THE MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
IVAN FRANKO NATIONAL UNIVERSITY OF LVIV
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Master thesis

Modeling of Impulse Responses to Shocks by System Dynamic Macroeconomic Model

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Hutsul D.I.
Supervisor:
Prof. Oliskevych M. O.

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Head of the department
Prof. Kyrylych V. M.

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Contents

Introduction

The central bank uses the exchange rate as an instrument of monetary policy and affects the state of the country's balance of payments through the state currency (Grui, A., Vdovychenko, A. (2019)).

Households observe the exchange rates as a source of safe savings without the big influence of inflation. Firms analyze the exchange rates to understand future production costs and expected sales. High exchange rate volatility makes production planning more difficult when production is dependent on imported materials. Therefore, forecasting future revenue is complex if a significant share of sales is in foreign currency. In turn, inflation is an important indicator that occurs together with the devaluation of the currency. In many cases, the purchase of foreign currency is also a way of saving, which depends on the expected difference in inflation between the two currencies. Households sell a currency that is expected to have higher inflation in exchange for a currency with lower expected inflation.

What can change the rate of inflation? One example is the increase in the value of local factors of production, such as wages. The increase causes a discrepancy between labor supply and demand. Long-term demographic changes and the short-term effects of large-scale migration are reducing labor supply in Ukraine. The impact of these structural factors on labor costs is further exacerbated by the increase in the minimum wage. The manufacturers may include the low price elasticity of demand and a large share of higher labor costs in the final price in a market with low competition. Although some factors can change it. Some of them are the number of employees with a minimum wage and the presence of the shadow economy in Ukraine. Thus, higher local inflation leads to a real increase in prices: it takes more units of foreign currency to buy the same number of goods and services in hryvnia. The benefits of stable inflation are obvious. Under such conditions, firms and households are more confident about their investments. In this case, this increases production capacity and, consequently, GDP growth in the long run.

Chapter 1

Impact of REER Gap on GDP Growth

1.1 Theoretical background

1.1.1 Real Effective Exchange Rate and GDP

Foreign trade which indicates net exports *(NX)* is one of the indicators of the equilibrium GDP (*Y*) model in an open economy:

$$Y = C + I + G + NX \tag{1.1}$$

Net exports depend on many factors, one of which is the exchange rate. Therefore, if the exchange rate decreases this leads to decrease the price of domestic goods abroad which increases exports, while the price of imported goods rises which reduces imports. The next function indicates net exports:

$$NX = \overline{NX} - q \cdot e \tag{1.2}$$

where $e -$ the real exchange rate, $\overline{NX} -$ autonomous net exports, $q -$ the elasticity of change in net exports.

Table 1.1: Impact of currency revaluation and devaluation on net exports and GDP[1]

	Export	**Import**	**Net Export**	**GDP**
Currency Devaluation	+	-	+	+
Currency Revaluation	-	+	-	-

The relationship between GDP and net exports occurs in a next way:

$$\Delta Y = \Delta NX \cdot m_e \tag{1.3}$$

[1] KNEU (2016)

In an open economy the spending multiplier (m_e) is determined by the following equation:

$$m_e = \frac{1}{1 - (c - im) \cdot (1 - t)} \quad (1.4)$$

where $c -$ marginal propensity to consume, $im -$ marginal propensity to import.

There are three main channels that the National Bank of Ukraine (NBU) uses to influence the national economy: interest rates, lending and the exchange rate. There are a number of factors which affect the currency supply and demand of the exchange rate:

1) First, demand and supply depend on exports and imports respectively. Therefore, an increase in exports causes an increase in the domestic currency demand, in turn an increase in imports increases its supply.

2) Second, demand and supply depend on the ratio between domestic interest rates and external interest rates. Hence, if the domestic interest rate rises compared to the world under other constant conditions, then it increases the domestic currency.

3) The third factor is inflation, which depreciates the currency. As a result, if inflation accelerates, the population tries to convert the national currency into a stable foreign currency, which will increase the supply of national currency and vice versa, if the foreign exchange rate decreases, the demand for national currency rises.

The proportion of one currency is exchanged for another represents the nominal exchange rate (IMF[2]):

$$\varepsilon = \frac{M_f}{M_d} \quad (1.5)$$

where $\varepsilon -$ is the nominal exchange rate, $M_f -$ is the amount of foreign currency, $M_d -$ the amount of national currency that is exchanged for foreign.

The real exchange rate (e) determines the purchasing power of the currency which depends on two factors:

[2] International Monetary Fund (What Are Real Exchange Rates?)

$$e = \frac{\varepsilon \cdot P_d}{P_f} \tag{1.6}$$

where ε – nominal exchange rate, P_d– the ratio of domestic prices, P_f – the ratio of foreing prices. Second, determines the price competitiveness of national goods.

The real effective exchange rate (REER) provides information on the competitiveness of domestic manufacturers in the world market and contributes to the strengthening of monetary conditions.

The REER (I_r) is calculated by following:

$$I_r = \sum I_r^i \cdot \frac{I_P^d}{I_P^f} \cdot T^i \tag{1.7}$$

$$\sum T^i = 1 \tag{1.8}$$

where I_r^i –index of bilateral real exchange rates of trading partners, I_P^f – index of foreign prices, I_P^d – index of domestic prices, T^i –weight of the country's trading partners.

Appreciation of the REER may be due to an increase in relative inflation in the economy and an increase in the nominal exchange rate. The real appreciation is interpreted as an increase in prices for domestic services and goods compare to prices for the same goods of trading partners. Long periods of overvaluation of the REER exceed the equilibrium level and adverse economic growth because it makes imported products more costly within the country and reduces the competitiveness of exports.

Instead, a significant and steady undervaluation of the REER leads to higher sensitivity of the economy to external crises and the formation of bubbles in the domestic financial sector. The disadvantage of the negative REER gap during a long time is the lack of incentives for domestic firms to increase their capacity utilizations and production capacity because price competitiveness is already high.

1.1.2 Literature review

A number of studies have been examined the assessment of the impact of the REER gap on economic indicators. Most of the studies show a negative correlation, proving that an undervalued currency can increase GDP growth. One of the first studies by David Dollar (1992) proved a negative link between the REER gap and GDP growth from 1976 to 1985 in a sample of 95 countries.

Most literature such as Rodrick (2008), Berg – Miao (2010), Habib (2017), Comunale (2017) and MacDonald – Vieira (2010) confirmed previous results and also introduced nonlinearities in the effect of the REER gap on GDP growth. According to the results, the undervaluation of the REER gap leads to GDP growth and the overvaluation of the REER gap contributes to the decrease of GDP growth. Therefore, Berg-Miao (2010) introduced a dummy variable to test for nonlinearities. Some studies such as MacDonald – Vieira (2010) and Rodrick (2008) found that some of the REER gap fundamentals determine GDP growth itself. Based on this assumption, Comunale (2017) does not include fundamentals to the GDP growth regression which is already included in determination the REER trend.

However, there is a second direction of the literature that shows asymmetric effects. Aguirre Calderon (2006) and Razin Collins (1997) point out in their study that both overvaluation and undervaluation have a negative impact on the economy, with overvaluation having a stronger impact.

Table 1.2: Literature review

Authors	Sample	Method	Variables
Dollar (1992)	1976–1985, 95 countries	Cross section OLS	Real exchange rate variability, investment, index of real exchange rate distortion
Rodric (2008)	1950-2004, 184 countries	Panel system GMM, cross-section regressions	Government consumption, inflation, terms of trade, gross domestic saving,

			institutions (Rule of Law), years of education,
Berg – Miao (2010)	1950-2004, 181 countries	OLS with time fixed effects	Terms of trade, government expenditure, openness, investment
MacDonald –Vierra (2010)	1980-2004, 90 countries	Panel system GMM	Inflation, government consumption, years of education, institutions (Rule of Law)
Aguirre – Calderón (2006)	1965-2003, 60 countries	Panel system GMM	Output Gap, secondary enrollment, private credit, trade openness, inflation rate
Razin and Collins (1997)	1975-1992, 93 countries	GMM, Fixed effect IV	Terms of trade, life expectancy at birth, government consumption, school enrollments

1.2 Analysis

1.2.1 The data and sample

Since the empirical literature has conducted an analysis for developing and developed countries that did not include Ukraine, I aim to investigate the impact of the REER gap on GDP growth in Ukraine. For analysis I use quarterly data for Ukraine from 2005 to 2020. Data is without taking into account the temporarily occupied territories from 2014. The data sources include the NBU, State Statistics Service of Ukraine and IMF databases. The data was lagged one period and seasonally unadjusted to avoid endogeneity problems. Figure 1.1 shows the data used for the GDP growth regressions.

The real effective exchange rate is calculated by the NBU. The following set of variables is used for the fundamentals of REER trend[3]: *Fiscal policy, The Net*

[3] Vdovychenko (2021)

foreign assets, Trade openness, Commodities terms of trade, Productivity differential, External Wealth of Nations Mark II database.

In analysis of time series before applying regression it is require to check if the time series is a stationary. A time series is stationary when the statistical properties of the distribution are constant over time. In this case I used the unit root test.

Augmented Dickey-Fuller (ADF) test:

$$\Delta y_t = \mu + \alpha t + \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon \tag{1.9}$$

$$\gamma = -\left(1 - \sum_{i=1}^{p} b_i\right), \beta_i = -\sum_{j=1}^{p} b_j \tag{1.10}$$

The null hypothesis is that y_t has a unit root:

$$H_0: y_{t-1}(\gamma) \neq 0 \tag{1.11}$$

Phillips-Perron (PP) test:

$$\Delta y_t = \mu^* + \delta^* t + \psi y_{t-1} + u_t \tag{1.12}$$

where u_t is I(0) and may be heteroskedastic and autocorrelated, that is following an ARMA (p,q). The null hypothesis is that y_t has a unit root:

$$H_0: \psi = 0 \tag{1.13}$$

The unit root test results (Table 1.3) indicates that six of nine variables are stationary in level. Because the probability values at least one of two tests are lower than the significance level of 5%. Non-stationarity of the variables can be explained by the structural breaks in Ukraine.

Table 1.3: Unit Root test results

Variable	**p-value of Tests**		**Status**
	ADF	**PP**	
GDP	0.0055	0.0490	Stationary
REERG	0.0086	0.0066	Stationary

GFCF	0.0111	0.1495	Non-stationary
DOMCR	0.0344	0.1312	Non-stationary
INTR	0.0094	0.0009	Stationary
CTOT	0.0439	0.0133	Stationary
GDPW	0.1696	0.1042	Non-stationary
GEXP	0.0000	0.0000	Stationary
OPEN	0.0006	0.0003	Stationary

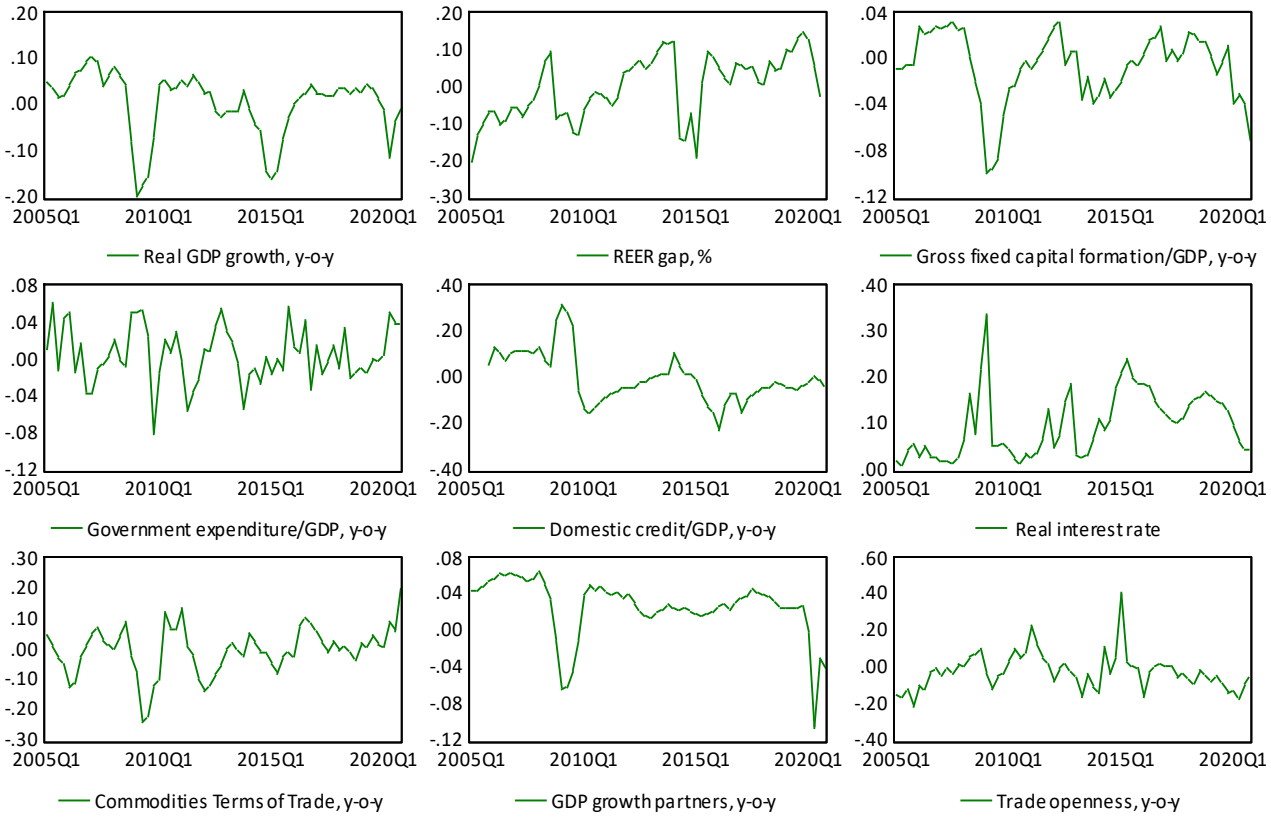

Figure 1.1: GDP growth and fundamentals

1.2.2 Estimating Real Effective Exchange Rate Gap

REER gap is estimated by a deviation from the equilibrium REER expressed as a percentage. Data and methodology of REER gap is taken from the study Vdovychenko (2021). According to the paper, the model for estimating the Behavioral Equilibrium Exchange (BEER) starts from take into account the uncovered interest rate parity (UIP). The UIP theory states that the relative change in foreign exchange rates is the interest rates differences between two countries and can be represented as:

$$E_t(\Delta s_{t+k}) = -(i_t - i_t^*) \quad (1.14)$$

where $E_t -$ the conditional expectations operator, Δs_{t+k} is the nominal exchange rate in foreign currency units with a bond maturity horizon in the first difference, i_t is nominal interest rate, i_t^* denotes foreign for the nominal interest rate.

By adding to both sides of the equation (1.14) $E_t(\Delta p_{t+k} - \Delta p_{t+k}^*) -$ the expected inflation differential, this gives equation in real terms:

$$q_t = E_t(q_{t+k}) + (r_t - r_t^*) + e_t \quad (1.15)$$

where $q_t = s_t - E_t(\Delta p_{t+k})$ is real exchange rate, $r_t = i_t - E_t(\Delta p_{t+k})$ is the real exchange rate, $e_t -$ a disturbance term. The current equilibrium REER can be represent as rewritten equation (1.16):

$$q_t' = \bar{q_t} + (r_t - r_t^*) \quad (1.16)$$

where $\bar{q_t} -$ the long-run equilibrium exchange rate. Equation (1.16) implies the estimation of equilibrium REER.

1.2.3 Estimating GDP Growth Regressions

Based on the empirical literature, I test the following two hypotheses:

Hypothesis 1. There is a statistically significant and negative relationship between REER gap and GDP growth.

Hypothesis 2. There are nonlinearities in the relationship between REER gap and GDP growth.

I use OLS method similar to Rodrik (2008). The baseline regression is next:

$$GDP_t = \alpha + \beta_1 * REERG_t + \beta_2 * GFCF_t + \beta_3 * GEXP_t + \quad (1.17)$$
$$\beta_4 * DOMCR_t + \beta_5 * INTR_t + \beta_6 * CTOT_t + \beta_7 * GDPW_t + \beta_8 * OPEN_t + \varepsilon_t$$

The dependent variable in the regression is the *Real GDP growth rate* (GDP).

REER gap $(REERG)$ indicates the deviation of REER from it's trend. The estimation method is shown in paragraph 1.2.2. I include the following control variables proposed in the literature to explain long-term GDP growth in Ukraine:

Gross fixed capital formation ($GFCF$) used as an proxy of investment. The indicator measured as a percentage of GDP. In the long run, investments affect GDP growth increasing aggregate supply and potential output which depends on factors of production. Since the main factors of production are labor and capital, their quantitative and qualitative parameters create the conditions for GDP growth. According to economic theory, the coefficient has to be positive in the regression.

Government expenditure ($GEXP$) measure as government final consumption relative to GDP. The variable is one of the components of GDP and included in empirical studies such as MacDonald – Vierra (2010), Berg – Miao (2010), Razin – Collins (1997), Rodrick (2008). According to Keynesian theory, government expenditure has a positive effect on GDP. Although a study of the empirical literature has shown a negative sign in regression. As for Ukraine, this can be explained by the fact that the government spending is projected for the next year, therefore, public expenditures cannot respond immediately to economic crises.

Domestic credit ($DOMCR$) as a percentage of GDP is used to denote access to finance provided by the banks to the private sector (Aguirre – Calderón (2006), Schröder (2013)). Bank crediting leads to GDP growth (Kremen (2020)), since banks lend to the real sector (non-financial) of the economy thereby helping to create jobs and increase production capacity.

Real interest rate ($INTR$) calculated as the interbank interest rate minus inflation. By increasing the interest rate firms and households are reducing their investment and consumption. This affects the economy, bringing inflation to the desired level. Hence, the central bank reduces GDP by decreasing in the inflation rate. In this case, we expect a negative sign.

Commodities Terms of Trade ($CTOT$) calculated as the ratio of exports prices and imports prices to GDP. Improving terms of trade lead to GDP growth. Since this increases the domestic income of the population which leads to an increase in demand for non-traded goods.

GDP growth partners ($GDPW$) is expected to have a positive impact on GDP growth.

Trade openness ($OPEN$) calculated as a sum of exports and imports relative to GDP. According to empirical studies, some authors found a negative coefficient of trade openness in a GDP growth regression (Rodrik 1999), while others found a positive coefficient and statistically significant (Berg – Miao 2010). The main part of Ukraine's exports are agricultural products and base metals, and imports contain a significant share of energy. Commodities of Ukraine's foreign trade and have a significant impact on GDP, the exchange rate, and hence inflation through the trade balance channel. Higher trade openness increase competition in commodity markets. Since competition leads to lower inflation, it follows that the coefficient of trade openness is negative.

1.2.4 A nonlinear approach

Most empirical studies found nonlinearity in the impact of the REER gap on GDP growth. The negative gaps, that is undervaluation, contributes to GDP growth, and a positive deviation from the trend, that is overvaluation, is dangerous to economic growth. To do this, I define a dummy variable which equals one when the REER gap is overvalued and zero otherwise.

$$Dum_t = \begin{cases} 1, & REER\ gap \geq 0 \\ 0, & REER\ gap < 0 \end{cases} \tag{1.18}$$

Figure 1.2 shows the dynamics of GDP growth and the REER gap during the estimation period. Two periods of negative gaps in REER (in 2008, 2014) indicate an overvaluation of REER. They reflect the periods of the fixed exchange rate regime in Ukraine. The significant overvaluation in 2012–2013 corresponds to the inflation rate, which was close to zero. After crises periods, REER twice quickly returned to the trend by using nominal devaluations. After 2015, REER achieved the trend due to the inflation targeting regime and the floating exchange rate. But there was a third period of negative gap in 2020.

It can be concluded that the periods of negative REER gaps are positively correlated with real GDP growth. This wrong positive correlation occurs because

of the crisis periods in Ukraine, namely the world crisis of 2008, the Ukrainian revolution in 2014, and the Covid-19 crisis in 2020. The assumption is that if I do not take into account the crisis periods, then I will get a negative correlation in the stationary regime. To check the nonlinearity, I use the threshold regression model. In this model, the treshold value switch between modes in the dynamics of GDP growth.

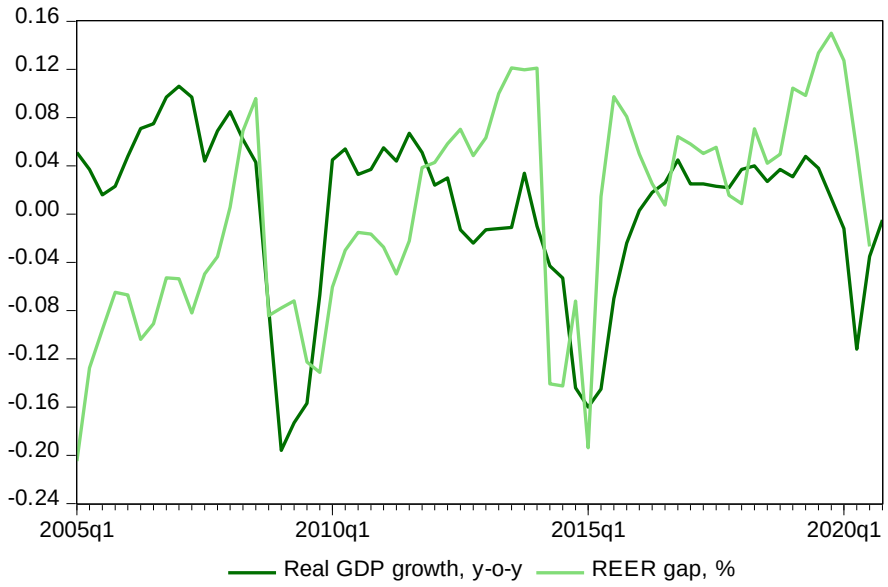

Figure 1.2: Behavior of real GDP growth and REER gap

Hence, I estimate the next regression in which is included the dummy variable. Also, I added one lagged value of GDP growth and other variables that are similar to the previous model (1.17). The threshold estimate is based on two structural equations of the regime as follows:

$$GDP_t = \alpha + \beta_1 * GDP_{t-1} + \beta_2 * REERG_t + \beta_3 * GFCF_t + \beta_4 * GEXP_t + \beta_5 * DOMCR_t + \beta_6 * INTR_t + \beta_7 * CTOT_t + \beta_8 * GDPW_t + \beta_9 * OPEN_t + \beta_{10} * Dum_t + \beta_{11} * REER * Dum_t + \varepsilon_t < \gamma \quad (1.19)$$

$$GDP_t = \alpha + \beta_1 * GDP_{t-1} + \beta_2 * REERG_t + \beta_3 * GFCF_t + \beta_4 * GEXP_t + \beta_5 * DOMCR_t + \beta_6 * INTR_t + \beta_7 * CTOT_t + \beta_8 * GDPW_t + \beta_9 * OPEN_t + \beta_{10} * Dum_t + \beta_{11} * REER * Dum_t + \varepsilon_t \geq \gamma \quad (1.20)$$

where γ is threshold value.

1.3 Results

First, I estimate two linear regression (17). The result is presented in Table 1. As we can see, the REER gap is statistically significant, but has a positive sign in the two models, which is not consistent with studies of the empirical literature. The result suggests that a 10 percent increase in the REER gap increase by 2 percent GDP growth in the first model and 1.45 percent in the second model.

Consider the signs of control variables. The growth rate of gross fixed capital formation is positive and statistically significant at 1 percent in the two models. As expected, we got a negative sign of the interest rate, which is statistically significant. The GDP growth of trading partners has the largest coefficient and statistically significant. Commodities terms of trade have a positive coefficient, as expected. In the second regression, we included the trade openness and government spending, which have a negative sign of coefficients.

Since the obtained result (Table 1) does not correspond with the results of the empirical literature, I found an explanation in the global and domestic crisis periods in Ukraine. Using Threshold regression, I divide the economy into two regimes: crisis and stationary. Variables such as the lag value of GDP growth, GDP growth of trading partners and commodity terms of trade are not included in the threshold variables.

I consider a crisis regime when the annual GDP growth is less than -3.5 percent. In this mode and model 3 we can see wrong positive sign of REER gap. When the economy is in a non-crisis period, that is GDP growth is greater than -3.5 percent in model 5, the REER gap has statistically significant and a negative impact on GDP growth, which is consistent with the results of the empirical literature. This means that increase REER misalignments by 10 percent increases GDP growth by 1.62 percent.

Moreover, I found asymmetries that correspond to the overvaluation and undervaluation of the REEER gap in models 4 and 6. In model 4 and the crisis period, the ratio of undervaluation and overvaluation is positive, which is similar to model 3 with a wrong relationship. In stationary regime, model 6 shows that

the undervaluation coefficient of the REER gap is negative and equal to 0.33 and is statistically significant at 10%. In turn, the overvaluation coefficient of the REER gap is equal to 0.95, but not statistically significant at standard levels.

Table 1.4: REER Gap and Economic Growth: OLS Regression

	(1)	(2)
GFCF	0.691***	0.681***
	(0.211)	(0.211)
DOMCR	0.05	0.047
	(0.043)	(0.044)
INTR	-0.31***	-0.272***
	(0.061)	(0.064)
CTOT	0.143**	0.175***
	(0.061)	(0.061)
GDPW	1.003***	1.007***
	(0.197)	(0.206)
GEXP		-0.161
		(0.145)
OPEN		-0.081
		(0.051)
REERG	0.2***	0.145**
	(0.056)	(0.067)
Constant	0.01	0.006
	(0.01)	(0.011)
Observations	60	60

Notes: Standard errors *** p<0.01, ** p<0.05, * p<0.1.

Table 1.5: REER Gap and Economic Growth: Threshold Regression

	Threshold value < -0.035		-0.035 ≤ Threshold value	
	Misalignment and Non-stationary regime		Misalignment and Stationary regime	
	(3)	(4)	(5)	(6)
GFCF	1.329**	1.698***	0.187	0.184
	(0.532)	(0.507)	(0.166)	(0.189)
DOMCR	0.532***	0.728***	0.013	0.018
	(0.128)	(0.132)	(0.035)	(0.038)
INTR	-0.294***	-0.339***	0.026	0.045
	(0.054)	(0.059)	(0.058)	(0.069)
GEXP	-1.593***	-1.866***	-0.349***	-0.32***
	(0.34)	(0.327)	(0.096)	(0.102)
OPEN	-0.027	-0.048	0.023	0.036
	(0.079)	(0.074)	(0.035)	(0.04)
REERG	0.421***	0.261*	-0.162***	-0.33*
	(0.131)	(0.132)	(0.053)	(0.196)
Dum (overval)		0.029		0.003
		(0.027)		(0.014)
REERG*Dum		0.456*		0.235
		(0.252)		(0.223)
Constant	0.016**	0.003	0.016**	0.003
	(0.007)	(0.012)	(0.007)	(0.012)
Non-Threshold Variables				
GDP(-1)	0.24***	0.237***	0.24***	0.237***
	(0.076)	(0.078)	(0.076)	(0.078)
CTOT	0.054	0.062	0.054	0.062
	(0.043)	(0.046)	(0.043)	(0.046)
GDPW	0.344**	0.417***	0.344**	0.417***
	(0.157)	(0.154)	(0.157)	(0.154)
Observations	12	12	48	48

Notes: Standard errors *** p<0.01, ** p<0.05, * p<0.1.

Chapter 2

Foreign Exchange Model

System Dynamics is a way to model a national economy. Such macroeconomic models help to understand the relationship between the many processes occurring in the economy and build a strategy to achieve the goals.

The presented model was developed by Professor David Wheat. This model considers the economic relationship between the two countries, ‘US’ on the left side and ‘EU’ on the right side. The countries represent identical economies, except the US and the EU used the different currency.

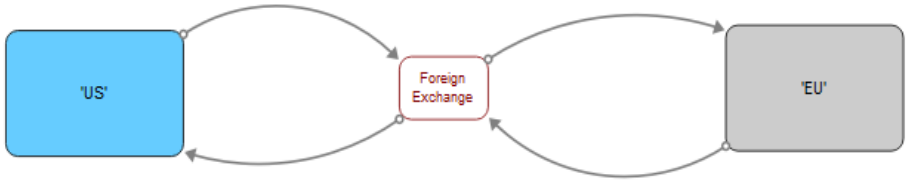

Figure 2.1: Overview of the model

The unit of currency in the US is the dollar ($) and the currency unit in the EU is the euro (€). As there are only two currencies in the system, one must be exchanged for the other. Initially, the exchange rate is 0.80 EUR/USD, which means that 80 EUR could purchases 100 USD and vice versa. If one currency appreciates, the other currency depreciates.

The idea is that if the demand is gradually increasing, then is needed more national currency to make those purchases. Imports for one country become exports for another. When a currency rises and depreciates, it pushes exchange rates in one of two directions.

The foreign exchange sub-model (Figure 2.2) achieves equilibrium when US imports equal EU exports. The assymption is that each transaction between countries is a transaction between firms in these two countries. If households want to buy foreign goods, they find a domestic company that imports. The government does not participate in all foreign exchange transactions.

Demand for currency depends on the demand for goods and services. The desired level of imports is the nominal value. This may change if the price changes or the actual imports change. Changes in prices or changes in real demand affect relative import payments. Therefore, a change in relative prices causes a change in the exchange rates. The relative EU import payments are the ratio of EU imports divided by US imports. The decrease in relative EU import payments causes the indicated exchange rate (XR) to fall. The imports elasticity and the interest rate elasticity are equal to one. The indicated XR depends on the previous value of the XR and changes in bond rates and import payments.

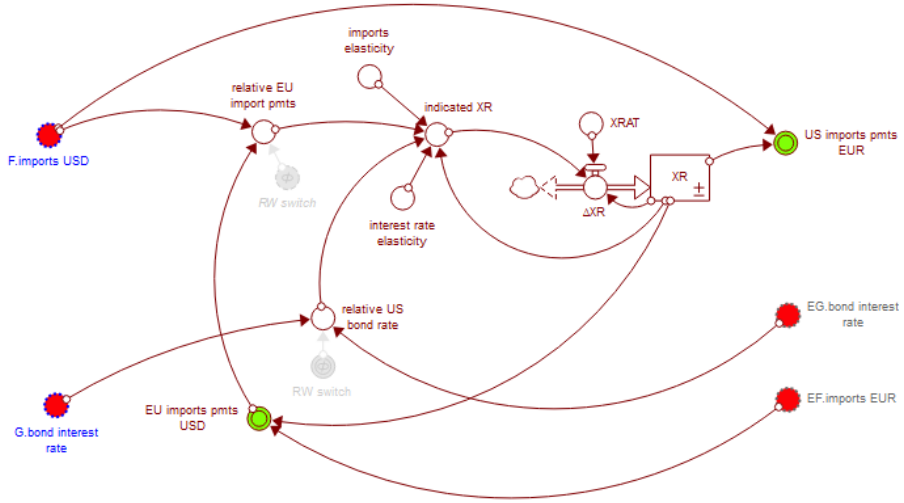

Figure 2.2: Foreign exchange sub-model

Figure 2.3 provides overview of the US side model and the EU side has the same structure. The supply side sub-model of the economy represents production sector. Increasing the supply of goods causes to economic growth for a country. It is important to find variables that bolster an economy's ability to supply more goods.

The demand side sub-model includes private decision making by households and firms, government and banking system. The government sector shows how political decisions about borrowing, taxation and spending affect the economy.

Therefore, an increase in taxes causes a decrease in private savings. Interest rates, in turn, affect consumption and investment. Inflation comes from the supply side to the central bank and domestic banks. Real GDP which determines the output affects the central bank. The central bank makes a decision on the level of policy

rate and the inflation target. These two pieces of information affect domestic banks. Thus, they set the loan rate for households and firms according to interest payments, and the government set the interest rate on bonds. The central bank can influence the money supply and interest rates which in turn change the level of bank reserves. Households buy services and goods from firms and receive wages and dividends in return. Firms make payments for imports and receive payments for exports.

Government deficit expenditures based on bonds issued to the household sector. According to this model, only the households sector buy bonds. Since there is no secondary market, there is no buying and selling between sectors.

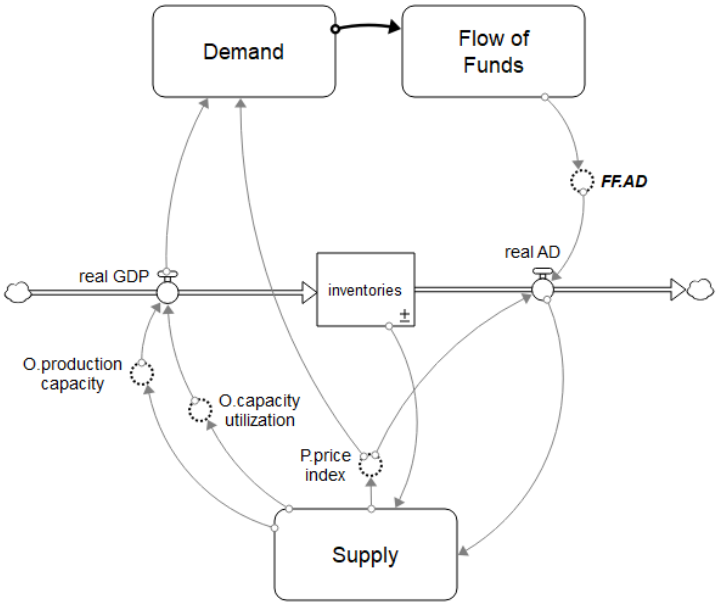

Figure 2.3: Overview of 'US' model

2.1 Structure of the model

2.1.1 Supply side

The aggregate demand is a nation's total annual spending on goods and services. Changes in aggregate demand affect prices and employment. In this model the supply side consists of 3 sub-models which represented in Figure 2.4.

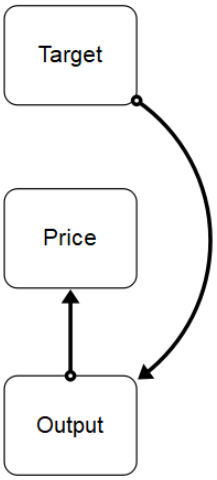

Figure 2.4: Overview of supply side

The production target sub-model

The target sub-model (Figure 2.5) includes inputs such as the real aggregate demand (AD), inventories and outputs such as capacity target and production target. Looking at capacity production, firms want to determine expected sales. This is a short- term (month/week) decision.

Real AD is a preliminary expectation for sale. Gradual update of the expected AD with new data comes from the real AD. How fast this happens depends on the expected aggregate demand adjustment time. Therefore, the shorter the adjustment time, the faster the expectations on the basis of data change and vice versa.

Inventory adjustment time is the period over which it is required to close a gap between expected and desired inventories. Another component of the desired production is the rate at which stocks have to be adjusted. Inventory coverage target (ICT) is the stocks over the sales ratio. In this case, inventories adjustment rate depends on 10 percent of the expected AD, which become the target for inventories.

The production target is the sum of the inventories adjustment rate and the expected AD. Both delays in the adjustment process in EADAT and IAT produce a delay between the production target, inventories and real AD. A long-term decision is about capacity target. Decisions for the future based on the present information. Capacity target determines the smooth production target.

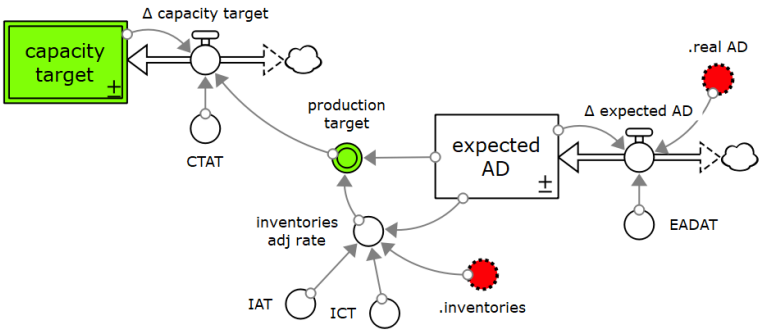

Figure 2.5: Structure of production target sub-model

The output sub-model

Production target and target capacity are the inputs coming from the target sub-model to the output sub-model (Figure 2.6). The production target with production capacity determine the level of capacity utilization for decision making. To set a goal, it takes 3 years to adjust production capacity. The relationship between the supply model and real GDP lies in production capacity and capacity utilization.

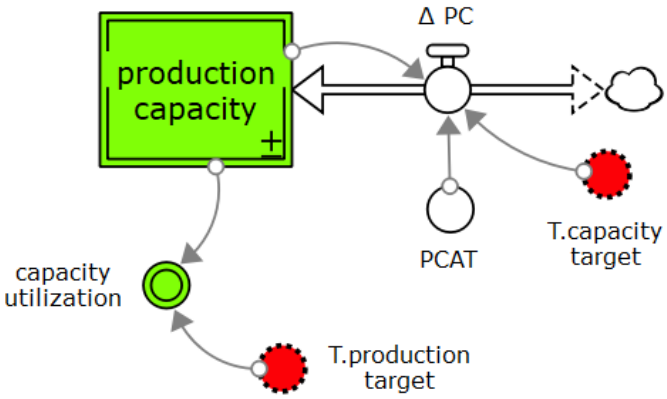

Figure 2.6: Structure of output sub-model

The price sub-model

The key macroeconomic concept is inflation, which is steady price growth. The input for the price sub-model (Figure 2.7) is capacity utilization that comes from the output sub-model.

Capacity utilization is an output gap. If capacity utilization equals 1, that is 100%, it means that there no output gap, so we produce at the same level at which firms can produce (GDP and production capacity will be the same). If the production target is more than production capacity, then capacity utilization is over than 100%.

This will pressure price based on capacity elasticity. We assume that the capacity elasticity equals 1, which means that the price index will grow at the same level with capacity utilization.

Therefore, higher power utilization leads to higher costs. Inflation is determined by changes in the price index. The price index is at the high level of the model and affects the real AD.

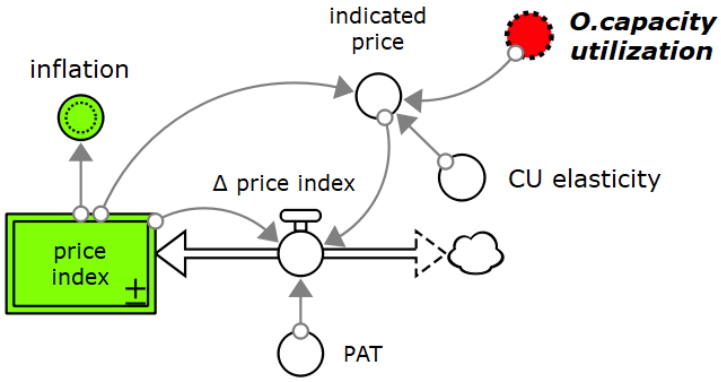

Figure 2.7: Structure of the price sub-model

2.1.2 Demand side

The demand side behavioral hypothesis is about what causes consumer to spend money, what caused firms to invest or spend for dividends so much, what causes government to spend. The behavior depends on decision makers in this sub-models.

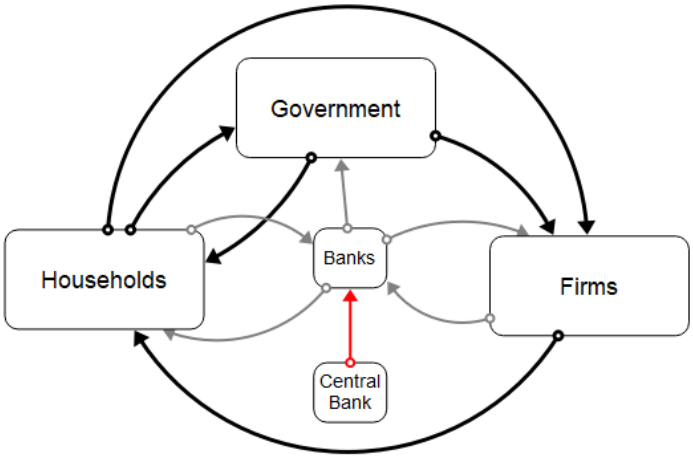

Figure 2.8: Overview of demand side

The firms sub-model

Let's start with firms, because firms that make decisions about production, pay wages and dividends, make investments. The main idea is what are the total expenditure to maintain deposits at the desired level. According to this, we need to know how much firms can spend on investment and wages, and eventually amount of revenue. In this model (Figure 2.9), exports parameter is the income received from exports. Payments for imports to the rest of the world is a part of expenses. There is a relationship between investment and desired loans. A large part of investment is founded by borrowing. Dividends are the difference between factor payments and the total amount of spending. First, the firm pays the wages, then the cost of imports and investments, and finally the rest is spent on dividends.

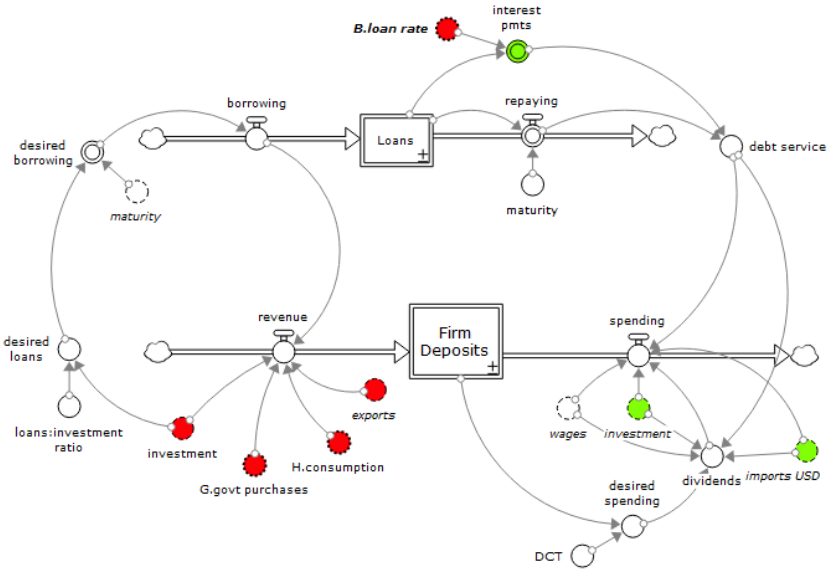

Figure 2.9: Structure of the firms sub-model

The households sub-model

Figure 2.10 shows the structure of the household sub-model. Disposable income is the amount of wages and dividends after taxes. The interest income and bank dividends are a sum of dividends from the bank sector and interest payments received from the government sector. An increase in disposable income leads to an increase in consumption. Consumption is a smoothing function, so it is a change in household deposits, and the impact of consumption is perceived gradually. DCT is deposit coverage target and is equal to 0.75 years, that is nine months. Changes in disposable income affect DCT. Desired household debt depends on the desired debt

service percent of disposable income. The desired debt service is approximately 10% of disposable income.

When households have a deficit of income, they borrow. Loans are defined by borrowing rate and loan repayments. After borrowing from banks, debt has to be repaid by households. Desired loans are determined according to the rate and maturity of the loan. Desired loans affect desired borrowings. Borrowings depend on the fraction approved by the banks. Banks decide how much to lend to households or firms. Because banks need to be confident in the borrower's payments, despite economic crises. Finally, borrowing becomes part of the income. Revenue is the sum of taxable disposable income and income from a bank loan. The reason is not to borrow too much, because households include debt payment in spending, and this causes less for consumption.

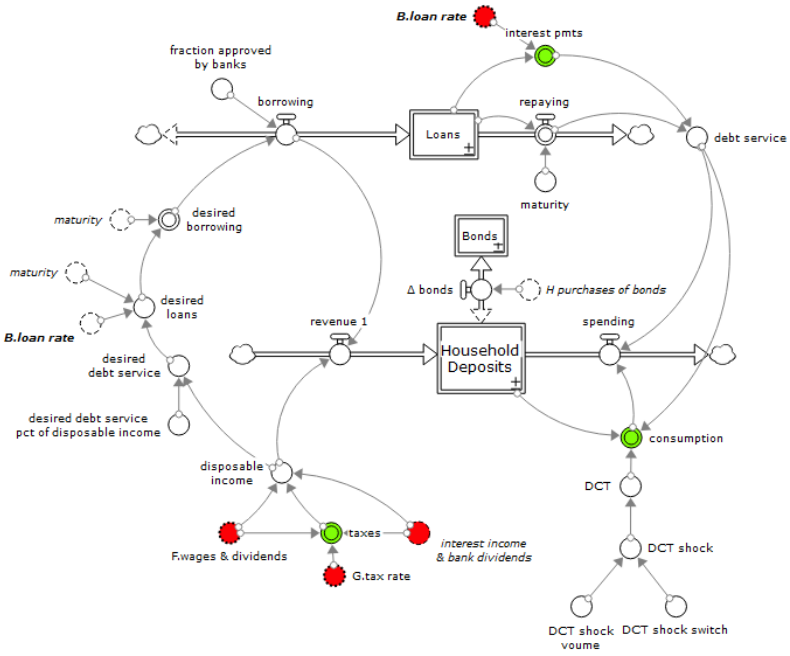

Figure 2.10: Structure of households sub-model

The government sub-model

The main idea of the government sub-model (Figure 2.11) is to repay the government debt by selling bonds. Thus, the net bond sales are equal to borrowing minus repaying. The purchase of bonds can be considered as the purchase of debt, otherwise, a loan money to a company. The bond itself simply represents this debt. Like any borrowed money, the bonds entitle households to receive interest payments for a certain period of time, at the end of which households will receive initial

amount back. Governments issue bonds to raise money to finance their daily operations.

The loan rate is the input and depends on what the central bank and the commercial banks have done in response to inflation. Debt service corresponds to spending. Taxes are income from households. The tax rate is fixed at 20 percent.

In this sub-model the assumption is that government purchases are exogenous. Government purchases is a function of population and spending per capita. The change in flow is the percentage change per capita divided by 100 spending per capita, similar to population growth. The percentage changes are zero.

Deficit is the difference between income, that is taxes, and spending. This is what the government want to borrow. Loans are equal to the deficit. Debt repayment depends on the initial government debt and maturity. Due to the loan of money, this amount is part of the income.

The maturity date also refers to the repayment date on which the borrower must repay total amount of the loan. The maturity of new debt issues involves excessive return on bonds. If the government does not strive for a balanced budget, then spending will not decrease when tax revenues fall. In this case, the government borrows cover the deficit. When the government has to borrow to pay for purchases and deficit, that reduces the stock of government deposits.

A decrease in government deposits causes interest rates to rise. Rising interest rates have effects throughout the demand side of the economy, which puts pressure on aggregate demand.

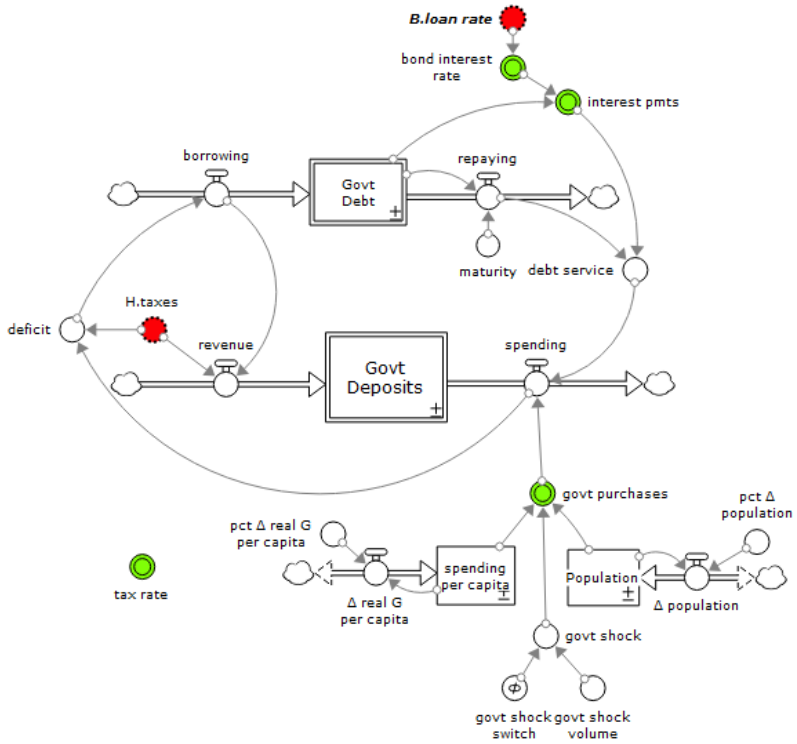

Figure 2.11: Structure of government sub-model

The central bank sub-model

The interest rate is one of the main elements of monetary policy. The central bank use to influence the value of money. The policy interest rate determines the levels of the rest interest rates in the economy, because this is the value at which private banks receive money from the central bank. These banks will offer their customers finance at the interest rate, which is usually based on the policy rate.

As interest rates tend to rise along with higher inflation expectations, consumers and businesses are faced with a choice between making purchases now or in the future. If they expect prices to rise rapidly, this will encourage them to make purchases at present than later. This step increases the demand for loans and reduces the supply of savings until interest rates rise enough to balance supply and demand. The relationship between borrowers' demand for money and lenders' money supply also affects interest rates.

The policy rate has a positive impact on the market rate (bank loan rate), which is negatively related to domestic demand. Domestic demand with net external demand will be total demand, which has a positive effect on domestic inflationary

pressures. This has a positive effect on inflation. Finally, it has a positive effect on the official exchange rate.

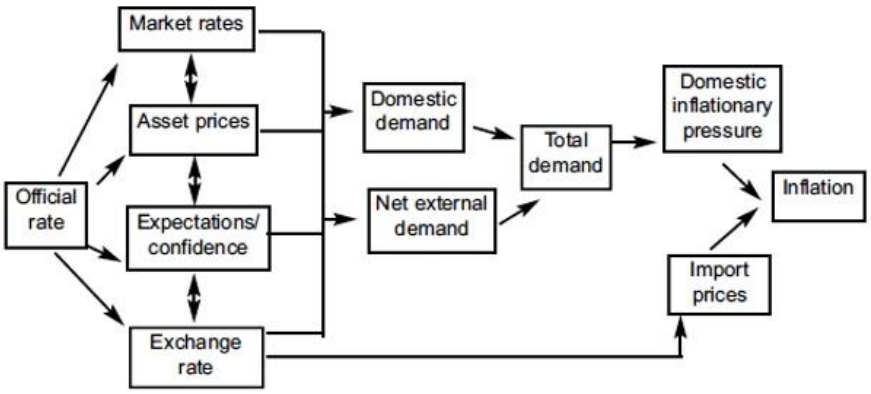

Figure 2.12: The transmission mechanism of monetary policy[4]

The policy rate (Figure 2.13) is an information stock that adjusts overtime to change the policy rate target. The input to the central bank sub-model is based on the Taylor Rule:

$$r = p + 0.5y + 0.5(p - 2) + 2$$

where $r -$ is the federal funds rate (nominal rate), $p -$ is the rate of inflation over the previous four quarters, $y -$ is the percent deviation of real GDP from the trend.

The main hypothesis is what causes to change the federal funds rate. The first variable that causes change is the gap between target inflation and actual inflation. The second variable is the output gap. The hypothesis is that the change in the rate of federal funds should reflect the output gap.

The output gap is the percentage difference in real GDP and production capacity (potential GDP). In this model, the inflation target starts at 0. The inflation gap is the difference between the inflation target and actual inflation.

If we make the monetary policy equal to 1, we get the equation of the Taylor rule. If the monetary police switch is 0, it means it is off, then we get the initial policy

[4] Alec Chrystal (2000)

rate. The policy rate change is the difference between the target policy rate and the actual policy rate adjusted by the policy rate adjustment time.

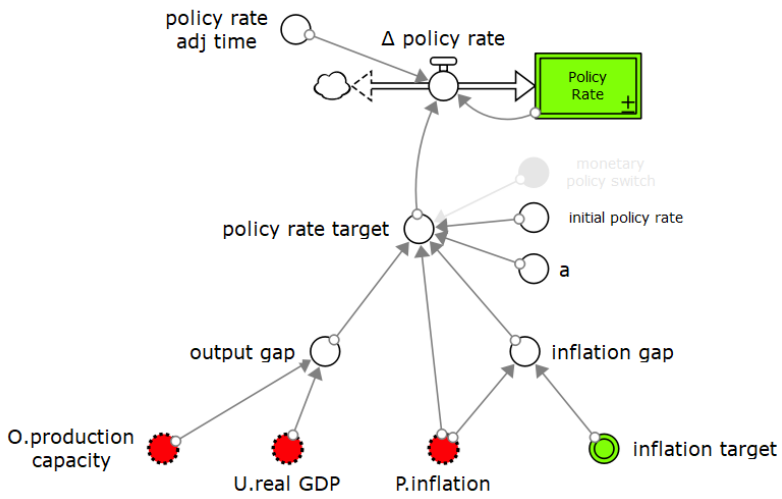

Figure 2.13: Structure of the central bank sub-model

The banks sub-model

The banking sector (Figure 2.14) has three inputs. The inflation target and the policy rate come from the central bank. The desired margin is the difference between the loan rate and the deposit rate. The loan rate is the sum of the bank markup and the policy rate.

In this case, the higher interest rate leads to an increase in debt service, which reduces private consumption. An increase in the interest rate affects consumption directly, as well as indirectly through the firm's decisions on dividends.

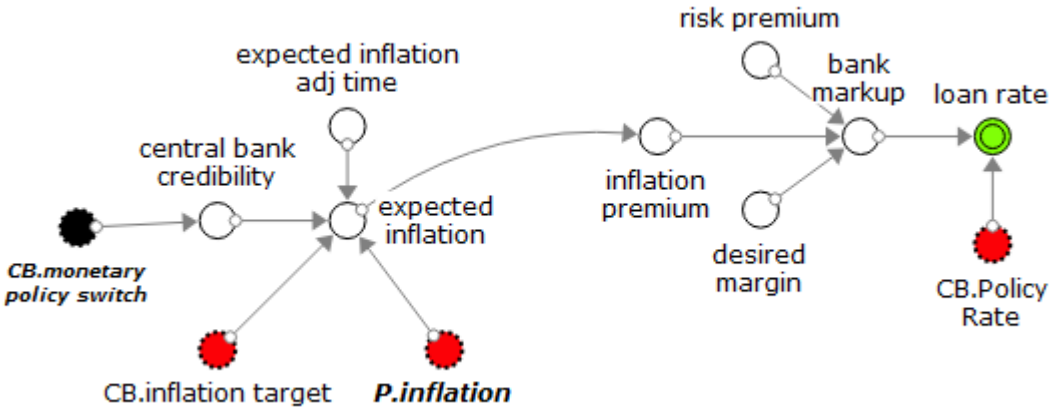

Figure 2.14: Structure of banks sub-model

The flow of funds sub-model

The inter-sector spending decisions on the demand side are received by the flow of funds sub-model (Figure 2.15). The flow of funds from households to firms is consumption. Firms pay wages to workers and pay dividends to household business owners. The total amount of government procurement goes to business firms. All investments in capital goods are considered to be spent by commercial firms and received by commercial firms.

Banks lend money to households, and households are required to repay these loans. When a bank lends to a household, household deposits increase. Bank reserves increase in their account with the central bank. Households receive interest income from the banks. Then the households are responsible for paying all the taxes.

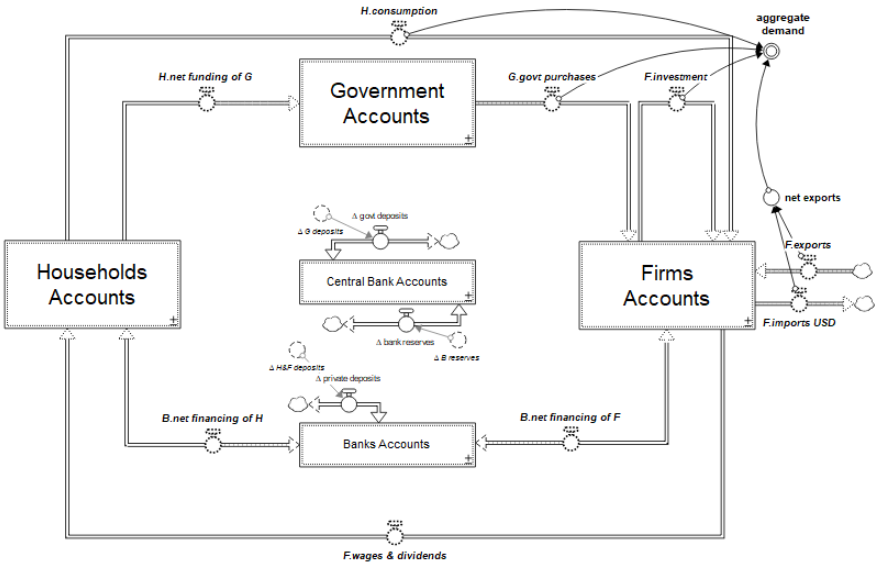

Figure 2.15: Structure of the flow of funds sub-model

2.2 Behavior of the model

Net government funding includes mostly taxes. In equilibrium, the government pays interest on the debt, but does not create any new debt. When the model is shocked by the increase in government spending, there is a combination with additional bond sales, and this upsets the balance of government debt. This is a part of the additional funding becomes of households.

Initially, net funding and government purchases are 2.56 trillion dollars per year. The government sector pays interest as a result of reduced government spending. When the shock occurs, the increase in government spending is so small, so there is no changing in government accounts, but is an increase in government debt.

I take 10 percent of the aggregate demand for the value of the shock. Therefore, government purchases increase to 286 billion dollars per year in 3 months.

Let’s take a look at a behavior of the components of the aggregate demand (Figure 2.16). Before the shock occurs, total aggregate demand equals 20 trillion dollars per year, net export is equal zero. Net effect of the government shock is very small. After the shock, the aggregate demand increase by 286 billion dollars per year and equals 20.286 trillion dollars per year. In 5 years aggregate demand equals 20.167 trillion dollars per year.

Let's look at changes in government purchases. If I increased public purchases from 2.860 trillion dollars per year to 3.146 trillion dollars per year in 3 months, as a result, the same amount of government purchases after the shock stay at the same level for up to 5 years.

When aggregate demand grows, which leads to GDP growth, then investment begins to grow because it is a constant fraction of GDP. Investments start with 3 trillion dollars per year. We can see that the amount of investment after the shock has reached a new level of equilibrium, which is slightly higher than the previous, is equal to 3.025 trillion dollars per year.

Net export starts from zero but also reaches a new level of equilibrium, which is equal to 0.002 trillion dollars per year.

The situation with consumption is the opposite. First, it decreases by 14.140 trillion dollars per year to 13.995 trillion dollars per year. Secondly, it increases between 4 and 5 years. Finally, consumption reaches a new level of equilibrium, which is equal to 13.993 trillion dollars per year in 5 years.

Consumption is a function of household deposits and debt service. The first reason for the following result of consumption is an increase in debt service, as the interest rate rises. Further, household deposits pay for bonds, which leads to a decrease in deposits. Therefore, paying for bonds will reduce consumption.

The result of this shocking experiment is that if we increase government spending, it taxes money from the household sector and invests it in the government sector.

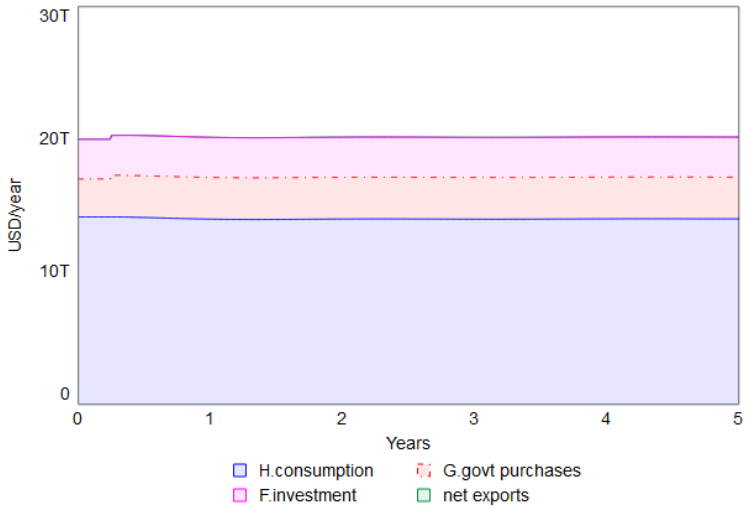

Figure 2.16: Aggregate demand by applying the government shock

Partial Model Test: Households sub-model

Next, I test the behavior of the household sub-model (Figure 2.10) to see if the model reproduces experienced and anticipated the reference mode of the Ukrainian economy. The purpose of the sub-model is to analyze the dynamics of consumption.

Behavioral assumptions in households sub-model: households have a debt service target (and, therefore, borrowing target) based on disposable income.

For this model, I used Ukrainian annual data for the period from 2006 to 2019. The source of the data is the State Statistics Service of Ukraine and the NBU.

Table 2.1: Main exogenous inputs

Variable	Unit
Bond purchases	UAH/year

Loan rate	unitless
Government interest	UAH/year
Taxes and wages&dividends	UAH/year

In this sub-module are three parameters, which difficult to measure accurately in real life. Therefore, I used optimization for these parameters to better replicate historical data, but with realistic constraints on these parameters. In this case, I use such value of parameters:

- Desired debt service pct of disposable income = 10,
- Maturity = 1 year,
- Fraction approved by banks = 1.

Figure 2.17 shows the result of the partial model test of households sub-model. The level of consumption as well as the level of disposable income has steadily increased between 2006 and 2019. The simulated behavior (blue line) replicate the historical data (red line). After 2014 there is a huge discrepancy in compared values due to the crisis in Ukraine which the model do not take into account. Consumption has an upward trend in period of 2005-20019 with more rapid increases in 2015-2019 due to the devaluation of the national nominal currency. This model includes borrowing money and buying bonds.

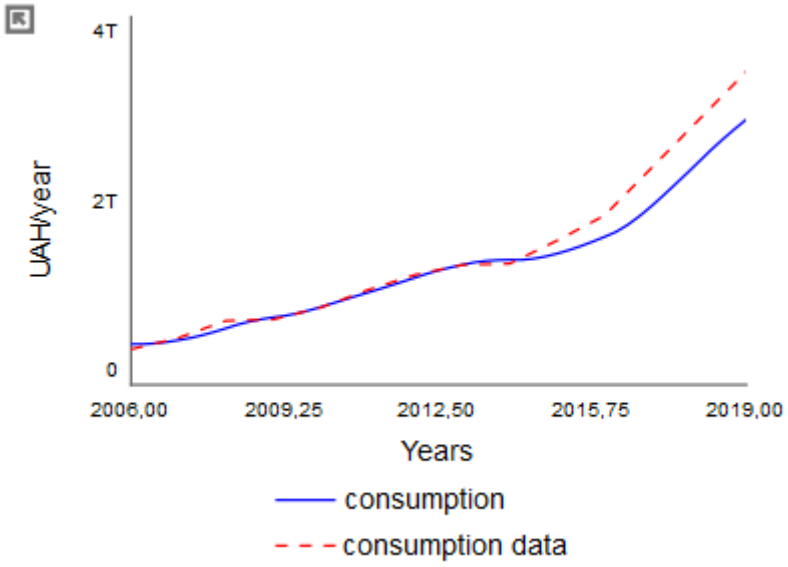

Figure 2.17: Behavior of household consumption

Chapter 3

Wages and Prices Model

The exchange rate can affect prices in the country in different ways. On the one hand, prices tend to rise than fall. Therefore, a decrease in the exchange rate leads to an increase in domestic prices, but an increase in the exchange rate has little effect on lower prices. In turn, in case of high inflation, the ratio between domestic prices and the exchange rate changes in a sufficient way.

Consecutively, rising prices due to currency devaluation will lead to a change in wages. These initial changes in domestic prices and wages usually lead to the effect of a secondary increase in prices and wages, because after a while the production costs begin to change. Because of this, there is a causal loop in the impact of wages and prices.

The purpose of this model is to describes the link between wages and prices, which are determined by inflation. Productivity also has an impact on macroeconomics. Increasing labor productivity is an important criterion in exchange rate stability.

3.1 Structure of the model

The increase in the value of goods is the result of increasing wages. This leads to increses a cost of production. The main aim of firms is to have a profit. The profit occurs when sales is higher than cost of production. In this way, employers should raise prices for goods and services that they produce. Therefore, to renew the balance, it is necessary to increase wages in response to rising prices in the commodity market.

The analysis aimed to use System Dynamics to create a dynamic explanatory model. The reinforcing loop (Figure 3.1) represent connection between two main KPI’s: the average wage and the price index.

The average wage is measured by hourly wages per employee. Then, the firms have to identifie the unit labour hour cost. It depends on labor hour productivity which is measure the hourly output per worker and overtime effect. Based on the general working conditions in Ukraine, there are two main cases: part-time and full-

time jobs. Sometimes employees work overtime as well as under-time which affects labor costs differently. To make the model simple, the difference in overtime and undertime working hours is not taken into account.

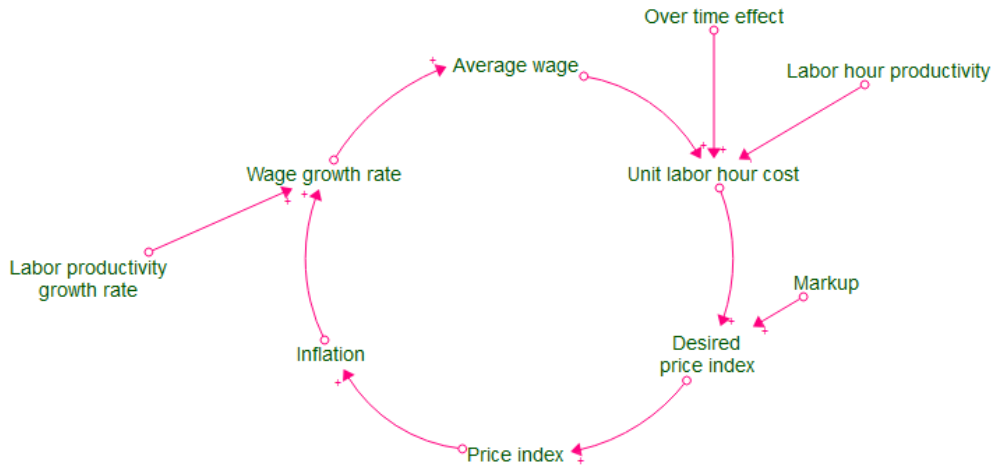

Figure 3.1: Casual loop diagram

Manufacturers to have a profit include a markup (margin) of the cost of goods and services. While firms add a markup, they get the desired price index. It takes some time to bring the actual price index closer to the desired level. Price index used to measure inflation in the economy.

Inflation is a process in the economy when the amount of money in a country is much more than required by the needs of the population. Thus, the population has much money but cannot purchase products due to their low availability and shortage of goods and services. For this reason, the opportunity to purchase it is lower and the cost of goods will increase. A small excess of the money supply is a positive factor for the country's economy. However, for an individual citizen receiving a fixed wage, inflation always results in a gradual decline in his standard of living. Therefore, due to rising inflation, prices need to be raised in order to bring back purchasing power.

Thus, inflation regulates wage growth which is wages adjusted for inflation and productivity growth. In this case, wages cannot change immediately because it requires some time.

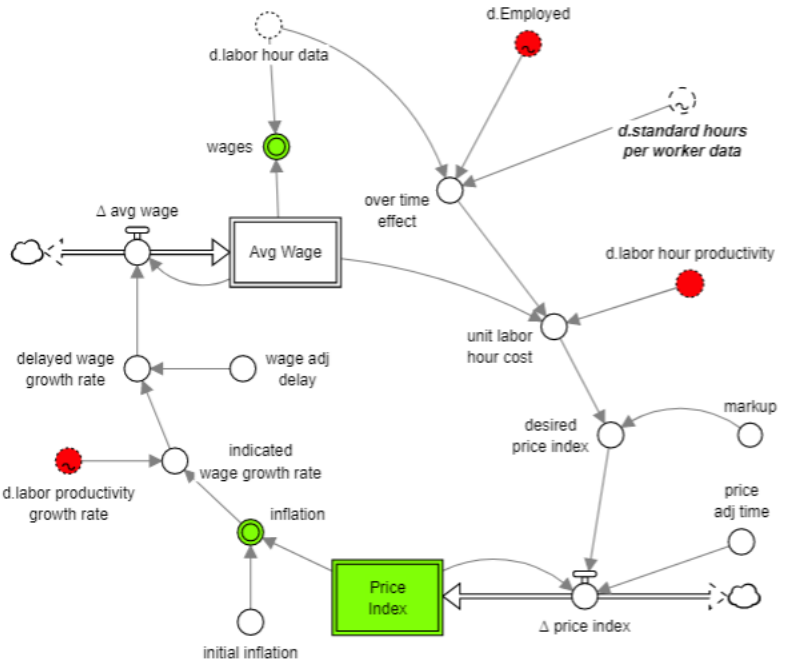

Figure 3.2: Structure of the model

3.2 Behavior of the model

In this section I applied the behavior-sensitivity test which compares the reaction of the model to the influence of factors ('shocks').

First, the test requires to set the model in equilibrium. Let's denote flows of the model:

$$\begin{cases} \Delta avg\ wage = y_1' \\ \Delta price\ index = y_2' \end{cases} \tag{3.1}$$

The following system of differential equations is presented:

$$\begin{cases} y_1' = (((\text{Avg\_Wage} * (\text{d. labor\_hour\_data}/\text{d. Employed})/\text{d. standard\_hours\_per\_worker\_data\_}) \\ \qquad /\text{d. labor\_hour\_productivity}) * (1 + \text{markup}) - \text{Price\_Index})/\text{price\_adj\_time} \\ y_2' = \text{Avg\_Wage} * \text{DELAY1}(\text{SMTH1}((100 * \text{TREND}(\text{Price\_Index; DT; initial\_inflation}) \\ \qquad /100 + \text{d. labor\_productivity\_growth\_rate}); ,25);\ \text{wage\_adj\_delay}) \end{cases} \tag{3.2}$$

In a model, equilibrium occurs when inflow equals to outflow. In this model, the delta average wage and the delta price index should equal to zero. It requires that the average wage is equal to 6.250 UAH/hour and the price index is equal to 0.56. The initial values for inputs is used. The test involves setting different reasonable values of parameters, the exact values of which are not known. The behavior is tested on the main KPIs and other sensitive parameters. This helps to understand the behavior generated by the structure of the model and testing the assumptions.

One of the main parameters over which the Ukrainian government have not a total direct control is the markup. Therefore, the main idea is to see how different values of markup affect the behavior of the model.

First, I assume changes in markup in one year. In this case, I set four different values of this parameter that is increase and a decrease of 50% and 100% in the initial value which is 150%. Figure 3.3 shows the behavior of the average wages, price index, inflation, and values of markup which is tested. Changes in the markup affect the equilibrium values of the main parameters. As we can see, the higher level of markup is set the higher values of the average wage, price index, and inflation is obtained and vice versa. It is noticeable that the change in the parameter has a direct impact on the behavior of the model.

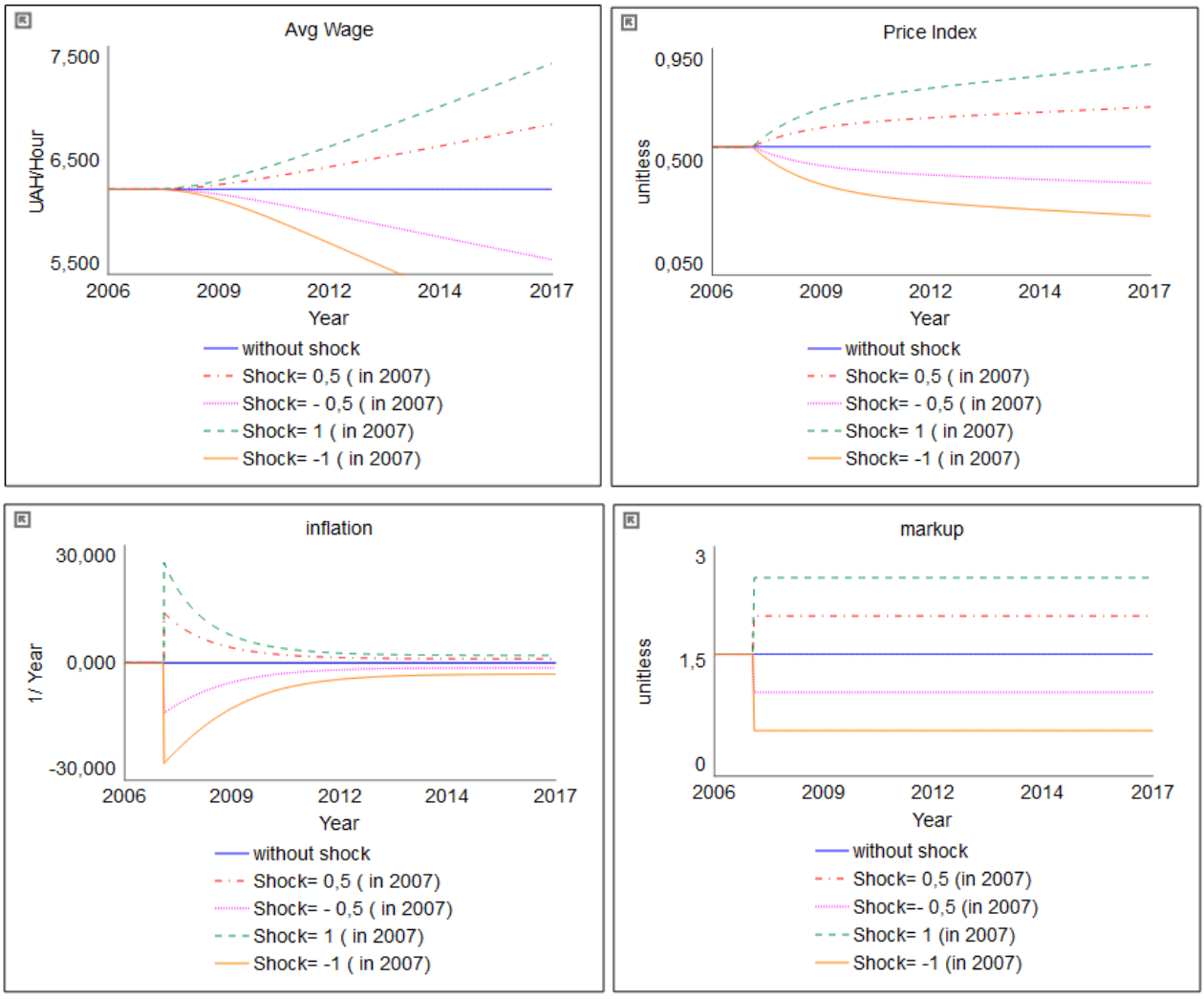

Figure 3.3: The effect of changes in markup on the main KPIs in 2007

Next, I added two shocks: an increase of 50% in 2008 and a decrease in the same value in 2013 and vice versa. Figure 3.4 represents the resulting behavior of applying two shocks. First graph shows the behavior of average wage. The stock starts to increase until 2013 and then increase increasingly until the average wage achieves to a new equilibrium value 6.586 UAH/hour, or decrease decreasingly to a new equilibrium value 5.878 UAH/hour. Assume changes the price index. If I used both shocks, the value initially increases until 2013 and then decrease decreasingly to achieve a lower equilibrium value of 0.591. After applying two shocks, the dynamic of inflation shows a step in 2008 and 2013. The negative step occurs when is set a lover value of markup and it changes to the positive step when value of markup is positive. There is a slow asymptotic approach to equilibrium.

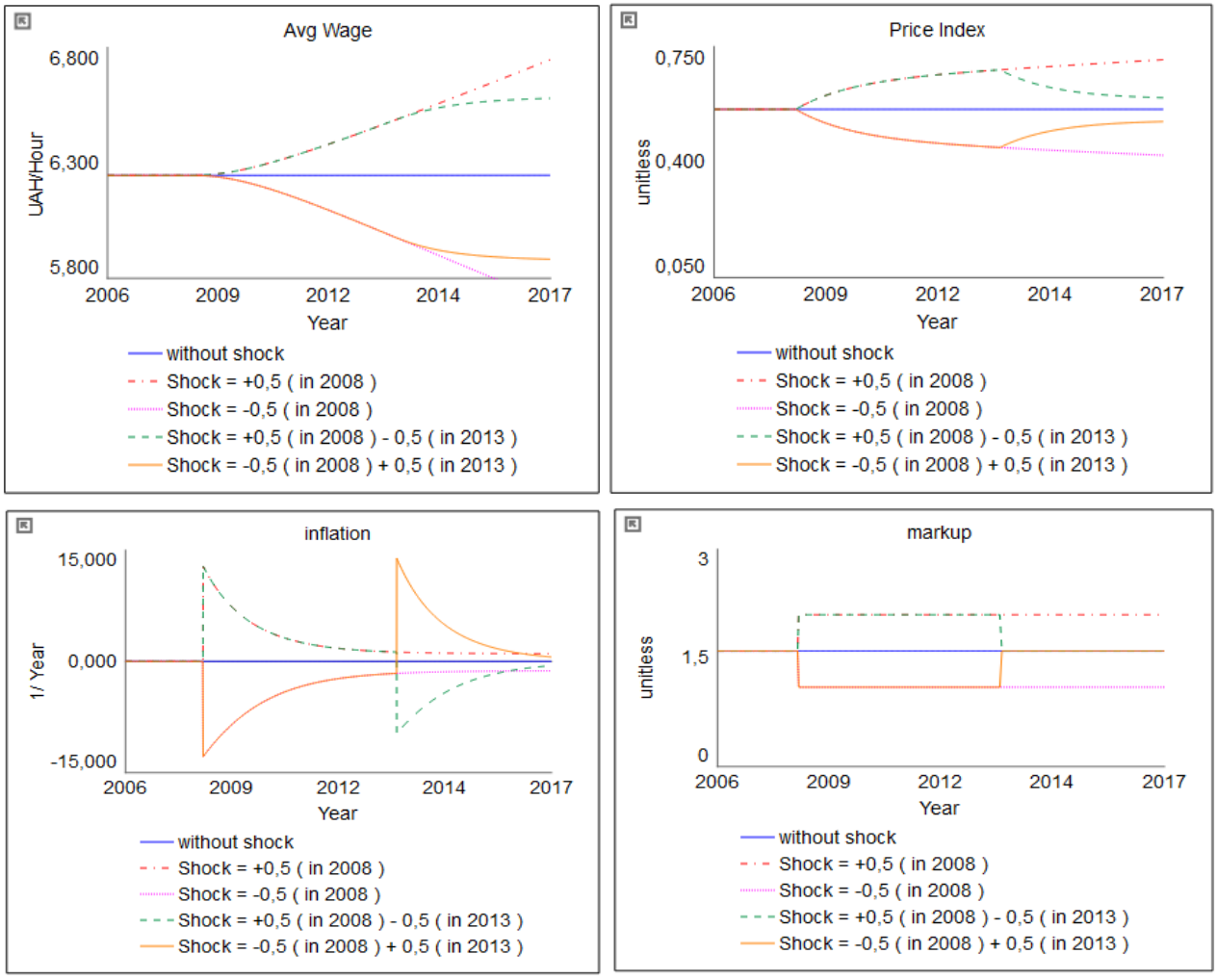

Figure 3.4: The effect of changes in markup on the main KPIs in 2007 and 2013

Summary

First, I consider the impact of the Real Effective Exchange Rate (REER) gap which is one of the major variables in a small open economy on GDP growth. Based on quarterly data from 2005 to 2020, I build the linear (OLS) regression and the nonlinear (Threshold) regression. According to the simulation results, the REER gap has a different impact on GDP growth depending on the economic regimes in Ukraine. In a baseline linear regression, I had not found a negative relationship between the REER gap and GDP growth which is not consistent with the results of the empirical literature. Introducing nonlinear regression and stationary regime, I found that a 10 percent decrease in the REER gap leads to an increase in GDP growth of 1.62 percent. Also, I found an asymmetric effect in the overvaluation and undervaluation of the REER, as the undervaluation has a greater impact on growth. That is, a 10 percent increase in undervaluation leads to an increase in GDP growth of 3.3 percent, in turn, a 10 percent increase in overvaluation leads to a decrease in growth of 0.95 percent.

Second, I studied a macroeconomic model using system dynamics approach. This model explains the exchange rate between two countries that use different currencies. To experiment the model, I tested the behavior of aggregate demand under the influence of the shock that arose in government spending. Also, I tested the structure of the household sector to check whether this model could be applied to the Ukrainian data. The results confirm that the system dynamics approach for modeling household consumption is appropriate for Ukraine, but additional shocks, such as the crisis repiods in Ukraine need to be included.

Finally, the main negative effect of inflation is the reverse effect on income. I tested a model which examines the relationship between the effects of the price index on wages. The main hypothesis of the model is that higher inflation is associated with higher average wages and vice versa. The result of testing the model indicates that an increase in the markup (margin) is one of the reasons for the increase in the price index, which in turn increases the level of average wages. Therefore, the reasonable value of markup is key to a positive impact on the economy of a country.

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