The Central Bank
of the Republic of Uzbekistan

Dynamic stochastic general equilibrium (DSGE) model for Uzbekistan and its implementation in practice

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Tashkent – 2023

Abstract

This paper describes a dynamic stochastic general equilibrium (DSGE) model for Uzbekistan, in which the production sector is subdivided into producers of domestic goods, primary exporters and non-primary exporters, considering also the differentiation in the propensity of households to save and its effect on monetary policy decisions. The DSGE model is an indispensable tool for analyzing economic processes and forecasting long-term economic trends. The practical application of the calibrated model includes analyzing the impact of such fundamental shocks on the economy as the supply shock and the shock of increasing government spending on consumption. The paper is useful for economists engaged in the design of economic policy and analysis of macroeconomic trends in the Republic of Uzbekistan.

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1. Introduction

Macroeconomic models are essential for decision-making and designing monetary policy parameters. Basic understanding of economic processes, their analysis and forecasting can be implemented through simpler theoretical models, while complex macroeconomic models allow using the general equilibrium approach, which is important in the long-term economic forecasts, alternative scenarios, macroeconomic risk assessments, as well as monetary and fiscal policy strategy analysis.

One of such models is the dynamic stochastic general equilibrium (DSGE) model.

In the last decade, new generations of DSGE models have been widely recognized, which are currently applied by many central banks, including the US Federal Reserve System, the European Central Bank, the Swiss National Bank, the Bank of England and others. In the Central Bank of the Republic of Uzbekistan, the process of phased development of the DSGE model started in 2022 in cooperation with the Swiss National Bank.

The macroeconomic DSGE model is based on microeconomics principles and represents dynamic relationships between economic indicators. The main feature of this category models is the possibility of inter-temporal choice[1] of economic agents when making decisions on consumption or investment. An important role in these decisions is given to expectations about the future, which are influenced by changes in the level of uncertainty regarding future indicators, thus ensuring the dynamism of the model.

[1] Inter-temporal choice is the process of choosing between alternatives that differ in the amount and timing of the reward (compensation) received. In economic terminology, this choice refers to time discounting or lag discounting. It characterizes individuals' preference for smaller but earlier benefits over later but larger ones. For instance, when planning financial investments and savings, individuals have to decide how much of disposable income to spend now and how much to save for the future. These decisions have a direct impact on quality of life.

Moreover, the assumption of general equilibrium in the model encompasses the interaction between decisions on economic policy and the behavior of agents. In an economy, many small agents tend to take prices as given, while the equilibrium price is formed on the basis of supply and demand in the market, which determines the state of general equilibrium of the model. The equations of the model reflect the process of maximizing lifetime utility of households and profits of firms.

Simulation of stochastic shocks causing economic fluctuations allows us to observe their transmission to the economy more accurately.

The advantage of this model is that it allows to take into account the behavior of households, the impact of structural changes on the economy, to predict economic trends, to analyze the interrelations between micro- and macro-levels, to assess the impact of monetary and fiscal policy decisions on macroeconomic indicators, etc.

The DSGE model is designed to analyze macroeconomic trends over the long term, for a period of 3 to 10 years, and is widely used in academic research and analysis of macroeconomic policy decision-making. In the Monetary Policy Department, this model will be used to analyze current policies and assess the interplay between monetary and fiscal policies.

However, this category of models, along with the advantages, has a number of limitations. First and foremost, it should be noted that the DSGE model does not provide short-term projections of inflation, GDP and other economic indicators. It considers inflationary processes in terms of supply side and structural changes, thus demand factors, business cycles and output gap are not determinants in the model. Semi-structural quarterly projection models (QPM) are more appropriate for these purposes.

This paper presents a brief overview of the DSGE model for Uzbekistan, and illustrates different types of macroeconomic policy objectives for which the model can be used. The paper provides a description of the model structure, the concept and types of economic agents and assumptions regarding their behavior.

2. Description of a general equilibrium model

The basic DSGE model is a New Keynesian-type macroeconomic model for a small open economy. The model incorporates the concept of price[2] and nominal wage rigidity to capture the impact of fluctuations in any of the expenditure components-consumption, investment, or government spending-on changes in output. Furthermore, the model assumes that the economy is rather small for domestic demand and supply to influence world prices and interest rates, which are therefore taken as exogenous (external) factors.

The agents included in the model are as follows (Figure 1):

- Households:
  - Savers (optimizers) – OPT
  - Non-savers (hand-to-mouth) – HTM
- Firms:
  - producers of domestic absorption
    - producers of domestic value added – Y^d
    - distributors – D^{dist}
    - aggregator – D^{agg}
  - producers of non-primary exports – Z
  - producers of primary exports – Q
- Government (implementing fiscal policy)
- Central bank (monetary policy maker)
- Rest of the world – RoW

The model includes the structure and main components of GDP using all three approaches for its calculation: production, expenditure and income, which are harmonized within the model.

[2] Price rigidity is an economic phenomenon characterized by limited or slow adaptation of the prices of goods and services to developments in market conditions, such as changes in demand or supply. As a result, prices do not respond to these movements as rapidly or fully as might be expected

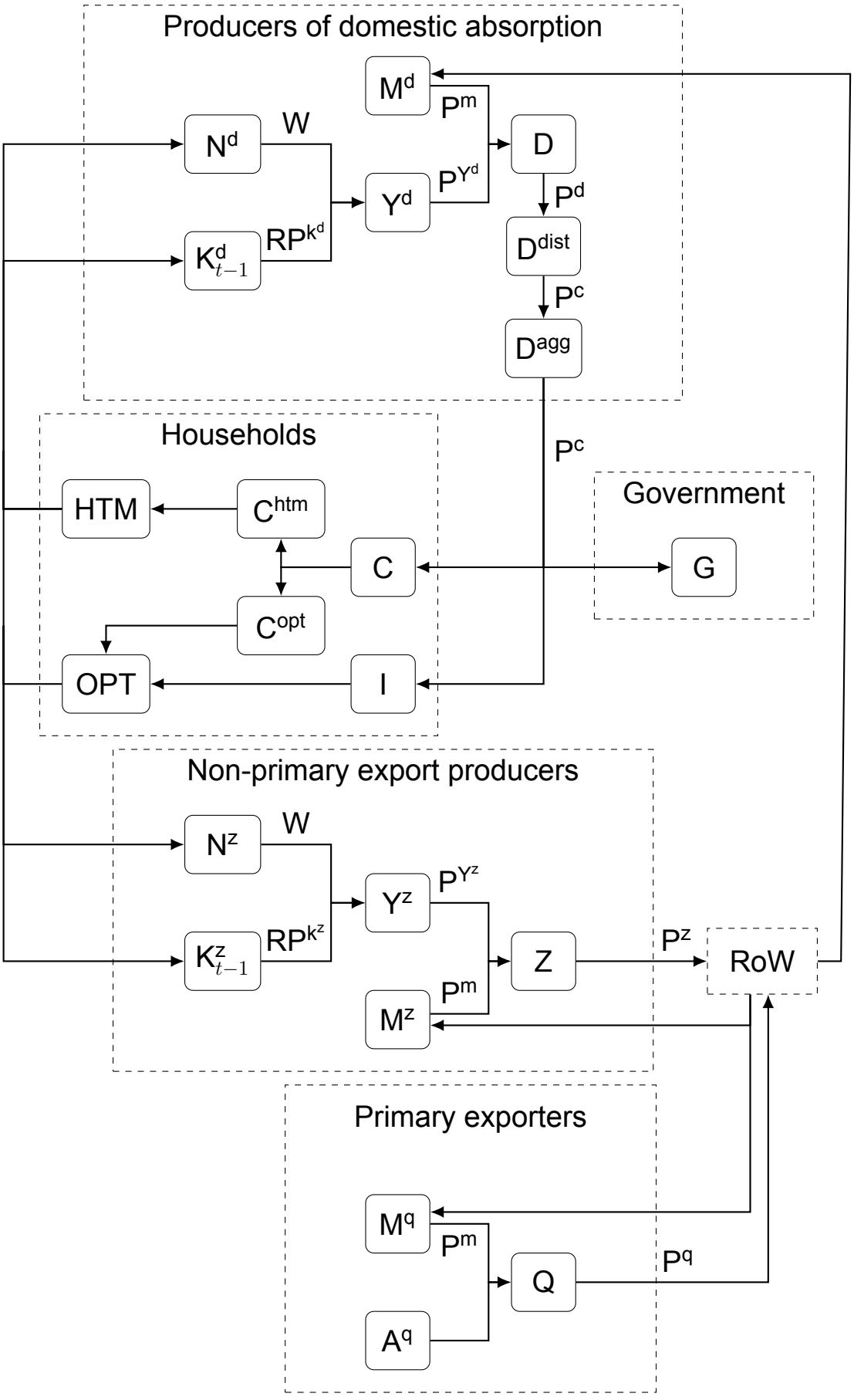

Figure 1. Flow of goods

where N – labor (measured in hours of work), K_{t-1} – capital stock at the beginning of the period, M – imported goods, Y – intermediate goods, C – household consumption, I – investments, G – public consumption, A^q – natural resources, P^c, P^d, P^m, P^{Y^d}, P^{Y^z}, P^z, P^q – price level of the respective sectors, W – wages, RP^k – rental price of capital. The upper indices indicate the relevant production sector or item.

Some of the key assumptions of the model are: rational behavior of households and businesses, who are price takers, i.e. they accept prices formed in competitive markets; and that the accumulated capital eventually loses its value due to depreciation, and new capital is generated through investment.

In general equilibrium, for all types of goods, optimal demand corresponds to optimal supply.

2.1. Households

Households (consumers) provide labor for production, and purchase consumer goods. Household behavior is determined by the following properties:

- forward-looking behavior, i.e., they are concerned about the utility of a good in all future periods, but with less concern in distant periods;
- they prefer to consume and are less willing to work;
- the marginal utility of consumption[3] is positive and declining, that is, with each additional unit of consumption a household receives less and less utility;
- the marginal disutility[4] of labor is positive and increasing, that is, every additional hour of work becomes harder to perform.

Households are categorized as:

- **Optimizers** who provide labor, own the capital stock, and make

[3]Marginal utility of consumption is the change in utility that a person receives from additional consumption of a unit of a good. It is measured as a derivative of utility by the quantity of a good consumed. Marginal utility usually decreases as the consumption of a good increases. It allows us to compare the utility of different goods and make decisions on how much of each good to consume in order to maximize utility

[4]Marginal disutility of labor is the change in the level of labor load of the work performed on account of an additional unit of work time

forward-looking consumption and investment decisions;

- **Hand-to-mouth households** who also provide labor but do not have savings, therefore, do not have the ability to invest.

Both types of households earn equal wages for their labor hours performed in the amount of W. In addition, saving households earn a rent RP^k for providing capital to firms. The rental price of capital compensates optimizers for the lost utility from foregoing current consumption and depreciation of capital.

Households' budget constraint is the equivalence of their expenditures to their incomes. It is assumed that households rationally choose their behavior, focusing on achieving the maximum possible utility subject to the budget constraint. That is, they determine how much to consume, invest and work based on the concept of optimality of aggregate utility.

Decisions on consumption and saving are made by a fixed pool of "infinitely living"[5] households. Another important assumption is that optimizers maximize expected lifetime utility. They are concerned not only with the decision on current consumption, but also with its impact on future consumption.

Main equations for households

Equations of consumption and labor supply are presented as follows:

$$
\begin{aligned}
C_t &= (1-\omega)\, C_t^{\text{opt}} + \omega\, C_t^{\text{htm}} \\
L_t &= (1-\omega)\, L_t^{\text{opt}} + \omega\, L_t^{\text{htm}} \\
P_t^{\text{c}}\, C_t^{\text{htm}} &= W_t\, N_t^{\text{htm}} - TAX_t^{\text{htm}} \\
\left(C_t^{\text{opt}}\right)^{-\sigma} &= \Lambda_t\, A_t^{1-\sigma}\, P_t^{\text{c}} \\
\theta \left(L_t^{\text{opt}}\right)^{\eta} &= \Lambda_t\, W_t,
\end{aligned}
$$

[5] In the DSGE model, households are assumed to exist for an infinitely long period of time. This allows us to consider the effects of their current decisions on future periods and to incorporate lifetime utility. Infinitely living households face a budget constraint and try to make consumption and saving decisions in a way that maximizes their lifetime aggregate utility. They consider both current utility of consumption and future consumption and are willing to allocate their resources between consumption and savings in order to achieve the highest possible well-being over their lifetime

where Λ_t – shadow price of wealth or money[6], ω – share of hand-to-mouth households, A_t – labor augmented productivity, σ – elasticity of inter-temporal substitution, η – elasticity of substitution of labour, θ – scaling factor for labour (it depends on the unit of labour, i.e. years, days, hours).

Investment and capital:

$$K_t = (1 - \delta) K_{t-1} + I_t,$$

where δ – capital depreciation rate.

2.2. Firms

Another agent is firms. Firms hire labor and rent capital from households, produce and supply (provide) goods and services that can then be utilized for both personal consumption and investment purposes.

The main objective of firms is to maximize profits from production, taking into account the present value of all future income.

Firms are subdivided into three types:

- producers of domestic absorption D;
- producers of non-primary exports Z;
- primary exporters Q.

2.2.1. Producers of domestic absorption

Relationship between production (real economy) and inflation in the model is provided by adding an agent who has the authority to set prices. In this regard, production of domestic consumption involves three stages:

- production of intermediate goods which are produced from capital, labor, and an import component;
- distribution of intermediate goods, through conversion into final goods by distributors who have some market power to set prices;
- aggregation of intermediate goods into final goods by aggregators on a competitive basis and distribution to private consumption,

[6]Shadow price of wealth or money determines how much additional utility each additional unit of wealth generates when spent in the optimal condition.

investment and government consumption.

Final goods are consumed by both optimizers and hand-to-mouth households, while investment goods are allocated only to savers.

In turn, the production of intermediate goods consists of two stages. In the first step, the firm hires labor N^{d}, pays wages W and rents capital K^{d}_{t-1} at a price $RP^{K^{\mathsf{d}}}$ and produces intermediate goods of domestic consumption. At this stage, gross value added Y^{d} of domestic consumption is generated. The second stage is the production of intermediate good D using Y^{d} at price $P^{Y^{\mathsf{d}}}$ and import component M^{d} at price P^{m}, which is further purchased by distributors.

The import component is sourced from the outside world, labor is supplied by both types of households (i.e., N^{opt} and N^{htm}), and capital is provided only by optimizers.

Distributors purchase intermediate goods D from the producers of the intermediate good at price P^{d}. Distributors set a markup μ, which is their profit. Distributors do not produce other goods, only converting the intermediate good into the final good, and the markup is their value added. The final good D, is then sold by distributors at a price P^{c} to aggregators.

Aggregators allocate the purchased final good D to household consumption C, investment I, and government consumption G. Aggregators do not produce a new good either, operating competitively and selling a unit of the good at the purchased price P^{c}.

2.2.2. Producers of non-primary exports

Non-primary Z exporters operate in the same way as producers of intermediate goods, except that they export all of their output.

Thus, non-primary exporting producers first hire labor N^{z} paying wages W, rent capital K^{z}_{t-1} at price $RP^{K^{\mathsf{d}}}$, and produce an intermediate export good Y^{z}. By utilizing Y^{z} at price $P^{Y^{\mathsf{z}}}$ and the import component M^{z} at price P^{m} the final export primary Z is produced, further directly exported to the rest of the world at price P^{z}.

2.2.3. Primary exporters

Primary exporters produce commodities Q, using natural resources A^q and imported equipment M^{q}, which are then exported to the rest of the world at a price P^{q}.

Main equations for firms

Producers of intermediate goods (condition of maximization - zero profit of firms):

$$\begin{aligned} RP_t^{K^{\mathsf{d}}}\, K_{t-1}^{\mathsf{d}} &= \alpha_{\mathsf{d}}\, P_t^{Y^{\mathsf{d}}}\, Y_t^{\mathsf{d}} \\ W_t\, N_t^{\mathsf{d}} &= (1-\alpha_{\mathsf{d}})\, P_t^{Y^{\mathsf{d}}}\, Y_t^{\mathsf{d}} \\ Y_t^{\mathsf{d}} &= \left(K_{t-1}^{\mathsf{d}}\right)^{\alpha_{\mathsf{d}}}\, \left(A_t\, N_t^{\mathsf{d}}\right)^{1-\alpha_{\mathsf{d}}}, \end{aligned}$$

where α_{d} – capital intensity of domestic value added.

Producers of domestic consumption (based on Leontief production function):

$$\begin{aligned} D_t &= A_{\mathsf{d0}}\, \frac{M_t^{\mathsf{d}}}{\alpha_{M^{\mathsf{d}}}} \\ D_t &= A_{\mathsf{d0}}\, \frac{Y_t^{\mathsf{d}}}{1-\alpha_{M^{\mathsf{d}}}} \\ A_{\mathsf{d0}}\, P_t^{\mathsf{d}} &= \alpha_{M^{\mathsf{d}}}\, P_t^{\mathsf{m}} + (1-\alpha_{M^{\mathsf{d}}})\, P_t^{Y^{\mathsf{d}}}, \end{aligned}$$

where A_{d0} – scale factor and $\alpha_{M^{\mathsf{d}}}$ – share of imports in domestic consumption.

Distrubutors (set a markup)

$$\mu\, \frac{P^{\mathsf{d}}}{P^{\mathsf{c}}} = 1 + (\mu - 1)\left(ADJ_t - \beta\, \frac{\Lambda_{t+1}\, D_{t+1}}{\Lambda_t\, D_t}\, ADJ_{t+1}\right),$$

where μ – distributors' markup, $ADJ_t = \xi\left(\log\left(\mathsf{d}P_t^{\mathsf{c}}\right) - \log\left(\mathsf{d}P_{t-1}^{\mathsf{c}}\right)\right)$ – price adjustment cost, ξ – adjustment coefficient for consumer prices, and $\mathsf{d}P_t^{\mathsf{c}}$ – consumer inflation.

2.3. Central Bank (monetary policy)

Monetary policy in the model is determined by the Phillips curve and the rule of inflation stabilization based on inflation expectations.

Agents in the economy consider the state of the economy and its effect on demand. As a result of higher economic growth, agents can expect an increase in demand and, based on this, adjust prices accordingly.

Thus, prices reflect not only the current state of the economy but also the expectations of agents. This leads to price rigidity, which is reflected in the difference between the production cost of a good and its consumer price $\frac{P^{\mathsf{d}}}{P^{\mathsf{c}}}$.

Inflation stabilization equation (a monetary policy rule based on inflation expectations):

$$\log(Rg_t) = \rho_{Rg}\ \log(Rg_{t-1}) + (1-\rho_{Rg})(\log(\overline{Rg}) + \kappa_{Rg}(\log(\mathsf{d}P_{t+h}) - \log(\mathsf{d}P_{tar}))) + \varepsilon_t^{Rg},$$

where ρ_{Rg} – interest rate persistence, $\mathsf{d}P_{t+h}$ – expected inflation for the period h, $\mathsf{d}P_{tar}$ – inflation target, ε_t^{Rg} – monetary policy shock.

2.4. Government (fiscal policy)

The government operates through budget revenues and expenditures. Budget revenues are generated from taxes paid by households and firms. These funds are directed for the provision of public services and infrastructure development, and also allocated in the form of subsidies (transfers) to households and firms.

Whenever there is a deficit that leads to an increase in public debt, the government covers it by issuing securities and offering them to optimizers in the amount of Bgh at the rate of Rg, and to the external world in the amount of Bgw at the rate of Rhw. This allows the government to raise the necessary funds to finance its liabilities.

Thus, optimizers are guaranteed by the government the return of money in the future, and as compensation the households receive a profit on the purchased securities, determined by the interest rate. In order to convince households, the government must set a positive real interest rate, which in turn will depend on the level of real interest rates in the economy.

Although households lend money to the government at the interest

rate Rg, which is a risk-free interest rate set by the Central Bank based on its monetary policy and aimed at stabilizing inflation, domestic intertemporal decision-making by households to invest or borrow money is based on the rate Rh, which also accounts for the households' risk premium $PREMh$.

Hence, the government needs to match households' preferences and encourage them to purchase bonds.

The fiscal policy constraint in the model, ensuring general equilibrium, is the fiscal rule, which determines behavior of fiscal policy. This rule implies that there is a long-run target for the debt-to-GDP ratio, and whenever the actual debt-to-GDP ratio deviates from the target, the model tries to bring it to the target by tightening or loosening the fiscal policy.

In this case, stabilization is achieved by adjusting revenues or expenditures, or a combination of the two, with public consumption being the default adjustment tool.

The model represents a Ricardian equivalence, according to which different forms of financing the same consumption are equivalent in terms of their impact on the real economy. An underlying property of this equivalence, regarding households, is the assumption that they are rational and forward looking. In our case, savers are infinitely forward looking and adjust their current consumption accordingly.

The public sector does not directly influence the optimal decisions by the private sector, but rather affects the economy only through public demand. Meanwhile, the source of financing public consumption (through taxes or borrowing) does not matter.

Main equations for fiscal policy:

$$
\begin{aligned}
PRIMDEF\_NGDP_t &= PG\_NGDP_t - TAX\_NGDP_t \\
\log\left(G_t\right) &= \log\left(\mathtt{d}A \cdot G_{t-1}\right) \\
&\quad - \kappa_G \left(\log\left(Bg\_NGDP_{t+h}\right) - \log\left(Bg\_NGDP_{ss}\right)\right) \\
&\quad + \varepsilon_t^G \\
Bg_t &= Rg_{t-1}\, Bgh_{t-1} + S_t\, Rgw_{t-1}\, \frac{Bgw_{t-1}}{S_{t-1}} + PRIMDEF_t,
\end{aligned}
$$

where $PRIMDEF\_NGDP_t$ – primary budget deficit to GDP,

PG_NGDP_t – government consumption to GDP, TAX_NGDP_t – budget revenues to GDP, Bg_NGDP_t – public debt to GDP, Bgh_t – public domestic debt, Bgw_t – public external debt, Rgw – interest rate on government external borrowings, S_t – nominal exchange rate.

2.5. External sector

The external sector purchases government bonds in the amount of Bgw at the rate of Rgw and provides debt services to optimizers in the amount of Bhw at the rate of Rhw. Moreover, the external economy generates remittance inflows in the form of transfers $TFw^{\star}$, which are channeled to households.

In the model, the price of imports in local currency is calculated as the product of the import price of the external good in foreign currency and the exchange rate. There is a difference in the prices of imports and exports, representing the terms of trade. For instance, with improved terms of trade, a country receives more for exports than it pays for imports.

In the model, the exchange rate is defined as freely floating and foreign demand is represented implicitly through the terms of trade.

In the steady state of the model, the real growth of exports is equal to the real growth rates of other indicators such as GDP, capital and others, determined by the rate of productivity increase in the economy.

In addition, in the steady state of the model, the real exchange rate and other relative prices are assumed to be constant values. In doing so, a real appreciation of the exchange rate requires a significant improvement in the current account.

In a small open economy, world prices in foreign currency and foreign interest rates are assumed to be exogenous. This means that import prices in foreign currency are not dependent on Uzbekistan's demand for these goods.

In this situation, the model maintains stability based on relative prices. An increase in imports influences import prices in local currency, although import prices do not change in foreign currency. Excess imports causes an external imbalance that worsens the trade balance and deteriorates the

country's net international investment position. The result is price increases in the local currency and depreciation.

To establish a relationship between a country's net international investment position and the nominal exchange rate, there is a risk premium included, under uncovered interest parity condition. The domestic interest rate is equal to the world interest rate multiplied by the expected depreciation of the domestic currency. The risk premium is linked to a country's net international investment position, so a deterioration in this position leads to an increase in the risk premium, which in turn results in a depreciation of the local currency.

Financial flows

Financial flows are conducted among the three agents in the model: households, government, and the external sector (Figure 2).

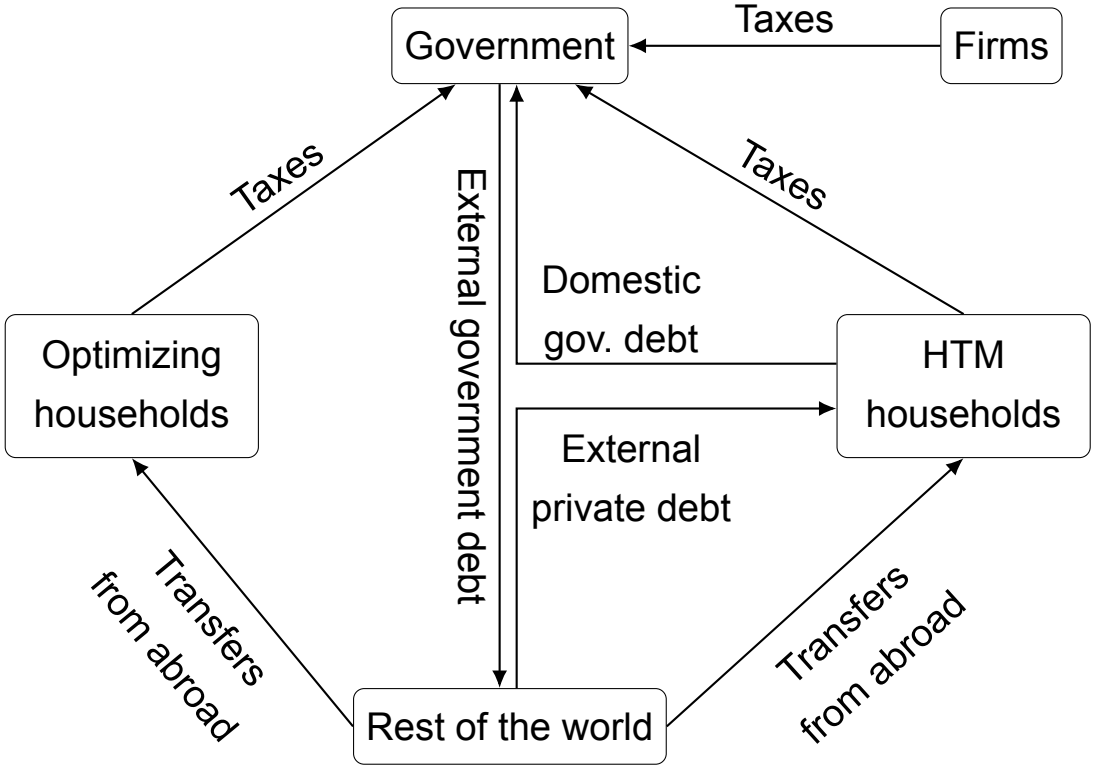

Рис. 2. Financial flows.

Main equations for linkage with the external sector.

Uncovered interest rate parity equation:

$$Rgh_t = Rhw_t \frac{S_{t+1}}{S_t} PREM_t,$$

where $PREM_t$ – risk premium, which depends on the ratio of net international investment position.

Net international investment position:

$$NIP\_NGDP_t = TB\_NGDP_t + TFw\_NGDP_t - \\ - \frac{\mathsf{d}S_t}{\mathsf{d}NGDP_t} Rhw_{t-1}\, Bhw\_NGDP_{t-1} - \\ - \frac{\mathsf{d}S_t}{\mathsf{d}NGDP_t} Rgw_{t-1}\, Bgw\_NGDP_{t-1},$$

where NIP_NGDP_t – net international investment position to GDP, $\mathsf{d}NGDP_t$ – nominal GDP growth, TB_NGDP_t – trade balance to GDP, TFw_NGDP_t – share of households' foreign transfers.

General equations for aggregation and equilibrium

Balanced real growth rates defining a single, stable, equilibrium state:

$$\log(\mathsf{d}A_t) = \rho \log(\mathsf{d}A_{t-1}) + (1-\rho)(\log(\mathsf{d}A_{ss}) + \varepsilon_t^{\mathsf{d}A}),$$

where $\mathsf{d}A_t$ – change in labor productivity, $\mathsf{d}A_{ss}$ – change in labor productivity under equilibrium state.

Equation for nominal GDP:

$$NGDP_t = P_t^{\mathsf{c}}\, C_t + P_t^{\mathsf{c}}\, I_t + P_t^{\mathsf{c}}\, G_t + P_t^{\mathsf{z}}\, Z_t + P_t^{\mathsf{q}} Q_t - P_t^{\mathsf{m}}\, M_t$$

Equilibrium state for labor resources:

$$N_t = N_t^{\mathsf{d}} + N_t^{\mathsf{z}}$$
$$L_t^{\mathsf{htm}} = L_t^{\mathsf{opt}}$$

Total imports:

$$M_t = M_t^{\mathsf{d}} + M_t^{\mathsf{z}} + M_t^{\mathsf{q}}$$

3. Response of the economy to a supply shock (inflation)

In the context of the DSGE model, let us examine the impact of a one-time inflation shock of 1 p.p. on the dynamics of macroeconomic variables and further transition to a new steady state.

This shock is characterized as a supply shock. The shock occurs in the first time period and causes acceleration of consumer inflation by the value higher than the shock itself, that is explained by the impact of increased inflation expectations, considered by the model.

Interpretation of the DSGE model results can be divided into two stages. The first stage is the initial response of the system to the shock. Further, after the first period, when the shock is equal to zero, the focus shifts to the dynamics of the model, based on the conditions caused by the given shock.

As a result of this shock, the real marginal cost, $P^{\mathsf{d}}/P^{\mathsf{c}}$, decreases as it becomes profitable for distributors to sell goods at a higher price. However, this decrease is not immediately reflected in the domestic producer prices P^{d}.

Meanwhile, according to the monetary policy rule the nominal interest rate Rg is increased as a response to the higher inflation, which leads to a rise in the real interest rate. To achieve the intended results, the interest rate hike must be significant as early as in the first period.

Higher real interest rate simultaneously influences the behavior of households, who start to reduce their consumption.

In the first period, the nominal rate Rg increase amounts to 0.8%, not exceeding the inflation rate (1.5%). This is explained by the expected inflation in this period, which is 0.6%. As a result, the real interest rate increases insignificantly (by 0.2%).

As it can be seen from the figure, private consumption C and investment I decrease, but government consumption G increases.

The decline in private consumption is caused by a decrease in real wages due to accelerating inflation. For hand-to-mouth households,

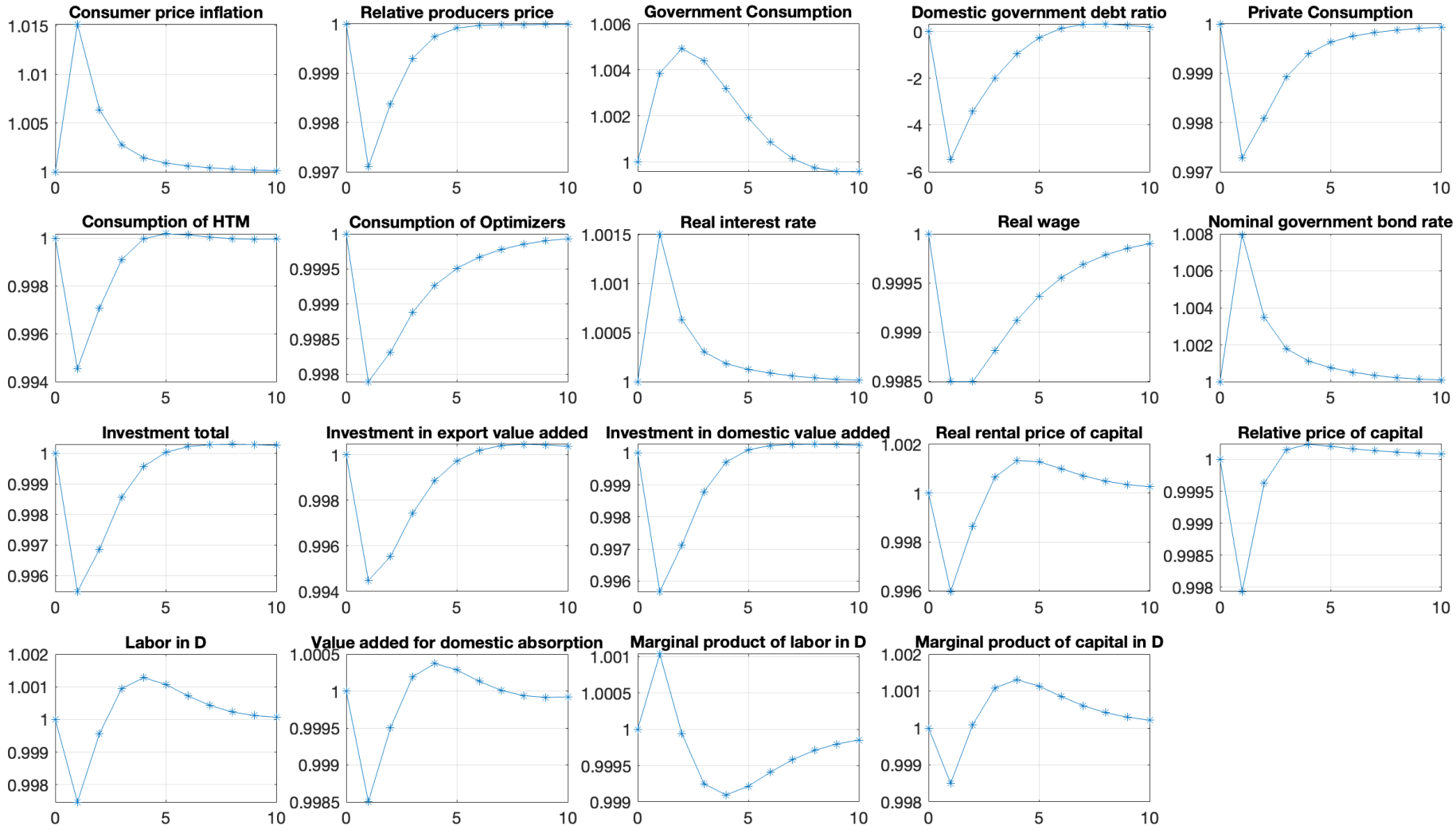

Figure 3. The response of the economy to an inflation shock.

consumption is determined by income, depending on real wages and working hours, while for savers it depends on the real interest rate. Therefore, hand-to-mouth households cut their consumption more sharply (by 0.6%) than optimizers (by 0.2%).

Investment decreases both in the domestic consumption sector I^{d} and in the non-primary export sector I^{z}. Investment demand and supply depend on the price of capital $RP^{K^{\mathrm{d}}}$. When inflation rises, the real rental price of capital $RP^{K^{\mathrm{d}}}/P^{\mathrm{c}}$ declines, deteriorating investment attractiveness and reducing investment volumes.

As a result of lower investment I^{d} and labor N^{d}, domestic output falls (by 0.15%). Output in the domestic consumption sector also shrinks due to weaker demand.

Also, with higher inflation, nominal GDP grows while the level of public debt remains unchanged, thus resulting in a decline of the public debt-to-GDP ratio from the target level. According to the fiscal rule[7] this provides an additional opportunity for the government to expand consumption without worsening the debt-to-GDP ratio.

This shock can be referred to as a cost shock or markup shock since distributors decide to sell goods at higher prices than before.

In the rigid-price model, all other prices do not instantly adjust to that sudden consumer price shock $\mathrm{d}P^{\mathrm{c}}$, which accounts for the effect of the shock through the change in relative prices given the monetary policy response.

Moreover, when analyzing the simulation of shocks, an important point to understand is how variables in general return to long-run equilibrium after an economic shock occurs, that is, in the given example, when consumption and investment start to increase, real interest rate returns to its initial level, and so on, as the shock is fading out.

At the second stage, due to a decrease in consumer demand, inflation decelerates and, accordingly, monetary policy responds by easing monetary conditions. As a result, the interest rate starts to return to

[7] The fiscal rule in the model is specified as an adjustment of the public debt-to-GDP ratio to the long-run target, by tightening or loosening fiscal policy.

the long-run equilibrium level, and correspondingly the propensity of households to save declines, thus boosting consumption.

Initially, when the demand for labor decreases, the marginal product of labor, that is, the additional output of a good from each additional worker, increases. In contrast, the marginal product of capital declines at a slower pace and remains more productive over a longer period.

Consequently, firms are willing to pay a higher interest rate for capital utilization, encouraging households to invest more, thereby boosting output.

Higher output also necessitates more labor to be hired, leading firms to raise wages. As output grows, households earn more for their labor and consumption increases accordingly.

So, in the initial period when the inflationary shock occurs, the real interest rate increases in response to the monetary policy. This leads to a reduction in consumption of optimizers. Meanwhile, lower real wages cause hand-to-mouth households to cut their consumption. Also, the real cost of capital falls, leading to a contraction in investment. All these processes eventually result in weaker domestic demand.

Further, weak demand contributes to inflation deceleration and, therefore, monetary conditions are loosened and the indicators gradually return to the steady state.

4. Response of the economy to an increase in public consumption

Another important issue of macroeconomic analysis is the assessment of the impact of changes in government consumption on the economy. To this end, in the DSGE model we simulated an increase in public consumption expenditures and examined its effect on the economy, as well as the transition process of the model to a new state of the macroeconomic equilibrium.

We defined an increase in government consumption by 1 percentage point relative to GDP as a shock.

Along with this, the model needs to identify a source of financing to cover the increased government expenditures. There are a number of alternatives to choose from: borrowing from external or domestic (households') resources, or raising taxes on households and firms.

Since the shock implies only an increase in government expenditures, taxes remain unchanged and by default the deficit is covered by borrowing (Figure 4).

According to the results of the simulation, at the first stage the budget deficit to GDP rises by 1 p.p., equivalent to an increase in government consumption, since there is no increase in revenues. Public debt amount expands accordingly to the increased deficit.

However, the public debt-to-GDP ratio `Bgh_NGDP` increases disproportionately to the budget deficit (by 1%). This is attributed to fiscal multiplier[8] of public expenditures.

In view of the increasing demand from the government, distributors raise the markup, which in turn leads to a rise in prices. Furthermore, this allows distributors to offer producers a more favorable price for supplying a good, resulting in higher marginal costs of production. However, due to the "rigidity" of producers' prices P^c, they adjust more slowly.

[8] Fiscal multiplier is the ratio of a change in output to an exogenous change in the fiscal deficit compared to their base levels

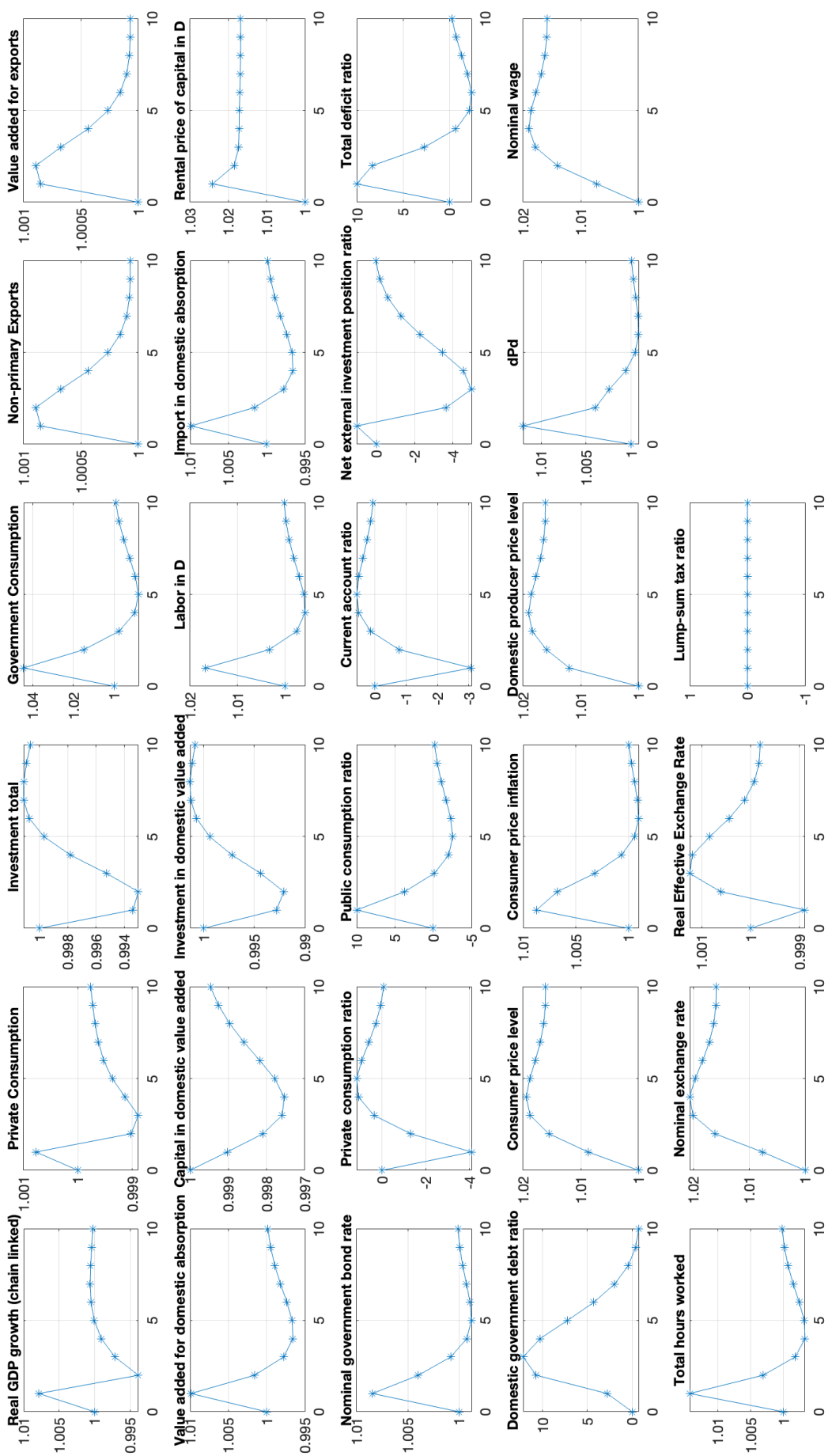

Figure 4. Response of the economy to an increase in public consumption

An important point to note is that stronger demand instantly triggers two processes. First, monopolistic distributors start demanding higher markups. Second, they may also hike the purchase price for producers to stimulate output.

The central bank responds to inflation acceleration by raising interest rates and encouraging households to purchase government bonds. This consequently causes an increase in the price of capital $RP^{K^{\mathsf{d}}}$, to support decreasing investment by households.

High rates on bonds and price of capital decelerate the fall in investment, but create additional costs for firms. As a result, firms prefer to enlarge labor to boost output.

In the first period, with current labor productivity remaining unchanged, hiring additional labor force N^{d} will require raising wages in the economy. Yet, the amount of capital does not change, as it is set in the initial period.

As wages and employment rise, households' incomes increase, and they respond to this in different ways, depending on their saving preferences. Hand-to-mouth consumers increase their consumption as income rises.

Optimizers, in contrast, are aware that increases in government spending and wages are transitory factors and respond cautiously, concerned about a possible public debt rise. They tend to avoid excessive spending, expecting the government to take measures to reduce debt, by raising taxes or cutting spending.

Thus, the created additional demand is satisfied by expanding production through more labor and more imports, rather than building new capital. In fact, investment declines marginally due to weaker demand for capital as a result of expectations that public debt will be stabilized in the future.

In addition, higher inflation along with unchanged nominal exchange rate leads to an appreciation of the real exchange rate, making imports more attractive.

Wage increases and real exchange rate appreciation decrease the

competitiveness of the non-primary export sector Z. Nevertheless, this sector experiences a small output growth of 0.1% owing to a difference in wage growth (by 0.7%) and depreciation of the nominal exchange rate (by 0.8%).

It is essential to consider the long-run perspective of the real exchange rate.

In the second stage, real wages decline requiring nominal wages to be raised, which in the long run results in an equal increase in nominal wages and consumer prices (as a result, real wages remain virtually unchanged).

Moreover, the amount of imports for domestic production M^{d} grows in proportion to the increase in output since it constitutes a certain part of the inputs to domestic production.

This generates a current account deficit, which affects the exchange rate and causes it to depreciate compared to wages. Initially, this deficit is covered by financing higher imports through borrowing. However, these developments are temporary as households will eventually have to disburse these debts, which results in a further depreciation of the exchange rate.

Thus, an expansion in public consumption expenditure initially stimulates domestic output and temporarily improves employment, however, it does not serve to generate long-run output growth.

The multiplier effect of higher spending is also temporary and limited. Thus, in the first year government spending adds about 1% to real GDP, and in the following years this effect fades out.

As a result, a new steady state of the economy is achieved with the same real growth rates, but higher prices and weaker exchange rate.