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Master thesis

System Dynamic Modeling of Labor Market Processes

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Introduction

The market refers to a system of economic relationships formed during the production process and the free flow of products, labor, and capital. The labor market is a system of social relationships that associate with the purchasing and selling of "labor". The labor market is unique in that it covers not just labor supply and demand, which are significant market components, but also the process of production in which the employees are involved.

Everyone who is able to work is covered by the labor market, both employed and jobless. Unemployed people are people who do not work but wish to work and are seeking a job. The labor force is formed of both employed and unemployed people. The labor supply is determined by these groups of individuals.

Product, demand, supply, and pricing are the elements that make up the labor market. The main agents of the labor market are employers and workers. The demand for labor is provided by employers. Increasing demand can be achieved, for example, by stimulating it through the creation of new jobs or direct investment in reconstruction and job creation. The labor supply represents the quantity of individuals who are willing and able to work, taking into consideration their age, gender, qualifications, education, occupation, and other factors. Labor supply is influenced by a variety of factors such as socioeconomic, demographic, psychological, and others. The cost of work is the wage.

This paper reviews the features of the application of a dynamic stochastic general equilibrium model (DSGE model) to investigate the government's monetary policy stabilizing impact on the labor market and other components of the Ukrainian economy. Applying the DSGE model makes it possible to deepen the analysis of the processes of the dynamic of a system in comparison with the NBU Quarterly Projection Model.

Many scientific papers are devoted to the research and development of models of economic equilibrium. Since the late 1960s, the central banks of the world's leading countries have used macroeconomic modeling.

Dynamic models, in contrast to static models, characterize the economy in dynamics. The model consists of endogenous variables’ lag. The models don't only consider the time dependency of variables, but also their relationship over time. This type of model involves the study of the economy's equilibrium state and determining the best path for the system's economic development.

Macroeconometric models gave way to computational and stochastic general equilibrium models in the 1990s. These models already take into account the behavioral strategies of economic agents that impact macroeconomic processes and describe variable models and databases.

To increase the efficiency of government monetary policy, the National Bank of Ukraine, in collaboration with Zoltan Reppa, Senior Economist of OGResearch, developed the Medium-Term Growth Model of Ukraine based on the DSGE model. The developed DSGE model allows to analyze the key macroeconomic indicators' dynamics under various behavioral scenarios.

Economic development indicators, which correspond to the National Economic Strategy for the period up to 2030, were estimated using this model.

In Chapter 2 another approach to study the labor market – System Dynamics Approach is considered. System Dynamics can help to do macroeconomic analysis.

The considered model was built using Stella Architect Software. The purpose of the given sub-model is to analyze the dynamics of labor supply regulation. The sub-model reflects the relationship between employment, unemployment, and working time per employee.

Chapter 1

DSGE Model

1.1 The features of the basic DSGE model

Dynamic stochastic general equilibrium models (DSGE models) are models of general equilibrium of the economy which take into consideration the effect of both endogenous and exogenous aspects of the environment in which the system functions. The DSGE models are one of the most significant instruments for studying the theoretical monetary policy's impact on the economy, and the Central banks also utilize them to carry out monetary policy stabilization measures in the framework of inflation targeting.

The word “dynamic” means that the solution determines the dynamics of all endogenous system variables. The word “stochastic” refers to how stochastic shocks impact the dynamics of variables, and general equilibrium. Also, in all periods of time and in all markets, supply is equal to demand.

The central banks of Canada, the United States, England, Sweden, Norway, and Finland have developed and widely used models of this type. Models of this type have also been introduced as basic models of analysis and forecasting in the Czech Republic and Romania. Models based on this approach are still one of the most effective instruments for analyzing macroeconomic dynamics and forecasting.

The basis of such models is two equations. The first is the IS curve based on the future, in which the current aggregate demand positively depends on the expected future income and negatively – on the real interest rate in the short term. Except for the use of future income expectations, this characteristic is similar to the traditional Keynesian IS curve. Another equation determines the aggregate supply function, which connects inflation to inflation expectations and current real marginal expectations.

The basic DSGE model consists of such main blocks:

- Modification of the aggregate supply or demand function;
- Development of the central bank's goal function.
- Description of the model of the transmission mechanism for the economy's monetary policy;

Figure 1 shows the mechanism for creating a DSGE model.

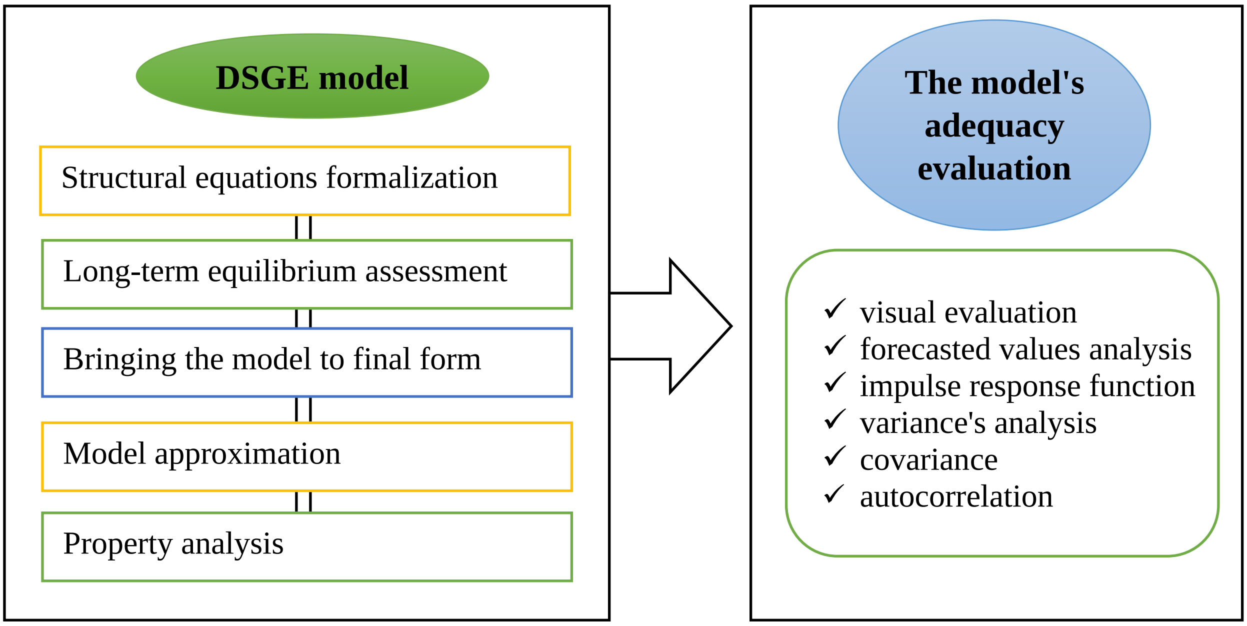


Figure 1.1. *General mechanism for building DSGE model*

In general, the model can be represented as follows:

$$\begin{bmatrix} X_{t+1} \\ Hx_{t+1|t} \end{bmatrix} = A \begin{bmatrix} X_t \\ x_t \end{bmatrix} + Bi_t + \begin{bmatrix} C \\ 0 \end{bmatrix} e_{t+1} \quad (1.1)$$

X_t is a vector of given variables in period t, x_t is an endogenous random variable's vector (*forward-looking* variables). The i_t is a vector of monetary policy instruments. The e_t is a vector of shocks that are distributed identically and independently with $E = 0$ and covariance matrix. A, B, C *and* H are matrices. The $x_{t+\tau|t}$ indicates $E_t x_{t+\tau}$ – rational expectation of $x_{t+\tau}$ based on knowledge given in the period t.

Assumptions of the DSGE model are as follows:

- agents of the economy optimize their target functions, i.e., decisions are made based on the outcomes of their functions' optimization, provided that there are constraints on possible actions and parameters;
- the economy's production function and constraints (technology constraints, fiscal and monetary policy restrictions) are determined;
- certain uncertainties about the future come as a result of stochastic shocks to the economy that are difficult to predict;
- expectations in the model are considered rational.

There are several advantages to using DSGE modeling. It may be used to simulate the behavior of controlled variables in response to various shocks, as well as to simulate various scenarios of monetary stabilization policy’s impact and forecast future development.

DSGE-models, however, have a disadvantage, despite their popularity among the world's leading countries. Most research models do not incorporate the financial component into their structures, which is a significant weakness of this approach.

DSGE models have been criticized for their inability to foresee the 2008 financial crisis. Models of this type were unable predict a crisis since the prevailing view was that large financial shocks were unlikely. The cost of developing and running DSGE models is significantly higher than that of other models. Other drawbacks were the imperfection of the banking sector and financial markets, heterogeneity, limited rationality, information overload, and coordination problems. Also, identifying the parameters of the model requires a sufficiently long time series, reflecting economic processes without qualitative changes. The large size of the model, which is effective in the process of modeling macroeconomic dynamics in the long run, is also one of the main disadvantages of these models.

However, despite all the above shortcomings, current-generation dynamic stochastic models remain the most effective tool for assessing monetary policy and making long-term forecasts.

Researchers believe that DSGE models are not incorrect, but that they must be modified to include all the significant factors, such as the financial sector, financial market imperfections, nonlinearity, heterogeneity, and other factors.

The National Bank of Ukraine uses the QPM model as the basic model. This model is based on modeling the deviations of macroeconomic variables from their equilibrium levels. The use of a QPM model is an effective tool for assessing risks and uncertainties, in particular when constructing alternative scenarios. This model allows to simulate the functioning of the economy and analyze the effects of exogenous shocks on the system. This model belongs to the DSGE models of medium size.

To increase the effectiveness of the government's monetary policy, the NBU is working to improve the developed comprehensive DSGE model.

1.2 Modeling Ukraine's Growth with DSGE model

Developed by OG Research and the National Bank of Ukraine, the DSGE model includes three agents, such as producers, the government, and households. In the model, there are considered domestic and export sectors. The last is divided by the commodity and non-commodity sectors. The main outputs of the model, or final goods, are labor, exports, domestic consumption, and investment. The government borrows domestically and internationally. The government's revenue consists of three types of taxes: labor, lump-sum, and value-added; and profit.

Conditions of general equilibrium in this model mean that the equations of the model are in equilibrium conditions; agents accept prices as given; functions of demand and supply are derived from optimal conditions.

Important agents of the model are households that optimize their expected consumption and labor utility functions over life, taking into account habits of preference, which are exogenous. Households have their own capital and can invest, but if they decide to change the inputs of production or investment, it will incur additional costs. Labor is provided by households, while capital is rented by producers in households. Also, households may save or borrow in foreign currency, as well as in government bonds.

Let's look at some of the model's equations that are connected to the labor market.

The utility function has the form:

$$E\sum_{t=0}^{\infty}\beta^{t}\left[\frac{\left(\frac{C_t}{L_t}-\bar{\Gamma}_t\right)^{1-\delta}}{1-\sigma}-\frac{\theta}{1+\eta}N_t^{1+\eta}+\nu\ logV_t\right] \qquad (1.2)$$

Here, β is subjective preference for certain periods of time. The $C-$ consumption, $L-$ labor force. The $\bar{\Gamma}-$ consumption reference level. The $\sigma-$ intertemporal substitution elasticity, $\eta-$ labor/consumption substitution. $N-$ working hours and V means the net worth.

The next formula determines the consumption reference level $\bar{\Gamma}$.

$$\bar{\Gamma}_t = \chi \overline{\left(\frac{C_{t-1}}{L_{t-1}}\right)} + \psi \frac{\overline{DLI_t}}{P_t^C L_t} \tag{1.3}$$

The χ is habit persistence, C_{t-1} is the consumption in previous period, and DLI means disposable labor income.

The equation (1.3) means that households would like to maintain at least some of the percentage of prior consumption that is typical of all households. A “bar” above $\bar{\Gamma}_t$ and C_{t-1} means that habit impact is considered exogenous. And last, if the household’s income increases, consumption will also increase.

The disposable labor income is calculated as follows:

$$DLI_t = (1 - \tau_t^L)\, W_t N_t - TX_t^{LS} \tag{1.4}$$

There, W is wage, TX_t^{LS} – lump-sum taxis.

The budget constraint of households has the next form:

$$C_t + I_t + E_t + BG_t^{lcy} + BH_t^{fcy} + TX_t^{LS} = \tag{1.5}$$

$$= (1 - \tau_t^L)\, W_t N_t + PR_t^K\, K_{t-1} + \Pi_t + R_{t-1}^H BG_{t-1}^{lcy} + R_{t-1}^{H_*} BH_{t-1}^{fcy} \frac{S_t}{S_{t-1}}$$

The I is investment, E – adjustment costs, BG_t^{lcy} – domestic savings, BH_t^{fcy} – foreign assets. The expression $(1 - \tau_t^L)\, W_t N_t$ means the labor income, $PR_t^K\, K_{t-1}$ – capital rentals, PR_t^K is the cost of renting one unit of capital for one year, Π is profits, and last two terms indicate the gross interest.

In equation (1.5), consumption and investment are priced the same. Changes in investment and capital incur adjustment costs, which are paid by households. Households receive profits and pay adjustment costs as well, but they do not consider them while optimizing.

$$\Lambda_t = \frac{1}{L_t}\left(\frac{C_t}{L_t} - \chi \frac{C_{t-1}}{L_{t-1}} - \psi \frac{DLI_t}{L_t}\right)^{-\sigma} \tag{1.6}$$

The equation (1.6) describes *the optimal conditions for consumption.* Here, the shadow price of income Λ_t is equal to the consumption's marginal utility. Multiply it by Λ_t to determine the additional utility of the extra income in period t.

The optimality conditions for labor are stated by the following equations:

$$\theta N_t^{\eta} = \Lambda_t \,(1 - \tau_t^L)\, W_t^F$$
$$W_t = (W_{t-1})^{\rho w}\, (W_t^F)^{1-\rho w} \qquad (1.7)$$

The Λ_t is the utility effect of the additional wage income. The θN_t^{η} means the disutility of an extra working hour. The $(1 - \tau_t^L)\, W_t^F$ represents the nominal income from an extra working hour. The W_t is the actual wage and W_t^F is the flexible wage.

Actual wages are real rigidities, and the disutility of extra labor is compensated by the utility of additional consumption, which is paid by additional wage revenue.

The production function of domestic goods producers has the following shape:

$$Y_t^D = (K_{t-1}^D)^{\gamma_K^D}\, (A_t^D\, VN_t^D)^{\gamma_L^D}\, (M_t^D)^{\gamma_M^D} \qquad (1.8)$$

The K_{t-1}^D is the capital in domestic sector previous period. The A_t^D is the labor-augmenting productivity in domestic sector, the M_t^D is import, and the VN_t^D is the variable labor.

The equation (1.8) displays the *Cobb-Douglas production function* with $\gamma_K^D + \gamma_L^D + \gamma_M^D = 1$.

Variable labor means that a certain percentage of employed labor is considered "unproductive":

$$VN_t^D = N_t^D - n^D \overline{N^D} \qquad (1.9)$$

The $\overline{N^D}$ is the value of the steady-state of labor.

If changing the share of labor and (or) import share changes, the producers will have to deal with the adjustment cost:

$$E_t^D = \frac{\xi_D}{2} P_t^D\, Y_t^D \left(\log\left(\frac{VN_t^D}{M_t^D}\right) - \log\left(\frac{VN_{t-1}^D}{M_{t-1}^D}\right) + \log dZ^D\right)^2 \tag{1.10}$$

The profit is calculated as follows:

$$\Pi_t^D = P_t^D Y_t^D - PR_t^D K_{t-1}^D - W_t N_t^D - P_t^M M_t^D - E_t^D \tag{1.11}$$

In the labor market, the ad hoc real wage equation has the form:

$$log\left(\frac{W_t}{P_t^C}\right) = \rho_w\, log\left(dZ\frac{W_{t-1}}{P_{t-1}^C}\right) + (1-\rho_w)\, log\left(\frac{W_t^F}{P_t^C}\right) \tag{1.12}$$

The equilibrium conditions for the domestic product and labor markets are given by the equations below.

$$Y_t^D = C_t + I_t + G_t \tag{1.13}$$

$$I_t = I_t^D + I_t^X \tag{1.14}$$

$$N_t = N_t^D + N_t^X \tag{1.15}$$

The index D means domestic and the index X – export. So, all employed consist of employed in domestic sector and employed in export sector.

So, the model equations related to the labor market are:

- ✓ Households

$$\Lambda_t(1-\tau_t^L)W_t^{flex} = \theta N_t^{\eta} \tag{1.16}$$

$$log\left(\frac{W_t}{P_t^C}\right) = \rho_w log\left(dZ\frac{W_{t-1}}{P_{t-1}^C}\right) + (1-\rho_w)\, log\left(\frac{W_t^{flex}}{P_t^C}\right) \tag{1.17}$$

- ✓ Domestic production

$$Y_t^D = (K_{t-1}^D)^{1-\gamma_M^D-\gamma_N^D}\,(M_t^D)^{\gamma_M^D}\left(A_t\,(N_t^D - n_D N_{ss}^D)\right)^{\gamma_N^D} \tag{1.18}$$

$$W_t\,(N_t^D - n_D N_{ss}^D) = P_t^D\, Y_t^D(\gamma_N^D - AUX_t^{NMD} + \beta\, AUX_{t+1}^{NMD}) \tag{1.19}$$

- ✓ Export production

$$Y_t^X = (K_{t-1}^X)^{1-\gamma_M^X-\gamma_N^X}\,(M_t^X)^{\gamma_M^X}\left(A_t\, A_t^X(N_t^X - n_X N_{ss}^X)\right)^{\gamma_N^X} \tag{1.20}$$

$$\mu_X W_t\ (N_t^X - n_X N_{ss}^X) = P_t^{X,0}\ Y_t^X(\gamma_N^X - AUX_t^{NMX} + \beta\ AUX_{t+1}^{NMX}) \tag{1.21}$$

The A_t^X means additional productivity in export sector in addition to general productivity A_t.

- ✓ Fiscal policy

$$TAX^L\_NGDP = \tau_t^L(WN\_NGDP_t + WG\_NGDP_t) \tag{1.22}$$

The WN_NGDP_t is the labor cost ratio to the Nominal GDP. The $NGDP$ is the Nominal GDP and is calculated as following:

$$NGDP_t = P_t^C\ Y_t^D + PX_t - PM_t \tag{1.23}$$

- ✓ Equilibrium and identities

$$N_t = N_t^D + N_t^X \tag{1.24}$$

$$\Pi_t = \frac{P_t^C}{1+\tau_t^C}\ Y_t^D + PX_t - WN_t - PM_t^D - PRK_t^D K_{t-1}^D - PRK_t^X K_{t-1}^X \tag{1.25}$$

$$WN_t = W_t N_t \tag{1.26}$$

If rewrite these equations in real terms, the equations change next:

- ✓ Households

$$log\ (W_t) = \rho_w log\ (dZW_{t-1}) + (1-\rho_w)\ log\left(W_t^{flex}\right) \tag{1.27}$$

- ✓ Equilibrium and identities

$$\Pi_t = \frac{1}{1+\tau_t^C}\ Y_t^D + PX_t - WN_t - PM_t^D - PRK_t^D K_{t-1}^D - PRK_t^X K_{t-1}^X \tag{1.28}$$

The other equations are the same.

In the steady-state, equations will take this form:

- ✓ Domestic production

$$Y_t^D = (K_{t-1}^D)^{1-\gamma_M^D-\gamma_N^D}\ (M_t^D)^{\gamma_M^D}\left(A_t\ (N_t^D - n_D N_{ss}^D)\right)^{\gamma_N^D} \tag{1.29}$$

$$W_t(N_t^D - n_D N_{ss}^D) = P_t^D Y_t^D \gamma_N^D \quad (1.30)$$

✓ Export production

$$Y_t^X = (K_{t-1}^X)^{1-\gamma_M^X-\gamma_N^X} (M_t^X)^{\gamma_M^X} \left(A_t A_t^X (N_t^X - n_X N_{ss}^X)\right)^{\gamma_N^X} \quad (1.31)$$

$$\mu_X W_t(N_t^X - n_X N_{ss}^X) = P_t^X Y_t^X \gamma_N^X \quad (1.32)$$

When the labor market is in a state of equilibrium, we have:

$$\frac{P^C AN}{NGDP} = \frac{P^C Y^D}{NGDP} \frac{AN^D}{Y^D} + \frac{P^C Y^X}{NGDP} \frac{AN^X}{Y^X} \quad (1.33)$$

1.3 Ukraine's DSGE model in MATLAB

The Ukrainian DSGE model was performed in MATLAB using the Macroeconomic Modeling Toolbox IRIS. IRIS is a powerful toolbox for modeling and forecasting macroeconomics in MATLAB.

Some of the MATLAB equations in which the elements of the labor market appear can be found in Appendix 1.

Let's consider the modeling process in MATLAB. It includes the next steps:

- Reading the model and initializing the parametrization.

At this stage, the Model Object is created from a text file by reading the model equations. Then initial parameter values and standard deviation values are assigned. Before solving the model, the calculation of the steady-state is performed. After all, the result is saved and reported. The outcomes don't make a lot of sense; they're just starting points for the calibration.

So, in the model, such initial parameter values are set:

```
beta    = 0.98;    % discount factor
chi      = 0.00;    % habit persistence
psi      = 0.00;    % DLI in consumption
eta      = 0.00;    % elasticity of labor supply to the real wage
theta   = 1.00;    % labor supply scale parameter

gammaNd = 0.4;     % labor intensity of production
gammaMd = 0.3;    % capital intensity of production
nd      = 0.0;            % share of fixed labor

gammaNxn = 0.4;    % labor intensity of production
gammaMxn = 0.3;   % capital intensity of production
nxn      = 0.0;           % share of fixed labor

gammaNxc = 0.4;    % labor intensity of production
gammaMxc = 0.3;   % capital intensity of production
nxc      = 0.0;     % share of fixed labor
mu = muxn = muxc = 1.1;    % mark-up parameter
xiNdMd = xiNxnMxn = xiNxcMxc = 0; % labor/import adjustment cost
```

```
ss_tauL  =  0.10;   % tax on income
rho_W  =  0.6;      % persistence in Real Wage
ss_dL   =  1;         % productivity growth
rho_dL  =  0.5;    % persistence of productvity growth shock
```

- ❖ Reading the data from the Excel files
- ❖ Creating a database of the model

This stage includes data transformation into model-consistent variables.

- ❖ The parameters' calibration

The parameters of the model have been calibrated to match the set target steady-state ratios. For convenience, dynamic parameters, that is, parameters that do not affect the steady-state, are also specified here.

So, such dynamic steady-state and direct behavioral parameters were set:

```
% labor force growth
 ss_dL     =  1.000;

% Direct behavioral parameters
 beta     = 0.98;
 eta      = 2.00;
 psi      = 0.25;
 chi      = 0.50;

 xiNdMd   = 1.50;
 xiNxnMxn  = 1.50;
 xiNxcMxc  = 1.50;

 nd  = 0;
 nxn = 0;
 nxc = 0;

% Exogenous persistences
 rho_dL             = 0.50;
 rho_W              = 0.60;
```

Such parameters as "gammaNd", "gammaNxn", "gammaNxc", "mu", "ss_tauL", and "theta" are calibrated to match set target steady state ratios, including, in particular, such target variables:

```
targetVariables.WN_NGDP       =  0.48; % return to previous average
targetVariables.Nd_L          =  0.66; % close to data
targetVariables.Nxn_L         =  0.155; % close to data
targetVariables.Nxc_L         =  0.10; % close to data
```

- ❖ Calibration and estimation of the shocks' standard deviations.
- ❖ Using the calibrated parameters and standard deviations for reading the model.

The model is read with the calibrated parameters and standard deviations, the steady-state is calculated, and the model is solved. The model that results can be used for filtering and simulation.

- ❖ Defining observed variables and running the Kalman filter. Report results.
- ❖ Setting baseline tunes, calculating the baseline, and reporting.

1.4 Baseline scenario for Ukraine's DSGE model: Labor sector

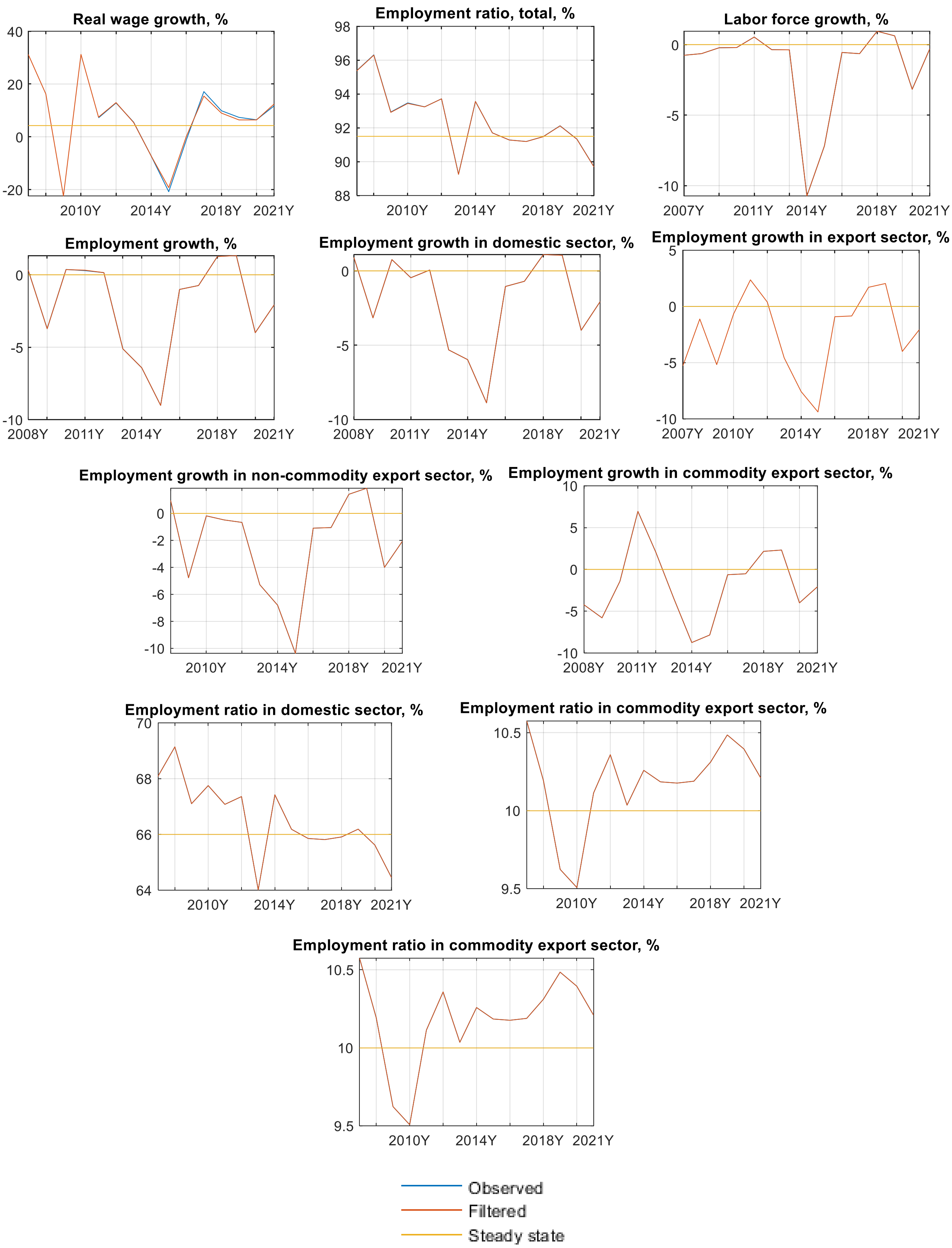


Figure 1.2. *Historical data and the steady-state of some labor market components.*

Figure 1.2 represents the historical data, denoted as 'observed' on the graph, filtered data, which was obtained using the Kalman Filter, and the steady-state of some labor market components: employment, labor force, and wage. The time horizon is up to 2021. Here, the lines of the graphs for 'observed' and 'filtered' overlap. It tells us about the well-fitting of the modeled data with the historical data.

The Baseline scenario represents the current calibration of the model without shocks and any changes. The time horizon for the forecast for the baseline scenario is 2022 to 2030.

Let's consider what will the labor market indicators look like on the forecast horizon.

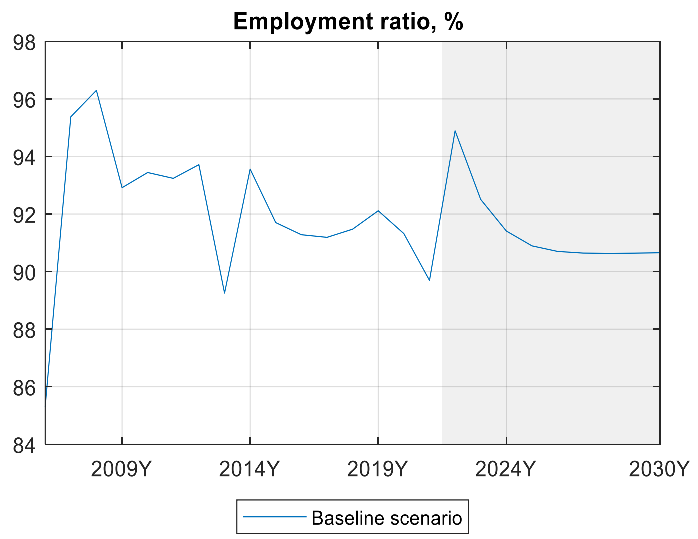


Figure 1.3. *Baseline: Employment ratio.*

Figure 1.3 shows the historical behavior to 2021 and the forecast for 2022-2030 for the Employment-to-Labor force ratio. In 2021, the Employment ratio is 89.7%, which means that the unemployment rate is 10.3%. In the first forecasted period (2022), the unemployment rate will reduce, but then it will increase. It is due to the steady-state value, which is 91.5% for the Employment ratio (8.5% for unemployment). That is, the model returns to its equilibrium.

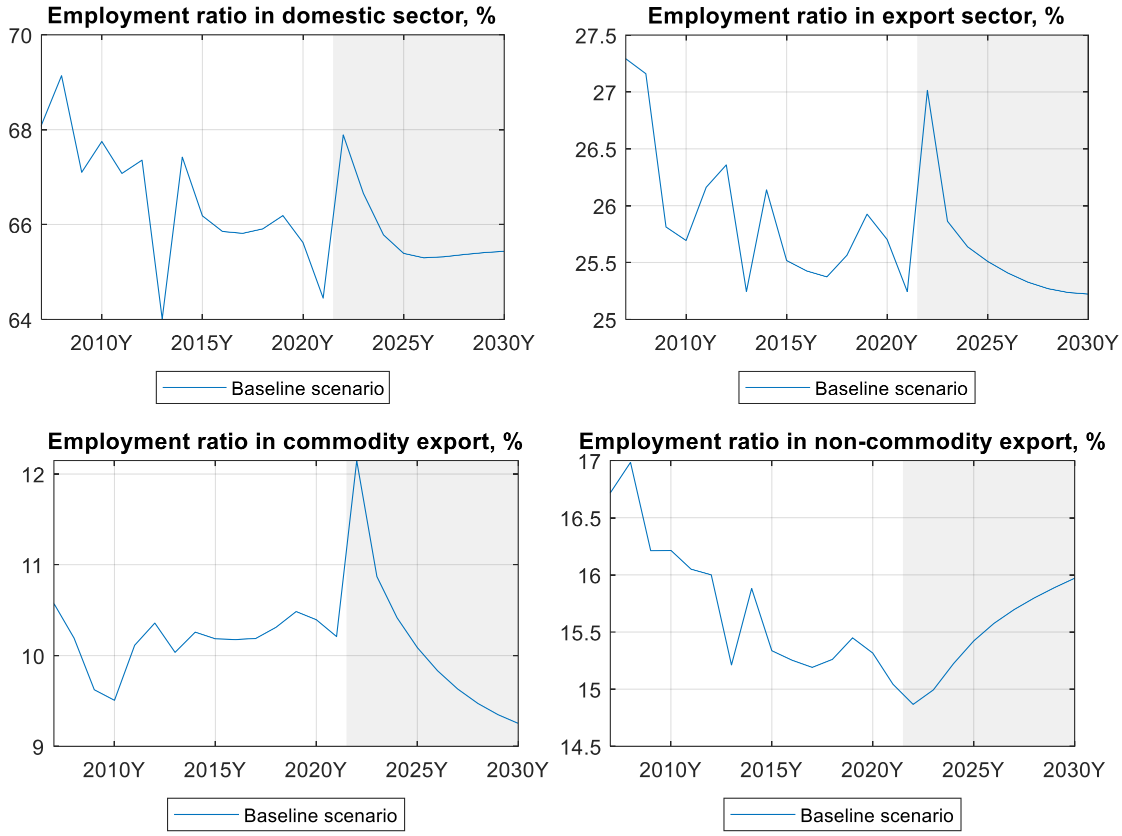


Figure 1.4. *Baseline: Employment ratio in different sectors.*

Figure 1.4 depicts what happens with the Employment ratio in various sectors, such as domestic, commodity, and non-commodity exports.

Figure 1.5. *Baseline: Real wage growth.*

Figure 1.5 depicts the dynamics of Real wage growth. In 2021, it is 12.4%. According to the forecast, in 2022 it will be 7.2%, and then this variable will go to a steady state of 4.25% growth in a year in comparison to the earlier year.

1.4.1 Impulse response function

Impulse response functions are used to track the dynamic impact of a "shock" or change in input on a system. Let's consider what shocks impact on employment ratio. To do this can be used the function of shocks decomposition.

The table below (Table 1.1) shows the contributions of shocks to the employment ratio in 2021. If the value of the shock's contribution is 1, then there is no contribution; if it is less than 1, then the contribution is negative; and if it is more than 1, then the contribution is positive.

Name of shock	Contributions to Empl. ratio	Name of shock	Contributions to Empl. ratio
shk_Nd	0.96255	shk_Ixn	0.99998
shk_dAxn	0.96373	shk_ N	1
shk_Id	0.97957	shk_TAXls_NGDP	1
shk_Md	0.98086	shk_dInvent	1
shk_Bg_NGDP_tar	0.98981	shk_dXdiscr	1
shk_NFA_NGDP	0.99173	shk_Nxc	1.0006
shk_W	0.99244	shk_tauC	1.0018
shk_Axc	0.99303	shk_RRw_star	1.0024
shk_Mxc	0.994	shk_CPREM	1.0024
shk_Remit_NGDP	0.99478	shk_Pd	1.0064
shk_PG_NGDP	0.99494	shk_PREM_UIP	1.0066
shk_Yd	0.99545	shk_Yxn	1.0121
shk_PREM	0.99564	shk_Mxn	1.0125
shk_tauPIE	0.99703	shk_dA	1.0126
shk_tauL	0.99795	shk_Nxn	1.0142
shk_Ixc	0.9984	shk_Bg_NGDP	1.0219
shk_dL	0.99857	shk_ToTn	1.0296
shk_PInvent_NGDP	0.99908	shk_C	1.0357
shk_Bg_lcy_ratio	0.99975	shk_ToTc	1.0369

Table 1.1. *Shock contribution to Employment ratio.*

In the table, the names of shocks are short for convenience. The full name can be found in Appendix 2. To explore how shocks impact on this variable and what the corresponding impulse response functions are, let's choose some of the shocks from the top and bottom of Table 1.1 and show the variables' reactions to these shocks.

For Labor demand in domestic production shock (shk_Nd) we have from Table 1.1 that this shock in 2021 leads to a reduction of Employment ratio in 2021.

Figure 1.6 shows the dynamics of this shock. As can be seen in 2021 the value of the shock is -0.3 = -30%.

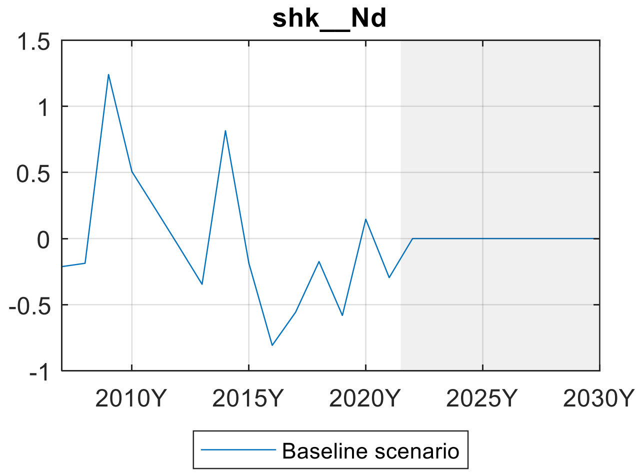
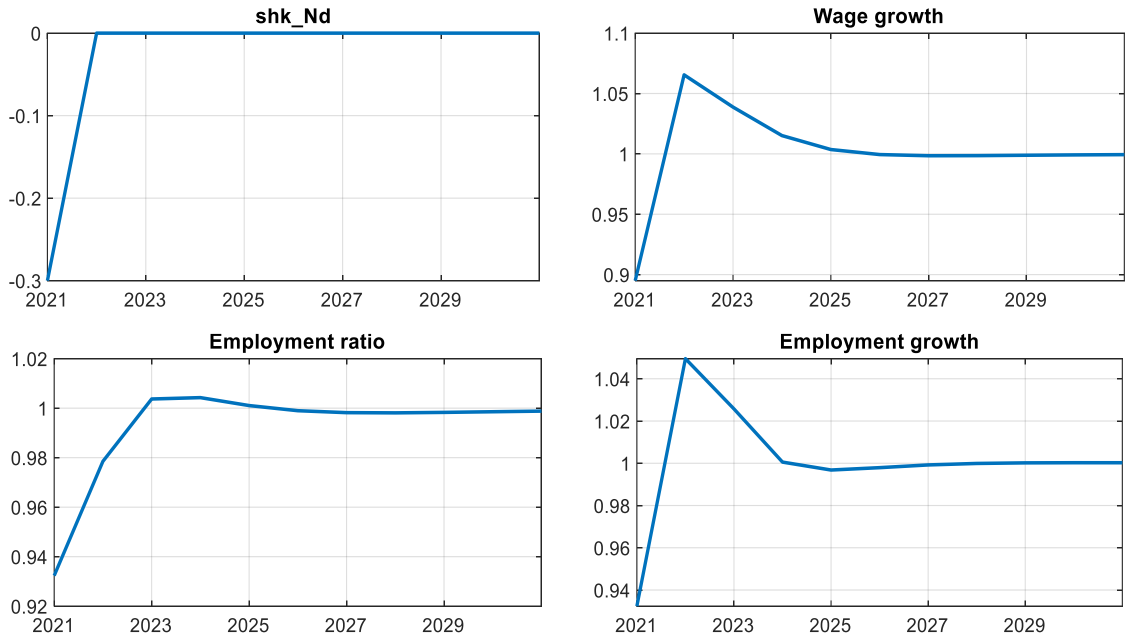


Figure 1.6. *Labor demand in a domestic production shock.*

Figure 1.7 depicts the effects of such a shock on total employment growth, the employment ratio, employment growth in various sectors, and real wage growth. As can be seen, the negative shock causes a decrease in the value of all considered variables in the first period and an increase in the second period.



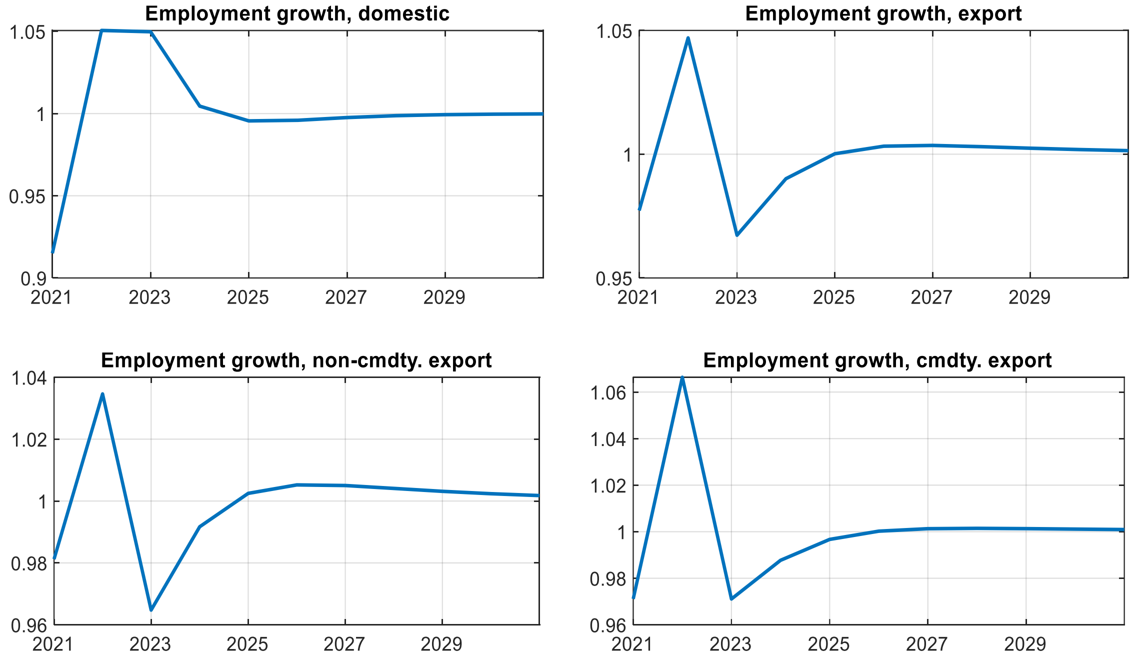
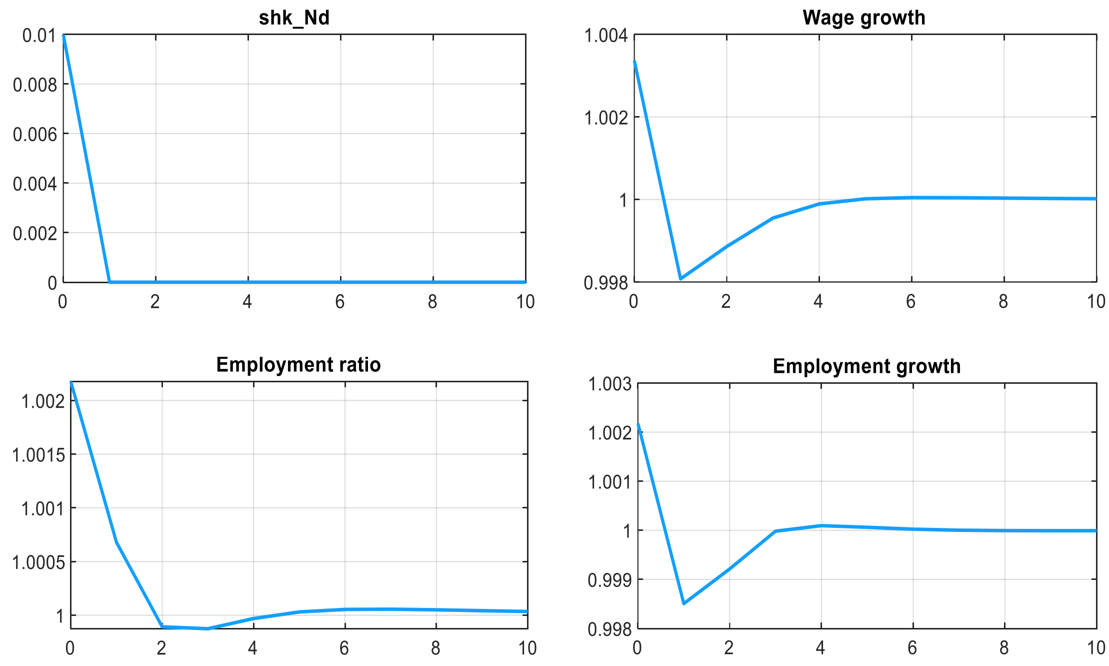


Figure 1.7. *Impulse response function for -3% of Labor demand in a domestic production shock.*

Figure 1.8 shows the contributions for 1% of Labor demand in a domestic production shock (shk_Nd) to the total employment growth, employment ratio, employment growth in different sectors, and real wage growth. So, 1% of the shock leads to a 3% increase in wage growth in the first period and a decrease of 2% in the second period. The Employment ratio increased by 0,25% in the first period, increased by 0,07% in the second period, and decreased by a non-significant percent (about 0,01%) in the third period.



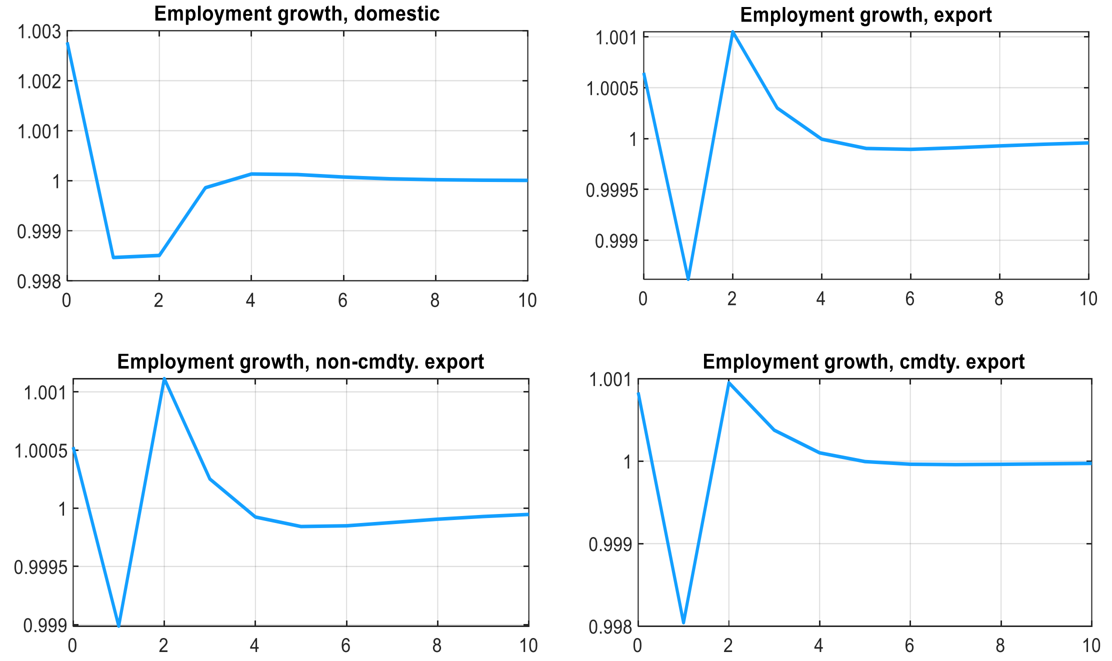
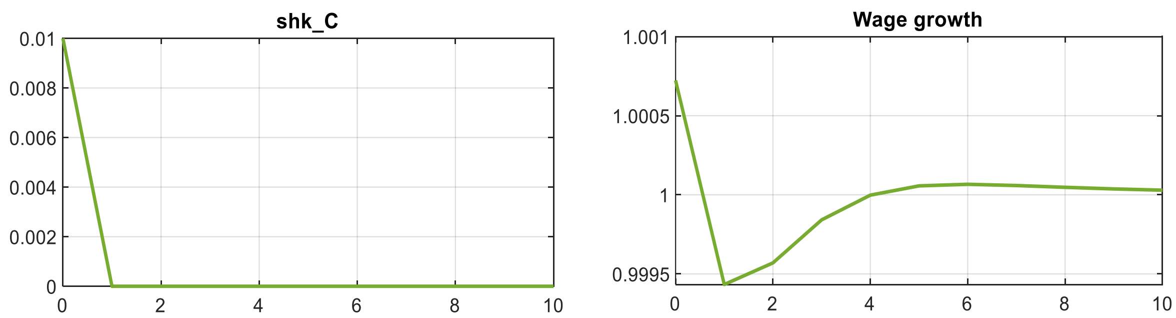


Figure 1.8. *Impulse response function for 1% of Labor demand in domestic production shock*

Now, let's consider how the Private consumption shock (shk_C) influences total employment growth, employment ratio, employment growth in different sectors, and real wage growth. It is shown on Figure 1.9. The positive shock of 1% leads to an increase in wage growth, employment growth, and employment growth in the domestic sector in the first period and a decrease in the second period. The Employment ratio increased in the first two periods. Employment growth in the export sector (commodity and non-commodity sectors) decreased in the first period and increased in the next period.



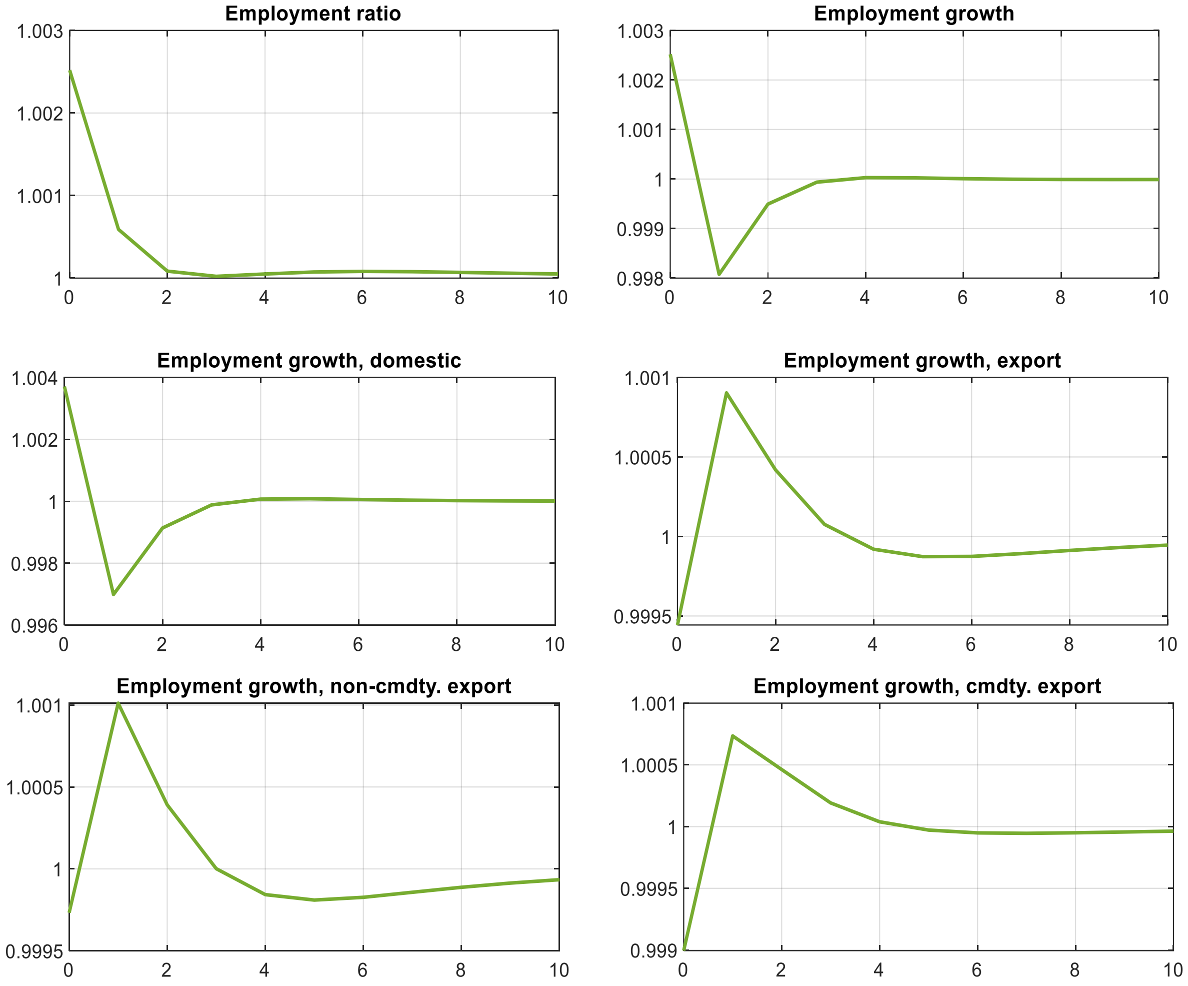


Figure 1.9. *Impulse response function for 1% of Private consumption shock*

So, impulse response functions and shock decompositions are really useful tools to analyze the impact of the shock on variables, provide an explanation of certain behavior, and analyze shock contributions to the variable's behavior.

1.5 On the way to the economic growth of Ukraine according to the government program up to 2030

On March 3, 2021, the Cabinet of Ministers of Ukraine adopted the National Economic Strategy for the period up to 2030. The strategic goal of Macroeconomic Policy is to maintain macroeconomic stability, create an efficient financial sector, and ensure the state's financial sustainability. So, we have a strategy and the challenge is to build a scenario that fits that strategy using the DSGE model.

Fore indicators of the direction of development, which are specified in the Table 1.2, were chosen. The second column shows the value of the corresponding indicator for 2030. The third column shows the value of the model in the baseline scenario for 2030. And the last column indicates what changes have been made in the model in order to achieve this goal for 2030.

Indicators	Government scenario for 2030	The baseline scenario for 2030	Changes in the model
1. Real GDP growth rates	7 %	3,7%	Adding a Productivity growth shock and a non-commodity export sector productivity growth shock.
2. The government's debt to GDP ratio	30-40% of GDP	50,4% of GDP	Changing the steady-state of the Government debt to GDP ratio and the autoregressive coefficient (Government debt ratio smoothing).
3. A gross fixed capital formation ratio	> 20% of GDP	17,8% of GDP	Adding the shock to Investment in domestic production
4. The unemployment rate	6%	8,3%	Adding the shock to domestic labor demand.

Table 1.2. *Indicators of the direction of economic development of Ukraine.*

Achieving each of these goals will lead to changes in the indicators of the labor market. Let's see what the implementation of this strategy will mean for our forecasts, particularly for the Employment ratio, and, as a result, for the unemployment rate.

Real GDP growth rates. From 3,7% to 7% in 2030

The value of the first indicator, real GDP growth rates, from 3.7% to 7% in 2030 was achieved by increasing productivity, as is shown on Figure 1.10. Two scenarios are considered in addition to the baseline. The orange line indicates a scenario with increasing general productivity for all sectors. And the green line is the scenario with increasing general productivity for all sectors and decreasing additional productivity in the non-commodity export sector. The new scenario is called 'Govt.', that is government scenario. In addition, each new scenario for achieving new goals for our indicators will be added accumulatively to the previous one.

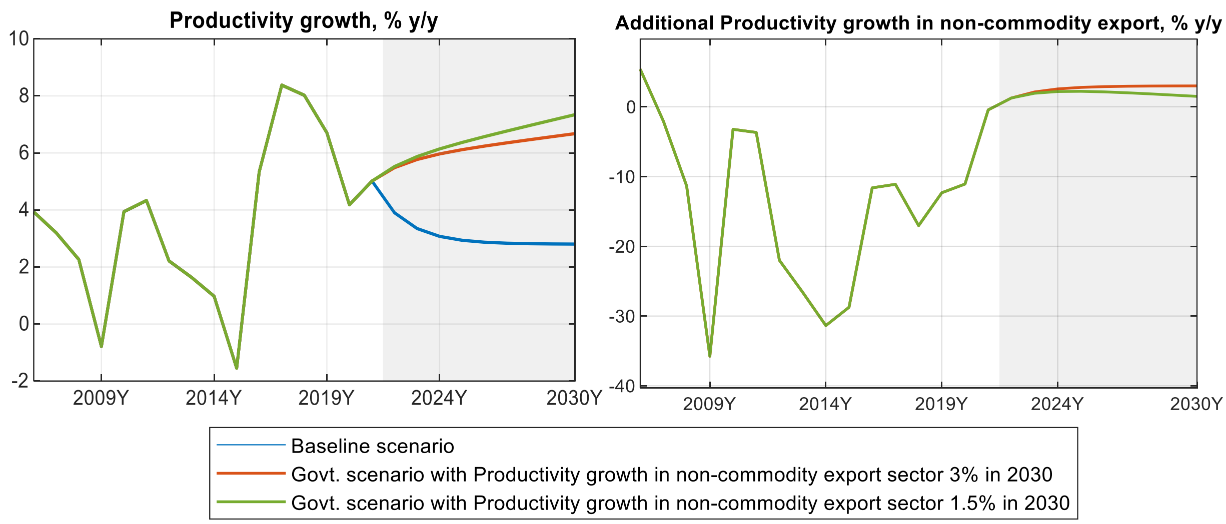


Figure 1.10. *Productivity growth, % y/y.*

Figure 1.11 reflects how such changes influence GDP growth and the Employment ratio. As can be seen, in 2030 GDP growth is 7%. The Employment ratio increased from 90,7% for the Baseline to 92,1% for the Govt. scenario in 2030.

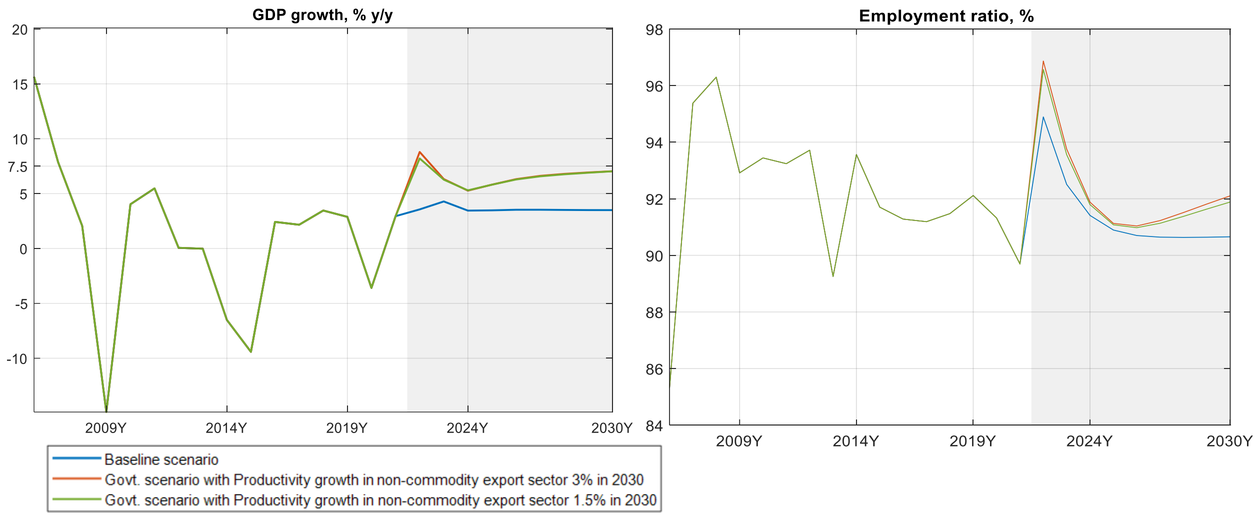


Figure 1.11. *Gross Domestic Product growth and Employment ratio, %.*

The government debt to GDP ratio. From 50,4% of GDP to 40% of GDP.

Achieving the government debt to GDP ratio goal will not significantly change the labor market indicators, like all the other variables. Figure 1.12 shows how the government debt to GDP ratio has changed. The purple line indicates the new scenario, and the green line indicates the previous scenario. All the next Figures will also contain baseline, previous govt. (indicated as ‘Govt. scenario’ on Figure) and new govt. scenarios.

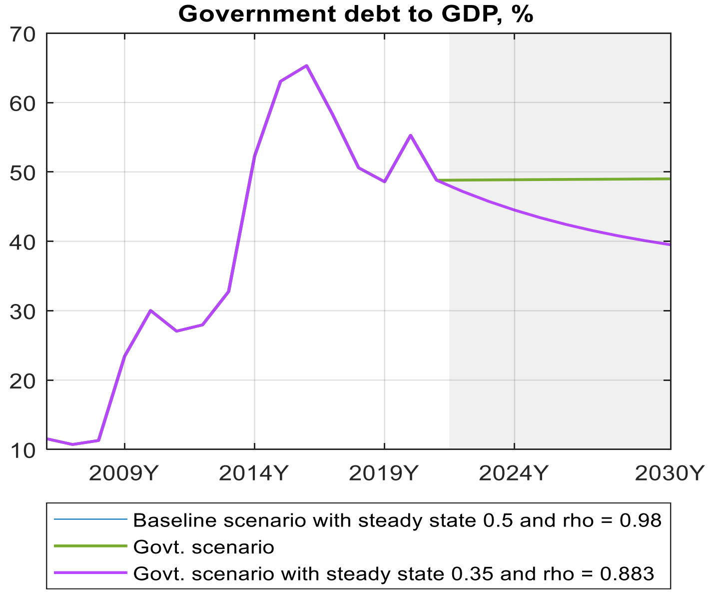


Figure 1.12. *Government debt to GDP, %.*

Steady State Sensitivity Analysis, the result is on Figure 1.13, showed that other variables don’t have significant economic changes, except for Private assets in foreign currency. It is because of the specifics of this model.

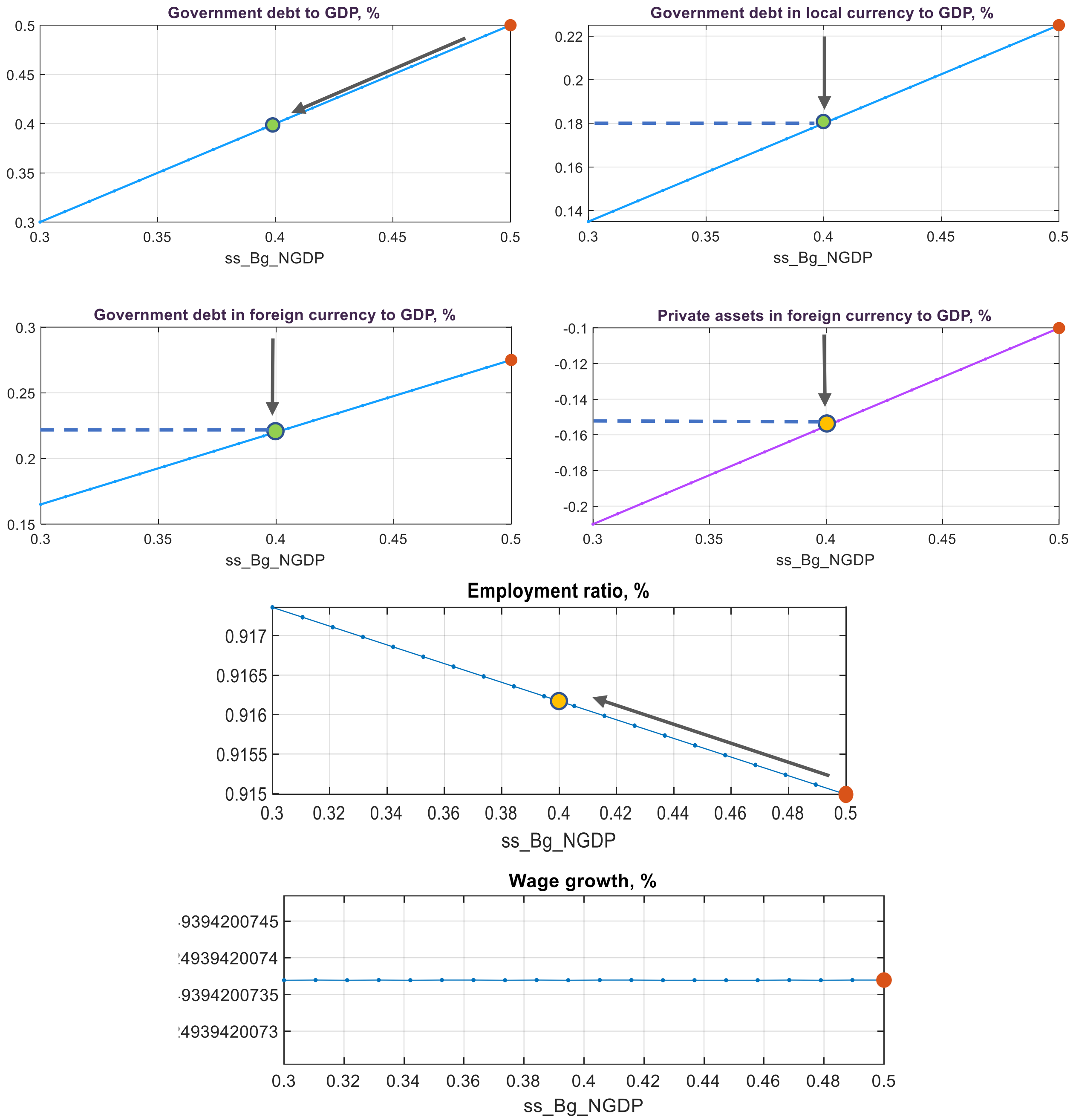


Figure 1.13. *Steady State Sensitivity Analysis for Government debt steady state*

The gross fixed capital formation ratio. From 17,8% to > 20% of GDP.

The increase in the gross fixed capital formation ratio from 17,8% to > 20% of GDP is shown on Figure 1.14 as the orange line.

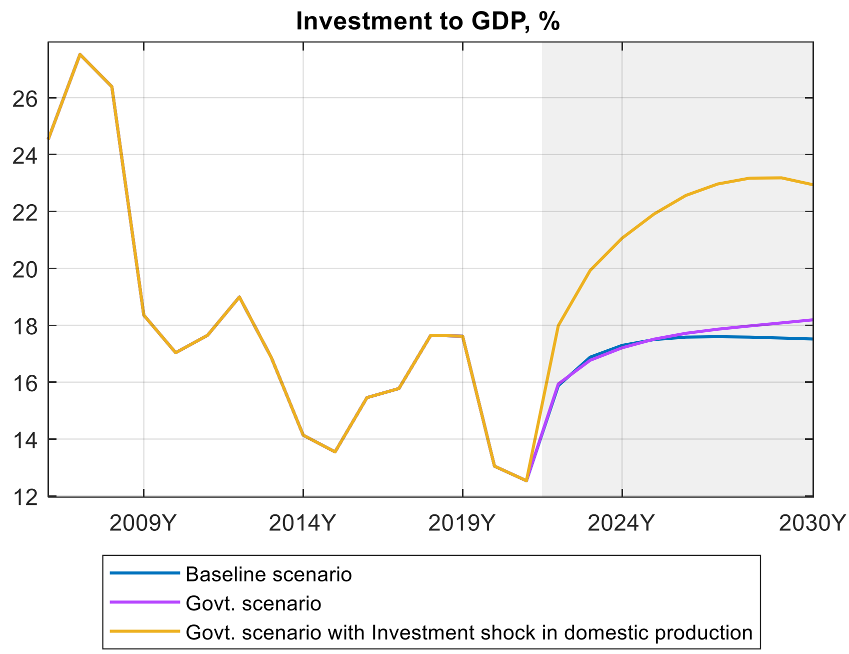


Figure 1.14. *The gross fixed capital formation ratio*

Figure 1.15 reflects the changes in GDP and Employment ratio. After increasing Investment, the Employment ratio significantly increased, which means a decrease in unemployment.

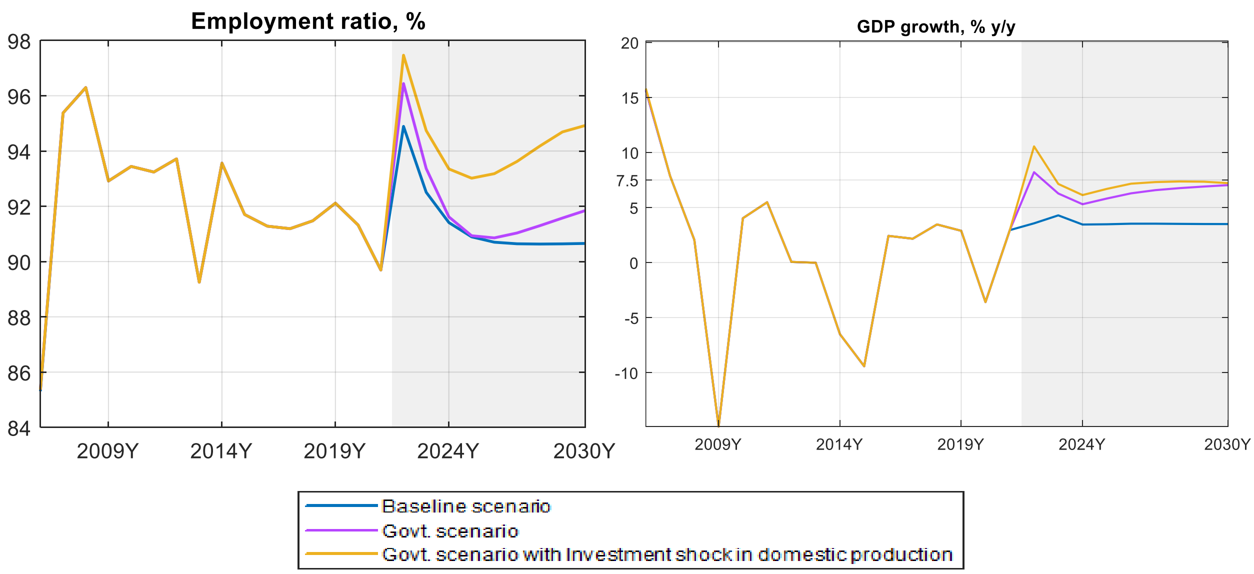


Figure 1.15. *Employment ratio and DGP.*

Unemployment rate. From 8,3% to 6% in 2030.

At the beginning, in the Baseline scenario, the forecast for the Employment rate looked not pretty good. So, this is fixed. And the green line on Figure 1.16 shows a more realistic scenario. Here, the goal of a 6% unemployment rate in 2030 is achieved. It was the last indicator we wanted to get. And, it is the final result. Now

Employment ratio looks much better. To see how other indicators and some important variables look, as components of GDP, for example, refer to Appendix 3 and 4.

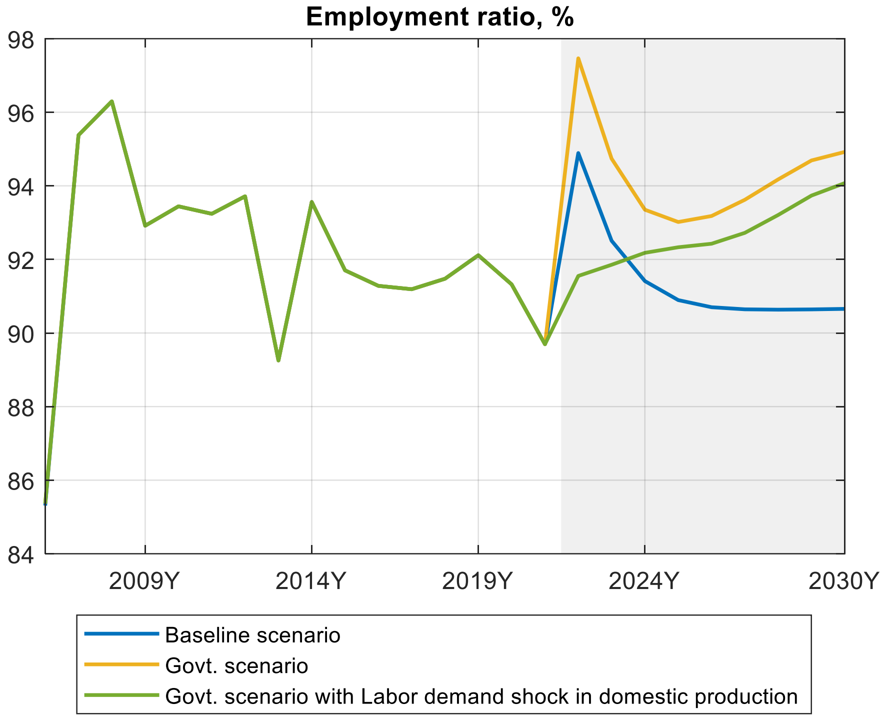


Figure 1.16. *Employment ratio.*

Chapter 2

A System Dynamics Approach to Studying the Labor Market: Employment and Labor Hours Model

2.1 Structure of the Model

The model's structure is based on the general structures of SD. The time unit of the model is a year, and the time horizon is 12 years. The labor hours productivity, avg. standard hours/worker, desired production, and initial WAP growth rate are exogenous in the model. The remaining variables are determined by others; that is, they are endogenous.

The main parameters that influence the behavior of the sector and that can be adjusted as part of the government's economic policy are the employment adjustment time, the delay in employment change, and the hours adjustment time. The inputs to Hours & Employment come from two sub-models: Production Target and Capital & Productivity. Consider that these variables are constant.

Figure 2.2 provides an overview of the structure of the sub-model.

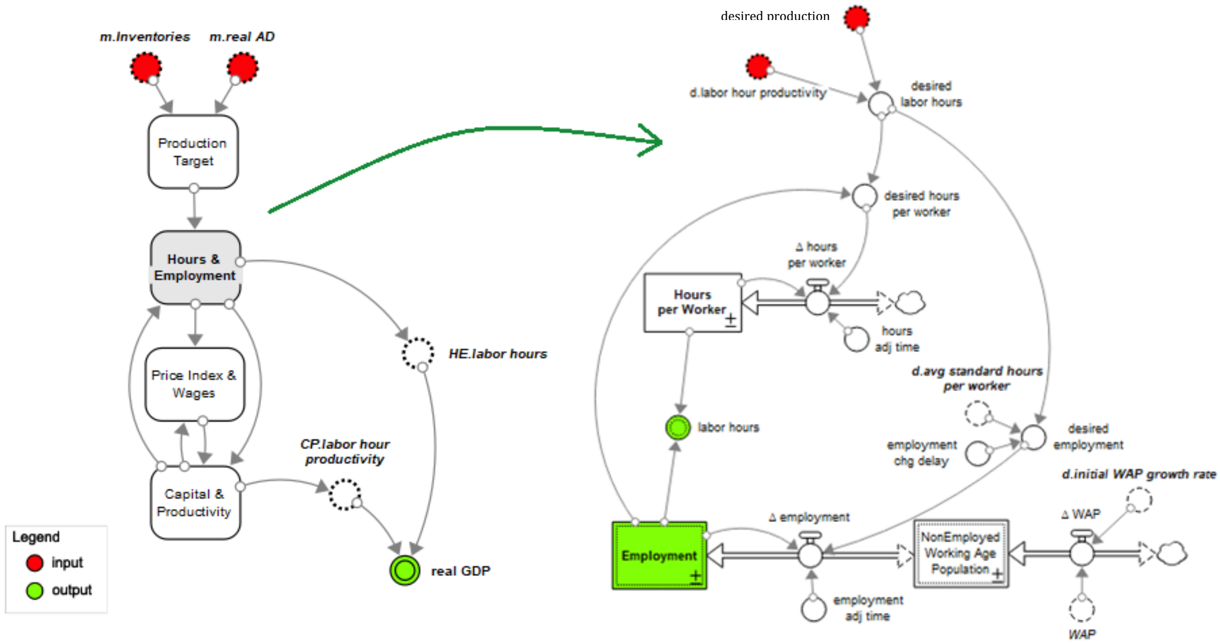


Figure 2.1. *Structure of Model*

Information about variables in this sub-model:

- *Labor hours*

The number of labor hours needed to reach the goal will be influenced by the production target and labor-hour productivity. The actual labor hours are calculated by multiplying the number of employed by the number of hours/worker.

- *Avg standards hour/worker*

The average weekly work time in Ukraine is 40 hours, and 50 working weeks/year. So, the average normal working hours/employee is 2000 hours.

- *Hours/Worker*

Changing the Hours/Worker (over–or–under time) is the initial response to shifts in desired working hours. The average daily work time in Ukraine is 8 hours, without including breaks. Overtime is defined as hours worked in excess of these limits.

- *Employment*

A shift in employed labor leads to a shift in GDP in the same direction. It takes less time to change the number of hours worked by one employee than it does to close the gap between existing and desired employment.

- *Employment adjustment time*

The adjustment time is determined by labor market conditions. In tight labor markets, it can be a long time. For Ukraine, the employment adjustment time is around one year.

- *Desired labor hour*

If a new production target is set, a new labor hour objective will be set as well.

- *Desired hours/ worker*

The number of hours/worker required to generate the target production can be calculated given the desired labor hours and actual level of employment.

- *Hour's adjustment time*

In most cases, changing the Workers' Hours may be done quickly. Producers can adapt rapidly to fluctuations in demand without modifying the real number of employees. The hours adjustment time for Ukraine is about 0.5 years.

- *Desired Employment*

A new production target involves a change in the number of staff. If the targeted output returns to normal, the number of hours per employee will likewise return to normal, and there will be no changes in employment. And, changing the target output will result in a change in the desired workforce. Changing the target output will result in a change in the desired workforce. Since this takes time to change, SMTH was included in the equation.

- *Working Age Population*

Persons in the working-age population (WAP) who are currently out of work will be hired as new workers. There no distinction between those who are working and those who are seeking a job.

- *Employment ratio*

The employment ratio measures how much of the working-age population has a job. The ratio is used to estimate the labor market's situation. A high ratio means that a large proportion of the WAP has a job, which has a positive effect on GDP. But this ratio doesn't tell us anything about working conditions, hours worked, salaries, or the size of the shadow market. So, the analysis of the labor market must be combined with other labor market components.

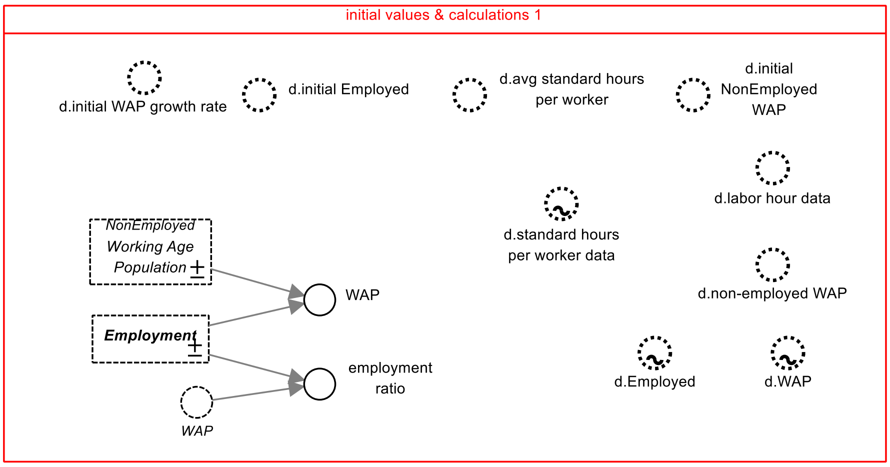


Figure 2.2. *Initial values and calculations*

Figures 2.2 and 2.3 show the initial values and calculations of the model.

Initial values	
	Value
d.initial Employed	19,0322M
d.initial WAP	32,576961M
d.initial WAP growth rate	-0,005
d.avg standard hours per worker	2k
HE.employment adj time	1
HE.employment chg delay	0,5
HE.hours adj time	0,5

Figure 2.3. *Initial values*

2.2 System Dynamic Model

All model equations are listed below.

Model Equations

$labor\_hours = Hours\_per\_Worker * Employment$	$[hours/year]$
$desired\_labor\_hour = desired\_production/labor\_hour\_productivity$	$[hours/year]$
$Hours\_per\_Worker = d.avg\_standards\_hour\_per\_worker$	$[hours/year/person]$
$Employment = desired\_employment$	$[persons]$
$NonEmployed\_Working\_Age\_Population = d.initial\_NonEmployed\_WAP$	$[persons]$
$WAP = Employment + NonEmployed\_Working\_Age\_Population$	$[persons]$
$\Delta\, hours\_per\_worker = (desired\_hours\_per\_worker - Hours\_per\_Worker)/hours\_adj\_time$	$[hours/year/person/year]$
$\Delta\, employment = (desire\_employment - Employment)/employment\_adj\_time$	$[person/year]$
$\Delta\, WAP = WAP * d.initial\_WAP\_growth\_rate/100$	$[persons/year]$
$desired\_hours\_per\_worker = desired\_labor\_hours/Employment$	$[hours/year/persons]$
$hours\_adjustment\_time = 0{,}5$	$[years]$
$desired\_employment = SMTH1(desired\_labor\_hours/d.average\_standard\_hours\_per\_worker;\ employment\_chg\_delay)$	$[persons]$
$d.average\_standards\_hour\_per\_worker = 2000$	$[hours/year/persons]$
$employment\_chg\_delay = 0{,}5$	$[years]$
$employment\_adjustment\_time = 1$	$[years]$
$d.initial\_NonEmployed\_WAP = initial\_WAP - initial\_Employed$	$[persons]$
$d.initial\_Wap\_growth\_rate = -0{,}005$	$[1/year]$

A System of Differential Equations

The main components of System Dynamics – stock and flow – for this model are represented by the next system of differential equations.

$$y_1' = y'_{hours\_per\_work} = \Delta\, hours\_per\_worker$$
$$y_3' = y'_{nonEmp\_work\_age} = \Delta WAP - \Delta employment$$
$$y_2' = y'_{employment} = \Delta employment$$

$$\begin{cases} y_1' = -\dfrac{1}{hours\_adj\_time} \cdot y_1 + \dfrac{desired\ production}{d.labor\_hour\_poduct \cdot hours\_adj\_time} \cdot \dfrac{1}{y_2} \\ y_2' = \dfrac{d.real\_AD}{d.labor\_hour\_poduct \cdot d.avg\_stand\_hours\_per\_worker \cdot empl\_adj\_time} - \dfrac{1}{empl\_adj\_time} \cdot y_2 \\ y_3' = \dfrac{WAP \cdot d.init\_WAP\_growht\_rate}{100} - \dfrac{desired\ production}{d.labor\_hour\_poduct \cdot d.avg\_stand\_hours\_per\_worker \cdot empl\_adj\_time} + \dfrac{1}{empl\_adj\_time} \cdot y_2 \end{cases}$$

2.3 The Behavior of Main Variables

A behavior-sensitivity test

A behavior-sensitivity study is performed by 'shocking' the model out of its equilibrium and comparing the resulting behavior (Barlas, 1996). The goal is to discover factors that the model is especially sensitive to, which may then be used as leverage points for managing, regulating, or improving the system if necessary.

Data series are not used as inputs; instead, initial values are used.

Stocks in equilibrium are equal to:

$$labor\ hours\ =\ 37.97\ billion\ hours/year;$$

$$Hours\ per\ Worker\ =\ 2\ 000\ hour/year/person;$$

$$Employment\ =\ 18.98\ million\ persons;$$

Figure 1.4 shows the model's behavior in equilibrium.

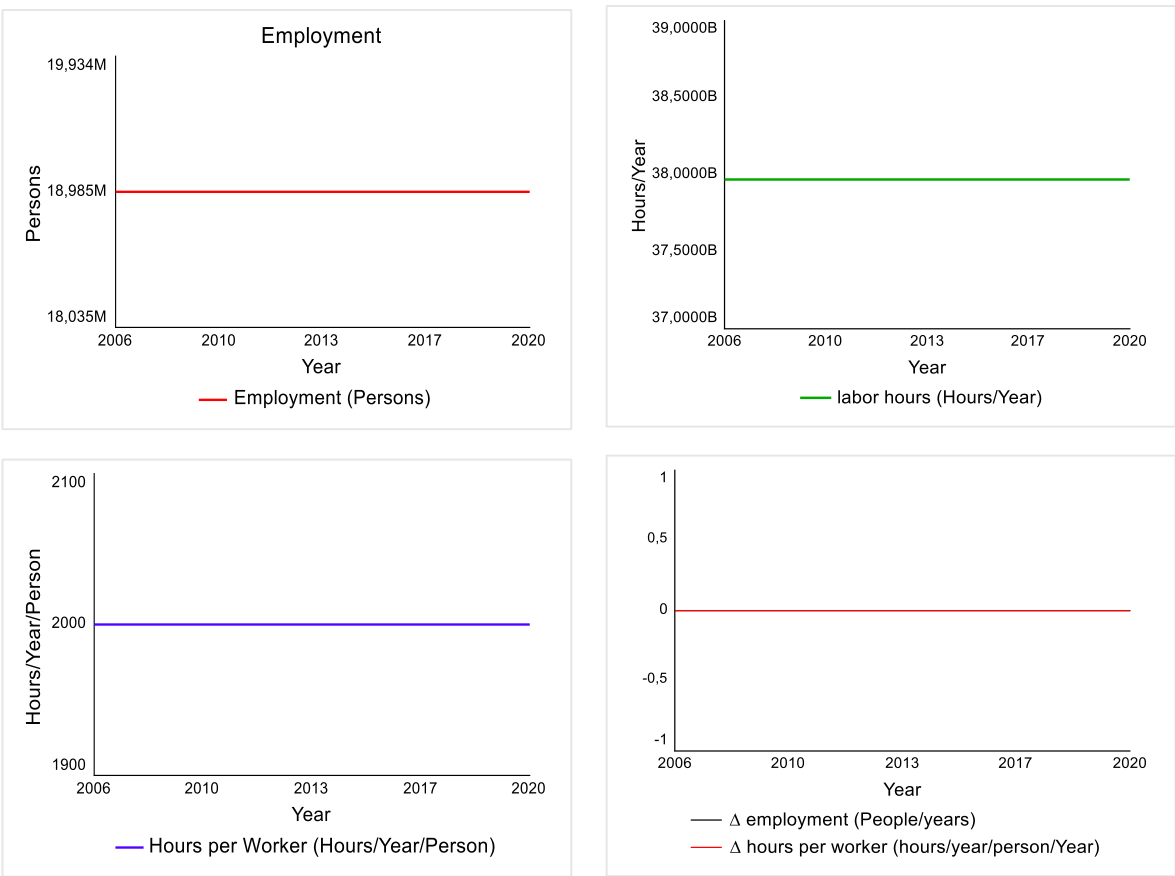


Figure 2.4. *Model's behavior in equilibrium*

The Working Age Population part of the model is not in equilibrium.

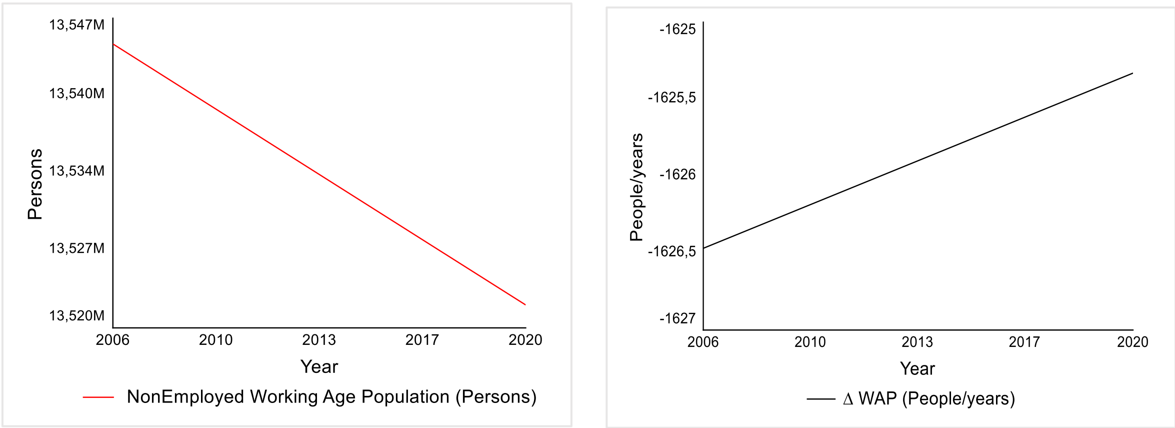


Figure 2.5. *Population of Working Age*

Individual tests showed that the sub-sector was the most sensitive to changes in the avg. standard hours per employee (In this example, the sensitivity means that if the exogenous variable's initial value is changed, the endogenous variable remains in equilibrium but not at the same level).

2.3.1 Shock tests

Shock in avg standard hours/worker

Let's consider the average hours spent by a worker on a job. It is shown on Figure 2.6. If we increase the avg. standard hour/worker from 2000 to 2100 in 2008, we can see that Employment after the shock reaches a new level of equilibrium, which is lower than the previous and equals 18.081 million people. The situation with NonEmployed WAP and Hours per Worker is the opposite because they also reach a new level of equilibrium, but higher than the previous and equal 12.546 million people and 2100 hours/year/person, respectively. As for working hours, it first increases, and then, after some time, decrease and reach their initial equilibrium.

If we decrease the avg. standard hour/worker from 2000 to 1900 in 2008, we can see that number of Employment after the shock reaches a new level of equilibrium, which is higher than the previous and equals 19.984 million people.

The situation with NonEmployed WAP and Hours per Worker is the opposite because they also reach a new level of equilibrium, but lower than the previous and equal 14.449 million persons and 1900 hours/year/person respectively. As for labor hours, it's first decreases, and then, after some time, increases and reaches its initial equilibrium. In addition, we did two tests with adding shock in 2008 and subtracting the same number of hours in 2011 and vice versa. The result is shown on the following graph.

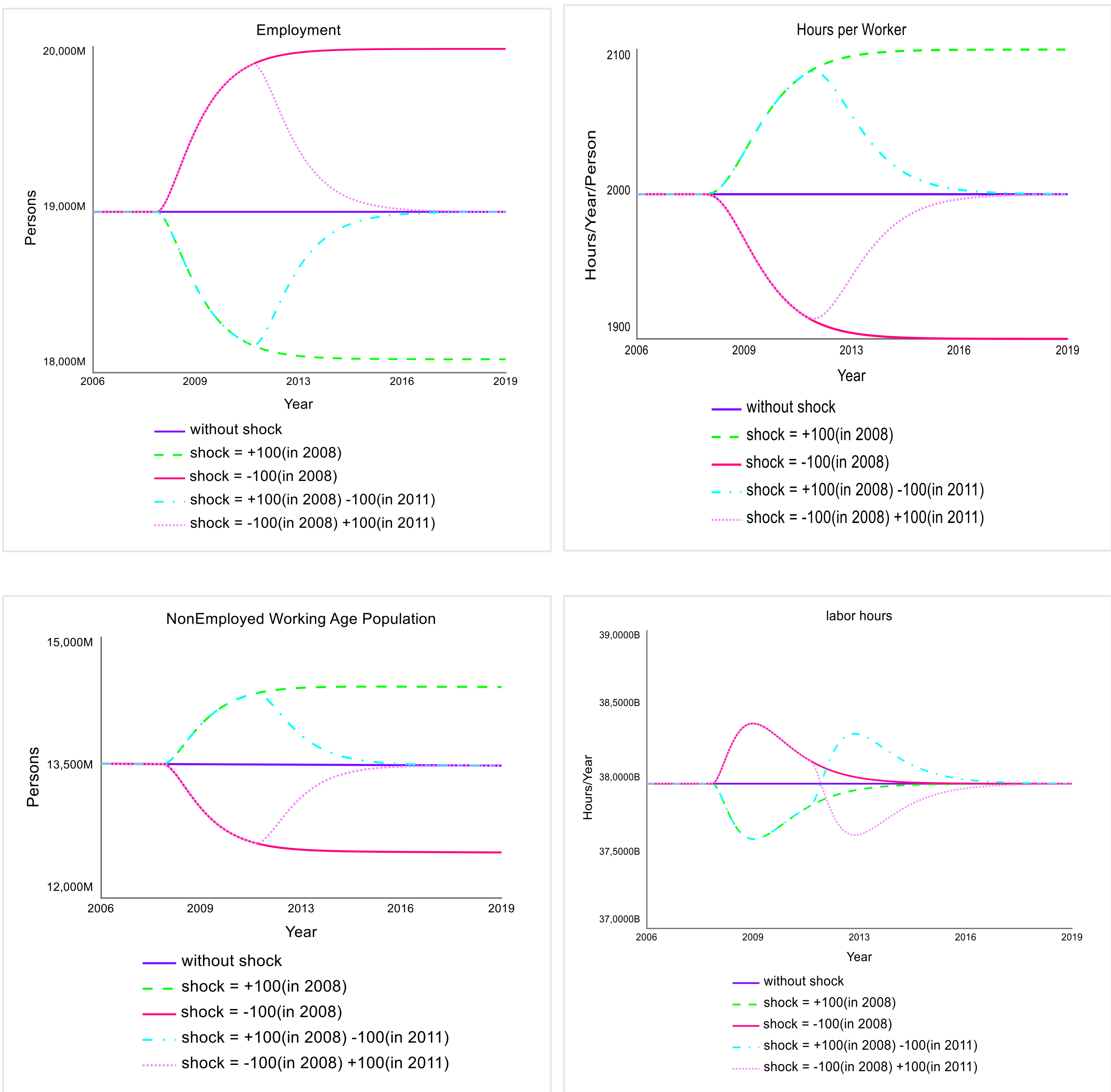


Figure 2.6. *Shock in avg standard hours/worker*

Shock in avg standard hours/worker and different values in empl adj time

If we do the same as we did in the previous test, but in addition, we add one more shock: changed employment adjustment time. The conclusion is that if AT is lower, the new level of equilibrium is reached faster and vice versa. If instead of increasing the average standard hour/worker, we decrease it by 100, the results will be symmetrical. The results of this shock experiment can be seen on Figure 2.7 below.

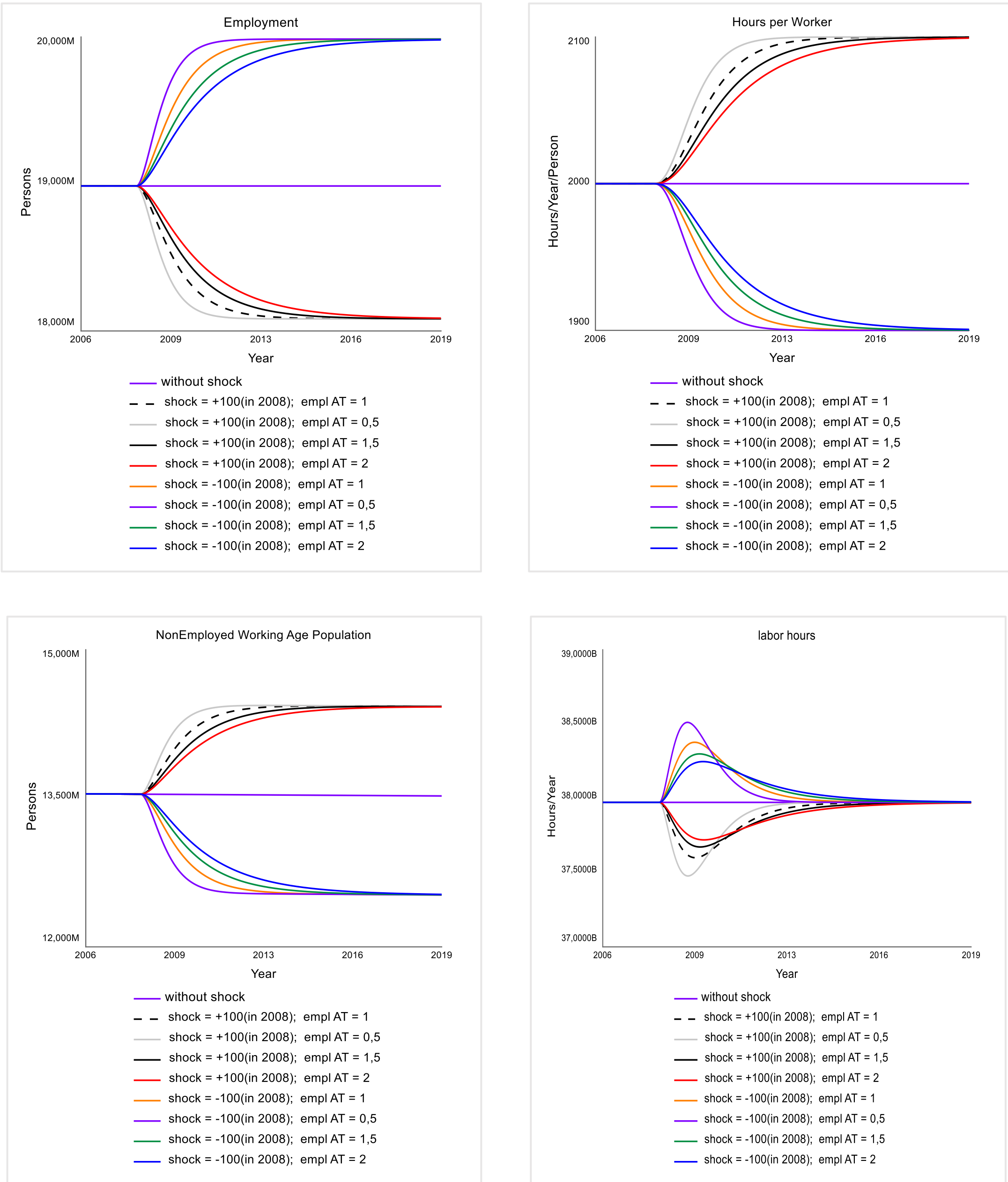


Figure 2.7. *Shock in avg standard hours/worker + different values in empl adj time*

Shock in avg standard hours/worker + different values in hours adj time

If we add the same shock to avg. standard hour/worker and change the hours AT we will get similar behavior. For Employment changing in hours AT does not change the speed of reaching equilibrium. The same situation is with NonEmployed WAP. The lower hours AT, the faster Hours per Worker reaches its initial equilibrium. And the same situation with labor hours. The results of this shock experiment can be seen on Figure 2.8 below.

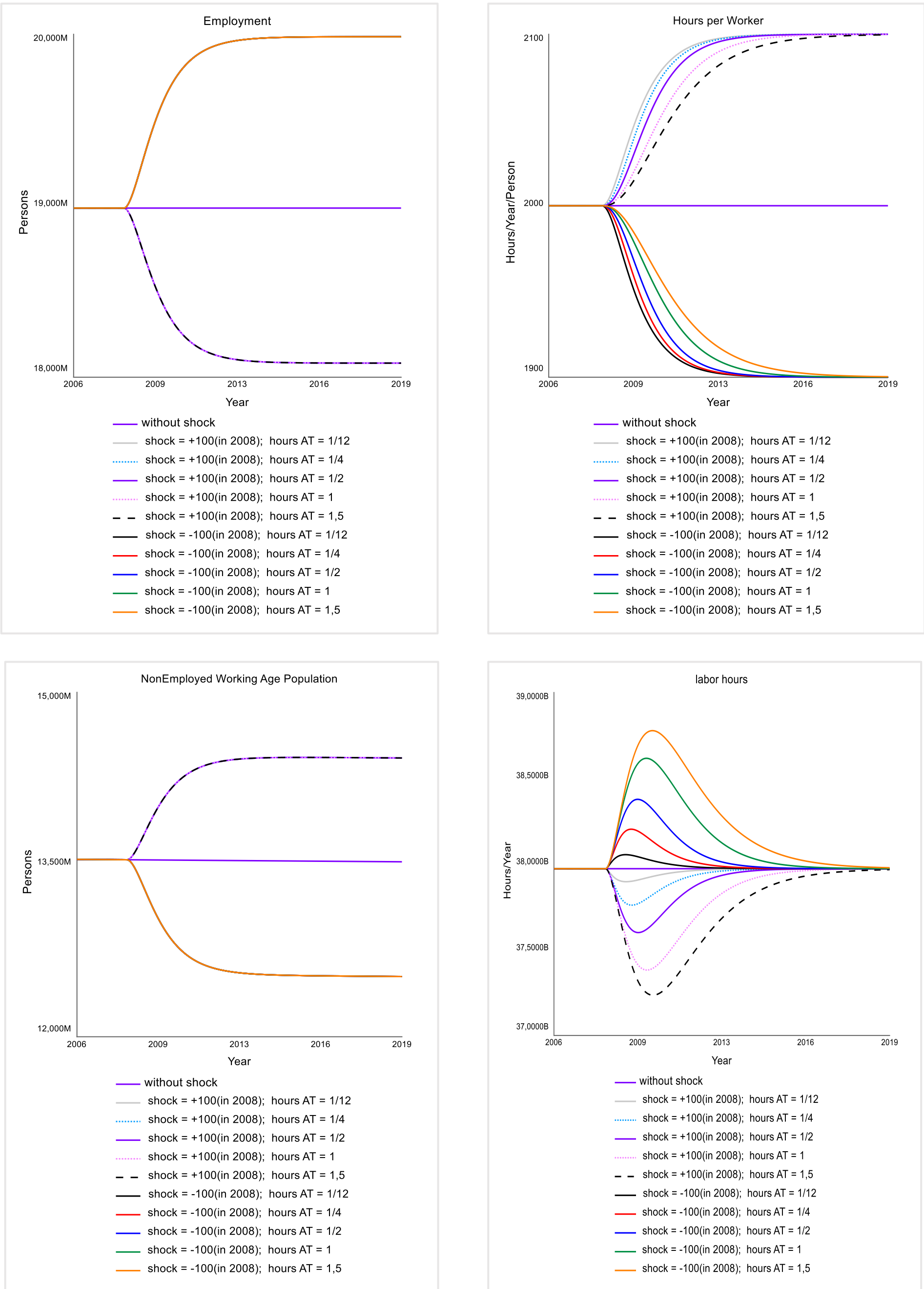


Figure 2.8. *Shock in avg standard hours/worker+different values in hours adj time*

Shock in avg standard hours/worker and different values in empl. chg. delay

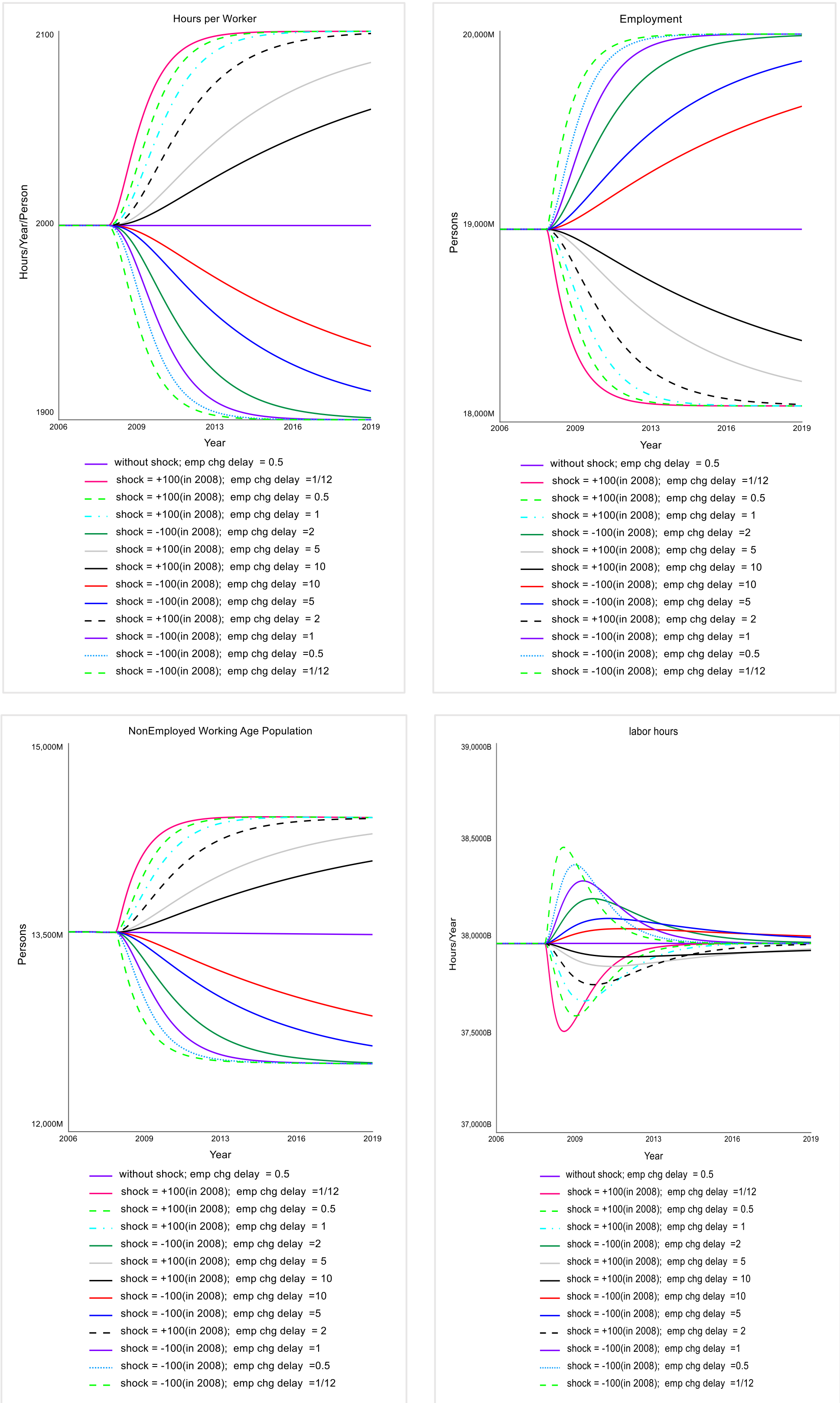


Figure 2.9. *Shock in avg standard hours/worker+different values in empl chg delay*

Figure 2.9 shows the change in employment chg. delay. The conclusion is that if the employment change delay is lower than 1, then the new level of equilibrium is reached. But if it is higher than 1, then the equilibrium is not reached during this period of time. The same situation with Hours per worker, with NonEmployed WAP, and with labor hours.

2.3.2 The sub-model flaw

1) The shift of a part of the working people from the formal to the shadow economy is one of the negative aspects of the current Ukrainian labor market. This isn't in the sub-model, but it has a huge effect on GDP, employment, taxes, and other things. In the first half of 2014, there were 4 579 000 informally employed individuals in Ukraine or about a quarter of the entire working population in age between 15 to 70. So, this is a significant flaw in the model.

2) In addition, our approach ignores the fact that a large number of Ukrainian WAP work overseas. In 2019, there were 3.2 million Ukrainians working permanently outside of the nation, accounting for 18% of the country's economically active population. Transfers from so-called earners were over 11 billion dollars in 2018 (almost 9% of national GDP, or 1/3 of the national budget, and more than foreign investments), and this figure is rising every year. However, the number of Ukrainian citizens working abroad is estimated to be between 5 and 7 million. This means that only 35% of them have an official work visa, and 40-55 percent of transfers from overseas to Ukraine are made informally and are not properly indexed, therefore the real amount of transfers varies between 15 and 17 billion USD every year.

The sub-module closely replicates the behavior of the reference mode. But we recognize that this sub-module needs certain modifications, and some of them have the potential to exacerbate the model's flaws, as detailed above.

Summary

Macroeconomics helps forecast economic conditions, which in turn helps improve decision-making by companies, consumers, and governments. Basically, the macroeconomic analysis focuses on three things: GDP, inflation, and the unemployment rate.

Economic development may be carried out in a number of ways. The first is to increase production, which leads to increasing labor productivity. With newer and better tools, workers may be able to create greater production in a shorter amount of time. However, there are two elements that are crucial to this process. First, someone in the economy must save so that resources may be freed up for the formation of new capital. Employees will be able to use the new capital productively if it is of the appropriate type, be in the right place, and at the appropriate time.

If we use the question of employment as a starting point for investigating the economy, we will learn a lot about how the entire economic system is built. GDP, interest rates, exchange rates, taxes, inflation, and government expenditure will all eventually interact in a comprehensive analysis of the origins and consequences of employment. The context of such themes, on the other hand, will be more evident if the central question is “How does that relate to employment?”

This paper shows how macroeconomics models such as the DSGE model and the System Dynamics model can help to study the labor market, analyze it and make important policy decisions.

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Appendix 1

MATLAB equations in which the elements of the labor market appear.

```
% __Households__

  % Shadow price of income
  Lambda * (C/L - chi * C{-1}/L{-1} * ss_dZ/ss_dL * (1 + shk_C) - psi * DLI/L) = ...
    1 - chi - psi * &DLI_C !! Lambda * C/L = 1;
  % Disposable labor income
  DLI = (1 - tauL) * W * N - TAXls_NGDP * NGDP;
  % Labor supply with flexible Wage Rate
  theta * (N/L)^eta = Lambda * (1 - tauL) * Wflex * exp(shk_N) ...
   !! theta * (N/L)^eta = Lambda * (1 - tauL) * W;
  % Actual Wage Rate with Real Rigidities
  log(W) = rho_W*log(ss_dZ/ss_dL*W{-1}) + (1-rho_W)*log(Wflex) + shk_W ...
   !! W = Wflex;

% __Domestic Producers__

  % Variable labor
  NVd = Nd - nd * &Nd;
  % Production function
  Yd = (Kd{-1})^gammaKd * (A*NVd)^gammaNd * Md^gammaMd * exp(shk_Yd);
  % Labor demand
  W * NVd = Pd * Yd * (gammaNd - $AdjNdMd0$ + beta * $AdjNdMd1$) * exp(shk_Nd) !! W *
NVd = Pd * Yd * gammaNd;
  AdjNdMd0    = xiNdMd    * (log(NVd      / Md)       - log(NVd{-1}   / Md{-1})   +
log(ss_dZxn));
  AdjNdMd1    = xiNdMd    * (log(NVd{+1}  / Md{+1})   - log(NVd       / Md)       +
log(ss_dZxn));

% __Non-commodity Exports Producers__

  % Variable labor
  NVxn = Nxn - nxn * &Nxn;
  % Production function
  Yxn = (Kxn{-1})^gammaKxn * (A*Axn*NVxn)^gammaNxn * Mxn^gammaMxn * exp(shk_Yxn);
  % Labor demand
  muxn * W * NVxn = Pxn0 * Yxn * (gammaNxn - $AdjNxnMxn0$ + beta * $AdjNxnMxn1$) *
exp(shk_Nxn) !! muxn * W * NVxn = Pxn0 * Yxn * gammaNxn;
  AdjNxnMxn0  = xiNxnMxn  * (log(NVxn     / Mxn)      - log(NVxn{-1}  / Mxn{-1})  +
log(ss_dZxn));
  AdjNxnMxn1  = xiNxnMxn  * (log(NVxn{+1} / Mxn{+1})  - log(NVxn      / Mxn)      +
log(ss_dZxn));


% __Commodity export producers__

  % Variable labor
  NVxc = Nxc - nxc * &Nxc;
  % Production function
  Yxc = Axc * L * A * Axn^((gammaMd + gammaNd) * gammaNxn / ((1-gammaMxn)*gammaNd +
gammaMd*gammaNxn));
  % Labor demand
  muxc * W * NVxc = Pxc * Yxc * (gammaNxc - $AdjNxcMxc0$ + beta * $AdjNxcMxc1$) *
exp(shk_Nxc);
  AdjNxcMxc0  = xiNxcMxc  * (log(NVxc     / Mxc)      - log(NVxc{-1}  / Mxc{-1})  +
log(ss_dZxn));
  AdjNxcMxc1  = xiNxcMxc  * (log(NVxc{+1} / Mxc{+1})  - log(NVxc      / Mxc)      +
log(ss_dZxn));
```

```
% __Equilibrium__

  % Labor
  Nx   =# Nxn + Nxc;
  N    =# Nd  + Nx;
% __External processes__

  % Labor growth process
  log(dL) = rho_dL * log(dL{-1}) + (1 - rho_dL) * (log(ss_dL) + shk_dL) !! dL =
ss_dL;

% __GDP ratios__

  % Inventories
  WN_NGDP     =   W  * N    / NGDP;

% __Other ratios__

  DLI_C = DLI / C;
  N_L = N / L;
  Nd_L = Nd / L;
  Nxn_L = Nxn / L;
  Nxc_L = Nxc / L;
  Nx_L = Nx / L;

% __Rates of Change__

  dN = N/N{-1};
  dNd = Nd/Nd{-1};
  dNx = Nx/Nx{-1};
  dNxn = Nxn/Nxn{-1};
  dNxc = Nxc/Nxc{-1};
  dW = W/W{-1};
  dDLI = DLI/DLI{-1};
  dL = L/L{-1};
```

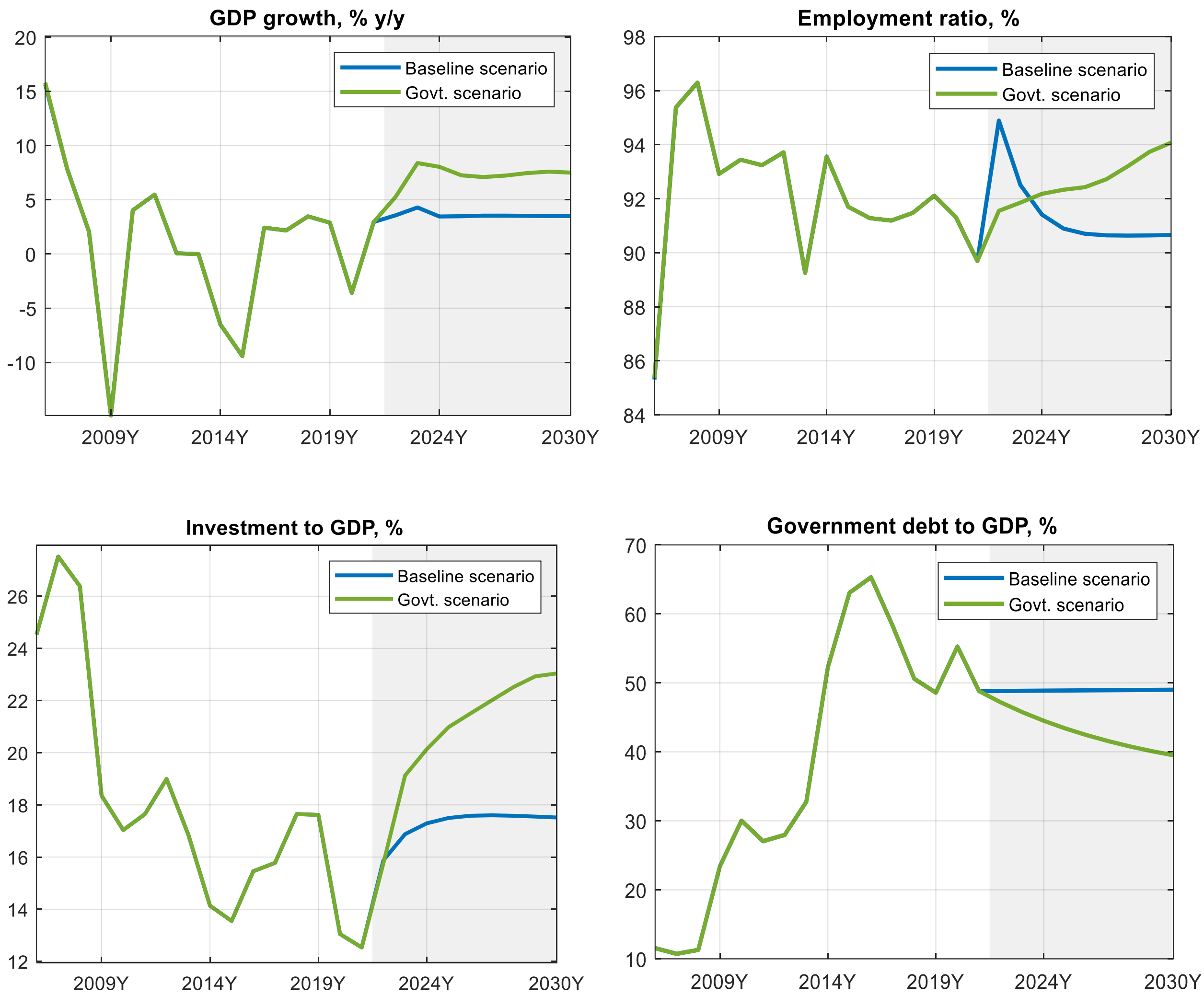
Appendix 2

Full names of shock contributions to Employment ratio

Short name of shock	*Full names of shock*
shk_Nd	Labor demand in domestic production shock
shk_dAxn	Productivity growth shock in non-commodity export
shk_Id	Investment in domestic production shock
shk_Md	Imports in domestic production shock
shk_Bg_NGDP_tar	Government debt ratio target shock
shk_NFA_NGDP	NFA ratio dynamics shock
shk_W	Real wage shock
shk_Axc	Productivity growth shock, commodity export
shk_Mxc	Imports in commodity export production shock
shk_Remit_NGDP	Remittance ratio shock
shk_PG_NGDP	Government consumption ratio shock
shk_Yd	Domestic production shock
shk_PREM	Sovereign risk premium shock
shk_tauPIE	Profit tax rate shock
shk_tauL	Income tax rate shock
shk_Ixc	Investment in commodity export production shock
shk_dL	Labor growth shock
shk_PInvent_NGDP	Inventory shock, share
shk_Bg_lcy_ratio	LCY financing ratio shock
shk_Ixn	Investment in non-commodity export production shock
shk_ N	Labor supply shock
shk_TAXls_NGDP	Lump-sum tax ratio shocks
shk_dInvent	Inventory shock, growth
shk_dXdiscr	Export growth discrepancy shock
shk_Nxc	Labor demand in commodity export production shock
shk_tauC	VAT tax rate shock
shk_RRw_star	Foreign interest rate shock
shk_CPREM	Credit risk premium shock
shk_Pd	Domestic RMC shock
shk_PREM_UIP	UIP premium shock
shk_Yxn	Non-commodity export production shock
shk_Mxn	Imports in non-commodity export production shock
shk_dA	Productivity growth shock
shk_Nxn	Labor demand in non-commodity export production shock
shk_Bg_NGDP	Government debt ratio dynamics shock
shk_ToTn	Terms of trade shock, non-commodity export
shk_C	Private consumption shock
shk_ToTc	Foreign relative commodity price shock

Appendix 3

Government scenario for 2030. Final results



Appendix 4

Government scenario for 2030. Final results for GDP components