росту ВВП на прикладі розвинутих країн.

Метою цієї статті є дослідження напрямків регулювання економіки на прикладі розвинутих країн, а саме можливості стимулювання росту ВВП, знаходячись у рамках обмежень побудованої моделі.

Ключові слова: політика регулювання економіки, стимулювання ВВП, розвинуті країни

Чугунов А.А., Ткачова О.С. Исследование модели стимулирования роста ВВП на примере развитых стран.

Цель данной статьи – исследование направлений регулирования экономики на примере развитых стран, а именно, возможностей стимулирования роста ВВП, находясь в рамках ограниченной построенной модели.

Ключевые слова: политика регулирования экономики, стимулирование ВВП, развитые страны

Chugunov A.A., Tkacheva O.S. Research on the models of the GDP growth stimulation. Case of developed countries.

The aim of this paper is to make the research on the possibilities of the economy stimulation in the case of developed countries, more precisely, to determine the ways of the GDP growth staying within the model framework that was built.

Keywords: economy's regulation policy, GDP stimulation, developed countries

From a macroeconomic perspective, the economy is a complex dynamic system. In a general sense, despite the complexity of its structure and size, any system seeks to enter into an equilibrium state and remain in it. However, this path is not instantaneous jump, because the system is constantly influenced by certain factors that trigger to shift up or down from the equilibrium state. For a system like economy, these changes are nothing more than a recession phases of economic growth or, conversely, its recovery. The last deep recession that has affected the world economy took place in 2008, and is known as the global financial crisis. Of course, five years is a too short period to finally bring the economy out of recession. This is because the crisis is still felt well in the world community; the urgency of solving this difficult situation is obvious. But, of course, there are certain positive changes.

I should be noted that the economy has a tendency to return itself to the deterministic mainstream, but it requires a significant amount of time. The government can accelerate this process by using one of several instruments of economic regulation, such as monetary or fiscal policy. Both are intended to stabilize the economy, if the latter was put out of balance, or stimulate it. Monetary policy operates with money supply and interest rates, and when using the fiscal policy, the government affects government spending or the tax system.

Obviously, these serious steps should be clearly validated; their effects should be tested and thoroughly examined in order to find the optimal way from a number of alternatives. Not surprisingly, that before solving out this problem in practice, the authorities use the estimations of theoretical models developed by economists. Recently, widespread popularity and demand were received by dynamic

stochastic models of general economic equilibrium. The name itself indicates that these models are able to capture a significant number of properties of the economic system and most fit the realities beyond the theoretical frame, including the dynamics of the system, because they show the economy in the time space, as well as the uncertainty of the future. Secondly, these models are built on microeconomic principles. In other words, the results of calculations for these models are obtained by direct optimization of economic agents' activity, including households, which maximize utility function subordinated to budget constraints, firms, which maximize profits taking into consideration the production function and the government, which acts as an intermediary in the circulation of resources, redistributing them between agents. Also, in these models it is possible to use endogenous shock influence and examine its effects on the economy as a whole.

Thus, on the one hand, the issue of regulating the economy is an interesting and topical springboard for theoretical research of scientists, who are constantly trying to improve existing models to their more precise matching of the real state of affairs. On the other hand, the results of these researches are used by governments, which are responsible for the future development of the economy.

Analysis of recent research and publications

Taking into account that the recessive situation in fact is not a new phenomenon in macroeconomics, naturally, in the literature there are many researches that outlined those problems and possible ways of revitalizing the economic growth. Of course, the global financial crisis has provoked the outbreak of another discussion: which of the possible tools the government must use for a sooner exit from recession.

The economy of the United States is the focus of attention of the world scientific society. Many sources starting point for further research was the «American Recovery and Reinvestment Act» [1], which was passed in 2009. It is a collection of stimulus actions that should be implemented by the government, totaling to \$ 787 billion (in 2011 the amount was increased to \$ 840 billion). Not surprisingly, there are lots of questions about the ability of this amount to justify expectations of its implementation.

Conventionally, studies and publications are difficult to be divided into empirical and theoretical, since they are typically combined from these two qualities. The overall goal of researches on this issue can be stated as the following: "How do economic indicators (mainly GDP) react to changes in government spending, taxes, or monetary policy?" For example, in [2-5] the attention was focused on the analysis of fiscal policy actions' impact on the economy. While [6] is an example of the study of monetary policy's effect. Theoretical basis in most cases are just dynamic stochastic models of general economic equilibrium with the inclusion of new Keynesian approach. For empirical calculations the vector autoregression is used

The unsolved aspects of the problem

On the basis of the above analysis of recent studies devoted to this issue, it was decided to focus on the mechanism of regulation of the economy by increasing public spending. In our opinion, this is the most promising tool. Change in interest rate as a monetary policy offers, or in the tax levy (the option of fiscal policy) are too time-consuming to implement. In addition, the "American Recovery and Reinvestment Act" pays more attention to government spending. However, attention will be focused on building and analytical calculation of theoretical model of the economy, in which households, firms and the state government will interact. During the model's calibration and parameterization, the data about developed countries will be used. This choice is the basis of the fact that the GDP of developed countries is well counted. This means that the numerical values of the input parameters that are key to the solution of the model can generate high-quality initial information and may be compared with real data.

Therefore, this article must firstly develop a theoretical model of the economy, and then find a system of equations that govern the equilibrium, and to conduct the parameters' calibration that are characteristic for developed countries. *The purpose* of this paper is to explore the possibilities of stimulating the GDP's growth and the sensitivity of its changes according to different input parameters.

The main material of the research

The first step in solving this problem is to build a model of economy and to describe the model's environment. The source [3] was the basis for the following model, but with some changes. Let us focus on the internal environment and the interaction of agents within it.

Let's economy is populated with plenty of identical firms and households, which term life is the infinity. This assumption allows leaving the representative member of each group for further consideration. Thus, the model consists of three agents: households, firms and government. Since the term of agents' life in the economy is the infinity, time is discrete value of $t = 0, 1 \dots \infty$. In each of these periods, the economy can be in one of the many states s_t , the number of which is the ultimate value. From period 0 to some period t , these states form the history of events $s^t = \{s_0, s_1, \dots, s_t\}$. These events are stochastic and the whole story has some chance of appearance. Let's denote this probability through $\pi(s^t)$. We take a few more assumptions, namely: let the economy produces only one final good, agents always behave rationally, generation is not blocked. Of course, these assumptions simplify the real situation and are quite strong, but that's just the base model, in addition, a complicated model may not always reflect reality better than simpler.

To calculate the equilibrium state of the economy in each period t and to obtain a sequence of the form

$\{C(s^t), L^{[s]}(s^t), L^{[d]}(s^t), K^{[s]}(s^t), K^{[d]}(s^t), B(s^t), I(s^t), R(s^t), G(s^t), w(s^t), d(s^t), \Pi(s^t)\}_{t=0}^{\infty}$

it is necessary to solve the dynamic stochastic equations, which are simultaneous solutions of the following optimization problems and equilibrium conditions:

- a household maximizes expected utility function for this life, which depends on consumption and leisure, which is subject to the limits of temporal budget constraint and capital accumulation equation. Household allows the firm to use labor and capital, for a fee, so the superscript ^[s] means «supply»;
- Firm rents capital and labor in the household and in each period maximizes its profits, which are subordinated to the production function, which is a Cobb-Douglas function. In sequence, the upper index ^[d] means "demand";

— government is responsible for the redistribution of resources, and in each period a so-called government budget constraint must be performed (the amount of government spending is equal to the sum of its revenues). The latter consists of taxes from households and income from government bonds;

— The – All markets are subject to the conditions of equilibrium, including the labor market, capital market and market goods.

The next step is to solve the optimization problem of households and firms. The first is computed by using the Lagrange method, the second is a direct capital and labor profit maximization, after substituting the Cobb-Douglas production function. By mathematical transformation, we obtain the following system of equations (1-10), governing the equilibrium:

$$\begin{aligned} & (C(s^t)^\gamma (1-L(s^t))^{1-\gamma})^{-\rho} C(s^t)^{\gamma-1} (1-L(s^t))^{1-\gamma} = \\ & = \beta \sum_{s^{t+1}} \pi(s^{t+1} | s^t) (C(s^{t+1})^\gamma (1-L(s^{t+1}))^{1-\gamma})^{-\rho} C(s^{t+1})^{\gamma-1} (1-L(s^{t+1}))^{1-\gamma} R(s^{t+1}) \end{aligned} \quad (1)$$

$$R(s^{t+1}) = (1-\tau^K)d(s^{t+1}) + 1 - \delta \quad (2)$$

$$C(s^t) / [(1-L(s^t))w(s^t)] = (1-\tau^L)\gamma / [(1+\tau^C)(1-\gamma)] \quad (3)$$

$$d(s^t) = \alpha K(s^{t-1})^{\alpha-1} L(s^t)^{1-\alpha} \quad (4)$$

$$w(s^t) = (1-\alpha)K(s^{t-1})^\alpha L(s^t)^{1-\alpha} \quad (5)$$

$$Y(s^t) = K(s^{t-1})^\alpha L(s^t)^{1-\alpha} \quad (6)$$

$$I(s^t) = K(s^t) - (1-\delta)K(s^{t-1}) \quad (7)$$

$$Y(s^t) = C(s^t) + G(s^t) + I(s^t) \quad (8)$$

$$G(s^t) = B(s^t) - R(s^t)B(s^{t-1}) + \tau^L w(s^t)L(s^t) + \tau^K d(s^t)K(s^{t-1}) + \tau^C C(s^t) \quad (9)$$

$$\ln G(s^t) = (1-\psi)\ln(\bar{G}) + \psi \ln G(s^{t-1}) + \varepsilon_t, \quad \varepsilon_t \sim iid \quad N(0, \sigma^2) \quad (10)$$

Where $C(s^t)$ – consumption;

$L(s^t)$ – time for work. The whole time was normalized to 1, so $1-L(s^t)$ is a time for rest;

$K(s^t)$ – capital;

$B(s^t)$ – government bonds;

$I(s^t)$ – investments in the capital;

$w(s^t)$ – real wages;

$d(s^t)$ – rent for capital;

$R(s^t)$ – the interest rate on government bonds;

$Y(s^t)$ – production (GDP);

$G(s^t)$ – public spending;

$\Pi(st)$ – income;

β – the discount factor, $0 < \beta < 1$;

γ – share of consumption in the utility function, $0 < \gamma < 1$;

ρ – coefficient that measures the relative risk tolerance, $\rho > 0$, $\rho \neq 1$;

δ – depreciation rate of capital;

α – share of capital in production, $0 < \alpha < 1$;

ψ – a coefficient that regulates the stability of shocks in equation (10), $0.5 < \psi < 0.95$;

τ^C – consumption tax;

τ^L – income tax;

τ^K – capital tax.

In order to solve the system of equations (1-10) the software which is called Dynare has been used. Dynare was generated with Matlab and is designed for calculations of such models. The program code

consists of a number of mandatory units, including: block of endogenous and exogenous variables' declaration (trivial block), block of parameters' declaration and assigning them to specific numerical

values, modeling block, block of initial variable values in steady state, and the block which determines the shock impact. In the parameterization block all constants of the model have such numerical values as in developed countries. For example, the share of capital in production is $\alpha = 0.4$. Modeling block involves equations (1-10). The next block, which specifies the initial values of the variables, can be obtained by calculating their values as functions of the constants. The last block governs the size of the average standard deviation σ in autoregressive process (10). It should be noted that under the hypothesis, government spending are followed by autoregressive process of first order. So government spending fluctuate relatively certain average value \bar{G} . Depending on what will be the impact of the shock influence σ , and the parameter ψ , impulse response functions of the system variables will vary.

Let the constants take the following values: $\beta=0.985$, $\gamma=0.4$, $\rho=0.1$, $\delta=0.025$, $\alpha=0.4$, $\tau^C=0.095$, $\tau^K=0.384$, $\tau^I=0.214$, $\bar{G}=0.13$, $\sigma=0.01$. This choice is driven by numerous empirical results in the literature, such as, for example, [3], and is a characteristic of

developed countries. Let us focus on the one variable – GDP $Y(s^t)$, namely, its impulse response function to the growth in government spending. Suppose the economy is in steady state and at zero time an increase in government spending happens, which is equal to $\sigma=0.01$. Let us consider and analyze how the GDP's percentage deviation from its steady state will change in the first period after the shock influence on the economy, according to the different values of ψ з рівняння (10), equation (10), which regulates the stability of shock impact. The results are shown in Figure 1. On the horizontal axis the values of the coefficient ψ are shown, which varies from 0.5 to 0.95 in increments of 0.05. In other words, the higher ψ , the longer the economy is feeling the effects of the shock, and thus requires longer time to all of the variables returned in its steady state. On the vertical axis it is the percentage deviation of GDP from its steady state in the first post-shock period. According to this graph, the increase in ψ leads to an increase in GDP.

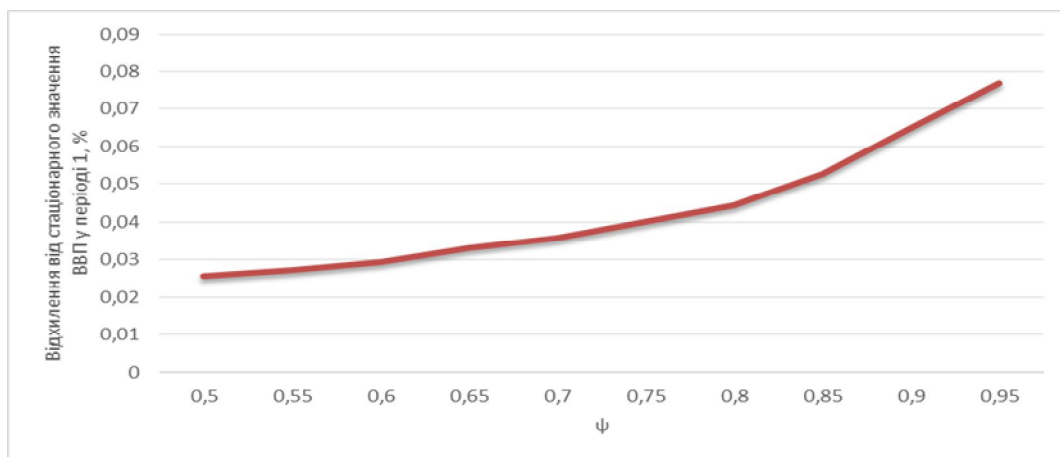


Fig. 1. Graph of the impulse response of GDP in the first period after the shock according to different values of ψ

Table. The values of key variables when the economy is in a steady state

Index	Symbol	The absolute value of the model	The relative value of the model	The relative importance in developed countries
Consumption	C	0.685	$C/Y=0.71$	0.67
Investments	I	0.147	$I/Y=0.15$	0.18
Government spending	G	0.129	$G/Y=0.13$	0.15
GDP	Y	0.962	-	-

* Due to the confidentiality of information, related to innovation activities of enterprises, code names of updated products are given

For example, we choose $\psi = 0.95$. In this value, the GDP will increase by 0.077% in the first period. To analyze numerical characteristics of these positive developments, we used steady state calculations for this model, which have been obtained after the program was launched to address. The table shows the absolute values of consumption, investment,

government spending and GDP, and the share of the latter, according to equation (8). As can be seen from the table, the shares of these indicators to GDP agree with real data. Indeed, in developed countries, consumption is about 67% of GDP, while the model generated very close value – 71%. Thus, easy mathematical calculations indicate that GDP in the

first period increased by 0.074. To find how much it is in terms of money, you can use proportions to compare the value with the real data. Time has been normalized to 1, so according to the calculations, a person spends approximately 30% of the total time on the job, and thus it is approximately 7 hours per day, which also corresponds to reality.

Conclusions

Our theoretical model generates results that correspond to the real data of economies of developed countries, including shares of government spending, consumption and investment in GDP. Mechanism of the economy regulation by increasing government

spending is the most promising among the instruments of monetary and fiscal policies. The increase in government spending by 1% within the constraints of the constructed model shows that the percentage deviation of GDP from its steady state strongly depends on the coefficient of shock influence stability regulation ψ . The higher ψ , the longer the economy is feeling the effects of shock and needs longer time to all variables returned in its steady state. At a value of $\psi=0.95$, GDP increases by 0.077% in the first period.

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