

An Open Economy DSGE Model with Labor Market Frictions*

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Abstract

This paper develops and estimates a small open economy DSGE model with search-and-matching rigidities on Hungarian data. Our main findings are as follows: (i) over and above what is implied by matching frictions, we do not find wages to be particularly rigid in Hungary; (ii) labor market developments are propagated to the broader economy; (iii) shocks originating outside the labor market are important for some, but not all labor market variables, and (iv) changes in activity are a very important driving force of fluctuations not only on the labor market, but also for other variables like inflation.

1 Introduction

This paper examines the impact of introducing search and matching frictions and sluggish real wages into an open economy DSGE model of Hungary. Our goal with this exercise is two. First, as the labor market is a significant source of shocks to the Hungarian economy, it is important to incorporate a more realistic labor market block into the existing Hungarian DSGE model (Jakab and Világi 2007). We hope to learn a great deal about the transmission of monetary

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policy shocks through the labor market, and also the impact of labor market originated shocks to the rest of the economy.

Second, we contribute to the existing literature on labor DSGE models by adding search and matching rigidities to small open economy framework. We do this primarily because the Hungarian economy is highly open, so it is essential to include the export and import sectors (as well as foreign borrowing and lending) to provide a realistic picture. On the other hand, we are able to explore interactions between labor market rigidities and openness: the impact of shocks that originate abroad on the labor market, and the impact of labor market disturbances on the exchange rate and the current account.

The model we develop is a built from standard elements, adopted to some of the special features of the Hungarian economy. Apart from the description of the labor market, we use a somewhat simplified version of Jakab and Világi (2007). The model has two final good sectors, one producing for domestic usage and the other for exports. Both sectors use capital, imported intermediates, and domestically produced intermediates. The latter are produced using only labor, and are where search and matching frictions are found. Price rigidities, on the other hand, only apply for the final good producers. Thus we follow much of the literature and separate the wage bargaining and price setting decisions for analytical convenience (see Trigari 2006, for example).

Imports are only used as intermediate goods, which confirms to recent models that emphasize the importance of local distribution costs (Burstein, Neves and Rebelo 2003). Our two-sector assumption reflects that the export sector is much more intensive in its usage of imported intermediates than the domestic sector.

We model the labor market similarly to Christoffel, Kuester and Linzert (2006). Thus we extend the Trigari (2006) framework with real wage rigidities, in the form of quadratic adjustment costs. We allow for adjustment in hours (the intensive margin) as well as in employment (the extensive margin). For simplicity, the model assumes efficient bargaining, which means that firm and workers bargain each period over both wages and hours. In contrast, right-to-manage bargaining takes place only over wages, with firms choosing hours afterwards.

Our model incorporates some additional features of the Hungarian economy, following Jakab and Világi (2007). We allow for the (short-run) non-rationality of inflation expectations in the form of adaptive learning. As inflation targeting (IT) is relatively recent in Hungary, and inflation has been declining from relatively high levels (30% in 1995 and 10% in 2000, before the introduction of IT). Also, big inflationary shocks have hit the Hungarian economy in the past few years. Thus we find it plausible that agents are sluggish in updating their inflation expectations, and the estimates of Jakab and Világi (2007) support this view.

We also depart from the labor DSGE literature by introducing other factors of production in addition to labor. We have already explained the importance of imported intermediates Hungary (on average) is growing faster than the advanced EU economies, and much of this growth is through capital accumulation. Investment in Hungary plays an important role not only in growth, but also at business cycle frequency and for monetary policy.

The rest of the paper is organized as follows. We first present some stylized facts of the labor market in Hungary. We then describe the model, with a special emphasis on the labor market. Next we discuss our choice of parameter values and our estimation strategy. Then we present the estimation results, and discuss the implications of introducing labor market rigidities to a small open economy DSGE model. Finally, we describe the directions we plan to follow with this research and then conclude.

2 The Hungarian labor market

In this section we present some stylized facts of the Hungarian labor market. Figure 1 plots the evolution of employment and activity in our sample period, 1995-2007. In addition to the raw data, we also plot the smoothed trends computed using the HP filter. There are a number noteworthy features on the figure. First, employment grew significantly over the period, by about 8%. Second, it was also volatile in the short run, especially in the second half of the sample.

Apart from the generally upward trend, activity is also very volatile. In fact employment and



Figure 1: Employment and activity

activity move quite closely together. Looking at Figure 2, which shows the cyclical component of the two series, reveals this very close co-movement.

These findings suggest that much of the fluctuation in employment results from a movement between employment and inactivity. Thus in order to match the data, we cannot rely on the baseline unemployment numbers, but need to consider also the pool of inactive when looking at job flows. There are two strategies to deal with this issue. Firstly, and ideally, inactivity can be modelled explicitly. Such an approach is pursued by, for example, Haefke and Reiter (2006).

Secondly, one can treat activity as exogenous but time varying, and incorporate changes in activity as a shock. For the time being we pursue this latter approach. While not as satisfactory as the first one, it still allows us to incorporate the activity/inactivity margin. More importantly, we can trace the activity shock through the model, and see how it affects the endogenous variables. As we show later, this shock is very important to explain not only the labor market outcome, but also other variables.

Figure 3 plots the evolution of the real wage and manufacturing hours. The real wage is not particularly volatile, and it is comparable to international experience. Hours volatility is also not very high, but also not trivial. The figure is not very informative whether there is much real (or nominal) wage rigidity at the aggregate level. It suggests, however, that modelling hours is

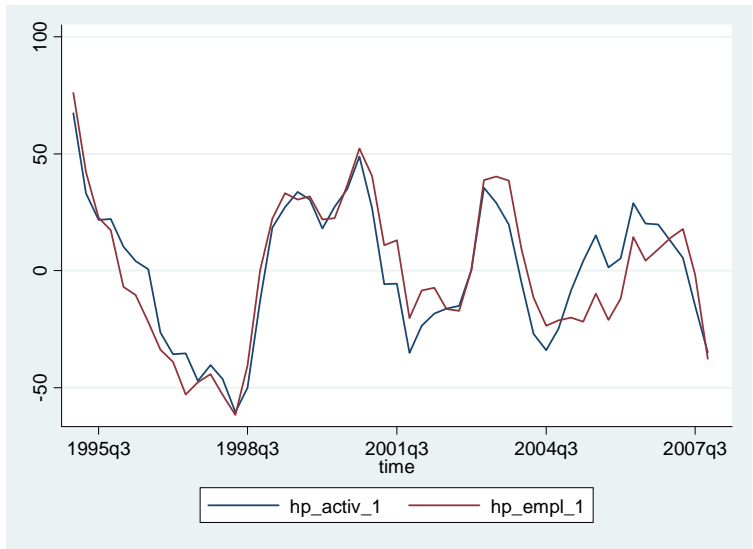


Figure 2: Employment and activity

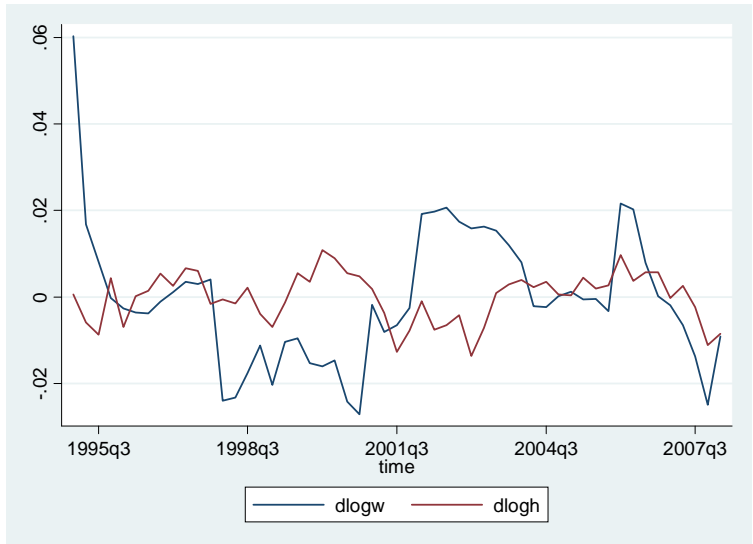


Figure 3: Real wage and hours

important in order to understand the behavior of the labor market in Hungary.

3 The model

3.1 Households

The representative household maximizes intertemporal utility by selecting streams of consumption, investment and foreign bond holdings. Consumption is subject to external habits, and investment is subject to adjustment costs defined on the ratio of current and previous investment. Household members are either employed or unemployed, but are able to fully insure each other against the random fluctuation of employment. We defer detailed discussion of the labor market to a later section.

Households' problem can be written as

$$\begin{aligned} \max E_0 \sum_{t=0}^{\infty} \beta^t e^{\eta_t^c} & \left[\frac{(c_t - h\tilde{c}_{t-1})^{1-\vartheta}}{1-\vartheta} - \Psi n_t \frac{e^{\eta_t^l} l_t^{1+\varphi}}{1+\varphi} \right] \\ \text{s.t.} \quad c_t + i_t + \frac{B_t}{P_t R_t} &= \frac{B_{t-1}}{P_t} + (1 - u_t) w_t l_t + u_t b_u + r_t^k k_{t-1} + D_t \\ k_t &= (1 - \delta) k_{t-1} + \left[1 - \Phi \left(\frac{e^{\eta_t^l} i_t}{i_{t-1}} \right) \right] i_t, \end{aligned}$$

where c_t is consumption, \tilde{c}_{t-1} is average consumption in the previous period, n_t and u_t are the employment and unemployment rates, l_t is hours supplied if employed, i_t is investment, B_t is bonds held by the household expressed in local currency, P_t is the consumer price index, w_t is the real wage rate, r_t^k is the (real) rental rate on capital, k_{t-1} is the capital stock carried over from the previous period, and D_t is lump sum net income from other sources such as dividends and government transfers. We assume that the investment adjustment cost $\Phi(\cdot)$ is increasing and convex, with $\Phi(1) = \Phi'(1) = 0$ and $\Phi''(1) > 0$.

Using λ and λQ as the Lagrange multipliers for the two constraints, the first-order condi-

tions (except for labor) are given as

$$e^{\eta_t^c} (c_t - h\bar{c}_{t-1})^{-\vartheta} = \lambda_t \quad (1)$$

$$\frac{\lambda_t}{P_t} = \beta R_t E_t \frac{\lambda_{t+1}}{P_{t+1}} \quad (2)$$

$$1 = Q_t \left[1 - \Phi \left(\frac{e^{\eta_t^l} i_t}{i_{t-1}} \right) - \frac{e^{\eta_t^l} i_t}{i_{t-1}} \Phi' \left(\frac{e^{\eta_t^l} i_t}{i_{t-1}} \right) \right] \\ + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} Q_{t+1} e^{\eta_{t+1}^l} \left(\frac{i_{t+1}}{i_t} \right)^2 \Phi' \left(\frac{e^{\eta_{t+1}^l} i_{t+1}}{i_t} \right) \quad (3)$$

$$Q_t = \beta E_t \left[(1 - \delta) Q_{t+1} + r_{t+1}^k \right] \frac{\lambda_{t+1}}{\lambda_t} \quad (4)$$

$$k_t = (1 - \delta) k_{t-1} + \left[1 - \Phi \left(\frac{e^{\eta_t^l} i_t}{i_{t-1}} \right) \right] i_t. \quad (5)$$

The first equation defines the marginal utility of income λ_t , the second is the household Euler equation, the third describes investment behavior, and the last is an arbitrage condition between investment into bonds and capital.

3.2 Final goods

There are two sectors producing final goods, one for domestic use and the other for exports. Both sectors contain an infinite number of monopolistically competing firms, who produce differentiated goods. These differentiated goods are then aggregated into a final product (by competitive retailers), using the usual CES aggregator:

$$y_{j,t} = \left[\int_0^1 y_{j,t}(i)^{\frac{1}{1+\mu_{j,t}}} di \right]^{1+\mu_{j,t}},$$

where $y_{j,t}(i)$ is a typical variety in sector j , and $\mu_{j,t}$ is the time-varying markup parameter.

Demand for variety i is then

$$y_{j,t}(i) = \left[\frac{P_{j,t}(i)}{P_{j,t}} \right]^{-1-1/\mu_t} y_{j,t}.$$

Variety producers use three inputs: capital, domestically produced intermediate goods,

and imported intermediate goods. The production function is Cobb-Douglas, and the cost-minimization problem is written as

$$\begin{aligned} \min \quad & k_{j,t} r_t^k + p_t^m y_{j,t}^m + p_t^d y_{j,t}^d \\ \text{s.t.} \quad & y_{j,t} = e^{a_{j,t}} k_{j,t}^{\alpha_j} \left[(y_{j,t}^m)^{\alpha_{zj}} (y_{j,t}^d)^{1-\alpha_{zj}} \right]^{1-\alpha_j}, \end{aligned}$$

where p_t^m and $y_{j,t}^m$ are the relative price and quantity of the imported intermediates, p_t^d and $y_{j,t}^d$ are the relative price and quantity of the domestic intermediate, and $a_{j,t}$ is an exogenous technology shock.

Real marginal cost can be easily derived as¹

$$mc_{j,t} = \chi e^{-a_{j,t}} (r_t^k)^{\alpha_j} \left[(p_t^m)^{\alpha_{zj}} (p_t^d)^{1-\alpha_{zj}} \right]^{1-\alpha_j} \quad (6)$$

and the input demands are given by

$$k_{j,t} = \frac{\alpha_j mc_{j,t}}{r_t^k} y_{j,t} \quad (7)$$

$$y_{j,t}^m = \frac{(1-\alpha_j) \alpha_{zj} mc_{j,t}}{p_t^m} y_{j,t} \quad (8)$$

$$y_{j,t}^d = \frac{(1-\alpha_j) (1-\alpha_{zj}) mc_{j,t}}{p_t^d} y_{j,t}. \quad (9)$$

Variety producers act as monopolists, and choose prices when allowed. We use the well-known Calvo assumption, so that firms can reoptimize prices with probability $1 - \gamma$. Those firms which do not optimize at the given date follow a rule of thumb. Rule of thumb price setters increase their prices by the expected average rate of inflation, as in Yun (1996), and to some extent by the difference between the past actual and perceived average inflation rates, similarly to Christiano et al. (2001), the SIGMA model at the FED (see. Erceg et al 2006) and Smets and Wouters (2003). However, here the indexation term applies not to actual aggregate

¹ $\chi = \alpha_j^{-\alpha_j} [\alpha_{zj} (1-\alpha_j)]^{\alpha_{zj}(\alpha_j-1)} [(1-\alpha_{zj})(1-\alpha_j)]^{(1-\alpha_{zj})(\alpha_j-1)}$

inflation, but to a perceived value ($\bar{\Pi}_{t+1}$), which agents constantly learn by a real-time adaptive learning algorithm.

Formally²,

$$\begin{aligned} P_{t+1}(i) &= P_t(i) \left(\frac{1 + \Pi_t}{1 + \bar{\Pi}_t} \right)^\vartheta (1 + \bar{\Pi}_{t+1}) \\ &= P_t(i) \left(\frac{P_t}{P_{t-1}} \frac{S_{t-1}}{S_t} \right)^\vartheta \left(\frac{S_{t+1}}{S_t} \right) = P_t(i) \left(\frac{\hat{P}_t}{\hat{P}_{t-1}} \right)^\vartheta \left(\frac{S_{t+1}}{S_t} \right), \end{aligned}$$

where ϑ measure the degree of indexation according to past inflation measures, $S_{k+1} = (1 + \bar{\Pi}_{k+1})S_k$, $k \geq t - 1$, and $S_{t-1} = P_{t-1}$ is given, furthermore $\hat{P}_t = P_t/S_t$. This implies that

$$P_s(i) = P_t(i) \bar{S}_{s,t}, \quad (10)$$

where

$$\bar{S}_{s,t} = \left(\frac{\hat{P}_{s-1}}{\hat{P}_{t-1}} \right)^\vartheta \left(\frac{S_s}{S_t} \right).$$

If firm i sets its price optimally at date t it solves the following maximization problem.

$$\max_{P_{j,t}(i)} = E_t \sum_{s=t}^{\infty} (\beta \gamma_j)^{s-t} \frac{\lambda_s}{\lambda_t} y_{j,s}(i) P_{j,s}^{1+1/\mu_{j,s}} [P_{j,t}(i) \bar{S}_{j,s}]^{-1-1/\mu_{j,s}} [P_{j,t}(i) \bar{S}_{j,s} - P_{j,s} m c_{j,s}],$$

This implies the following first order condition:

$$E_t \sum_{T=t}^{\infty} (\beta \gamma_j)^{s-t} \frac{\lambda_s}{\lambda_t} s_{j,t}^s(i) \left[\left(1 + \frac{1}{\mu_{j,s}} \right) P_{j,t} P_{j,t}(i)^{-1} m c_{j,s} - \frac{1}{\mu_{j,s}} \bar{S}_{j,s} \right] = 0, \quad (11)$$

where $s_{j,t}^s(i) = y_{j,s} P_{j,s}^{1+1/\mu_{j,s}} [P_{j,t}(i) \bar{S}_{j,s}]^{-1-1/\mu_{j,s}}$.

As indicated above, agents apply a real-time adaptive algorithm to identify the average inflation rate,

$$\hat{\pi}_t^p = \rho_\pi \hat{\pi}_{t-1}^p + g(\hat{\pi}_t - \hat{\pi}_{t-1}^p)$$

Here $\hat{\pi}_t$ is the observed actual, $\hat{\pi}_t^p$ is the perceived average inflation rate (both expressed in log

²We drop the industry index j when no confusion arises.

deviation from the steady state). The gain parameter g influences the speed of learning. The advantage of this setup is that the price Phillips curve takes the same form as in a model without learning (see the Appendix), except that the inflation variable is the difference between true and perceived inflation,

$$d\hat{\pi} \equiv \hat{\pi}_t - \hat{\pi}_t^p.$$

Note that learning only applies to the domestic sector, as uncertainty about monetary policy does not influence the export price (which is expressed in foreign currency).

3.3 Domestic intermediates and the labor market

Domestic intermediate production requires only labor as an input. The production function has constant returns to scale, and we normalize the unit labor requirement to 1. Firms in this sector produce an identical product, and there is free entry in the sense that anyone can set up an additional firm. Hiring workers, however, is costly: firms have to post a vacancy one period ahead. Filling the vacancy is probabilistic, and depends on the aggregate labor market conditions.

3.3.1 Matching

More precisely, we assume the usual constant returns to scale matching function

$$m_t = \sigma_m u_t^\sigma v_t^{1-\sigma}, \quad (12)$$

where m_t is the number of matches formed in period t , u_t is the unemployment rate and v_t is the number of vacancies. We define the probability of filling a vacancy q_t and the probability of finding a job s_t as

$$q_t = \frac{m_t}{v_t} \quad (13)$$

$$s_t = \frac{m_t}{u_t}. \quad (14)$$

The flow equations for employment and unemployment are simply defined as

$$n_t = (1 - \rho)n_{t-1} + m_{t-1} + \eta_t^n \quad (15)$$

$$u_t = 1 - n_t, \quad (16)$$

where ρ is the constant and exogenous separation rate and η_t^n is the exogenous shock to activity described in the previous section.

3.3.2 Value functions

The asset values of a filled job J_t and an empty vacancy V_t are

$$\begin{aligned} J_t &= \left(p_t^d - w_t \right) l_t - \frac{\gamma_w}{2} \left[p_t w_t - p_{t-1} w_{t-1} (\pi_{t-1}^w)^{\vartheta_w} \right]^2 \\ &\quad + E_t \frac{\beta \lambda_{t+1}}{\lambda_t} [(1 - \rho) J_{t+1} + \rho V_{t+1}] \\ V_t &= -\frac{\kappa}{\lambda_t} + E_t \frac{\beta \lambda_{t+1}}{\lambda_t} [q_t J_{t+1} + (1 - q_t) V_{t+1}], \end{aligned}$$

where the first terms are the net flow benefits and the expectation terms are the continuation values appropriately discounted.

Notice that adjusting *nominal wages* is costly (we reserve the notation w_t for the real wage, but use π_t^w to indicate nominal wage inflation). For analytical convenience, we assume quadratic adjustment costs, which are positive for deviations from previous period's nominal wage inflation. This is analogous to our pricing assumption where non-optimizing firms indexed their prices to perceived inflation. Here, for simplicity, we assume that learning has no role as firms know the values of the current and lagged average wage.

Given free entry to set up a firm, which is equivalent to posting a vacancy, the value of a

vacancy is driven to zero at all periods. Using this condition, we express the value of a job as

$$\begin{aligned}
V_t &\equiv 0 & (17) \\
&\Downarrow \\
E_t \frac{\beta \lambda_{t+1}}{\lambda_t} J_{t+1} &= \frac{\kappa}{\lambda_t q_t} \\
&\Downarrow \\
J_t &= \left(p_t^d - w_t \right) l_t - \frac{\gamma_w}{2} \left[p_t w_t - p_{t-1} w_{t-1} (\pi_{t-1}^w)^{\vartheta_w} \right]^2 + \frac{(1-\rho) \kappa}{\lambda_t q_t}.
\end{aligned}$$

Moreover, we manipulate the same equations to get an equation for the probability of filling a job:

$$\frac{\kappa}{q_t} = E_t \beta \lambda_{t+1} \left[\left(p_{t+1}^d - w_{t+1} \right) l_{t+1} - \frac{\gamma_w}{2} \left(p_{t+1} w_{t+1} - p_{t+1} w_t (\pi_t^w)^{\vartheta_w} \right)^2 + \frac{(1-\rho) \kappa}{\lambda_{t+1} q_{t+1}} \right]. \quad (18)$$

Next, we write the asset values belonging to a worker who has a job (W_t) and to an unemployed person (U_t):

$$\begin{aligned}
W_t &= w_t l_t - \Psi \frac{e^{\eta_t^l} l_t^{1+\phi}}{\lambda_t (1+\phi)} + E_t \frac{\beta \lambda_{t+1}}{\lambda_t} [(1-\rho) W_{t+1} + \rho U_{t+1}] \\
U_t &= b_u + E_t \frac{\beta \lambda_{t+1}}{\lambda_t} [s_t W_{t+1} + (1-s_t) U_{t+1}],
\end{aligned}$$

where the right-hand sides are again composed of the flow net benefits and the continuation values. Subtracting the second equation from the first, we get the net value of accepting a job:

$$W_t - U_t = w_t l_t - \Psi \frac{e^{\eta_t^l} l_t^{1+\phi}}{\lambda_t (1+\phi)} - b_u + E_t \frac{\beta \lambda_{t+1}}{\lambda_t} (1-\rho-s_t) (W_{t+1} - U_{t+1}). \quad (19)$$

3.3.3 Wage bargaining

Wages and hours worked are determined each period by bargaining between employers and employees. There are two versions of Nash bargaining that are widely used in the literature, efficient and right-to-manage. For now we stick the simpler case of efficient bargaining; we

plan to experiment with the other type in the future.

Firms and workers pick wages and hours to maximize the joint surplus:

$$\max_{w_t, h_t} (W_t - U_t)^\eta (J_t - V_t)^{1-\eta},$$

where η measures the bargaining power of workers. First order conditions are given by

$$\begin{aligned} \frac{\eta J_t}{(1-\eta)(W_t - U_t)} = & 1 + \frac{\gamma_w}{l_t} \left[p_t w_t - p_{t-1} w_{t-1} (\pi_{t-1}^w)^{\vartheta_w} \right. \\ & \left. - \beta (1-\rho) E_t \frac{\lambda_{t+1}}{\lambda_t} (\pi_{t-1}^w)^{\vartheta_w} (p_{t+1} w_{t+1} - p_t w_t (\pi_t^w)^{\vartheta_w}) \right] \end{aligned} \quad (20)$$

for the wage rate, and

$$\frac{\eta J_t}{(1-\eta)(W_t - U_t)} = \frac{p_t^d - w_t}{\Psi e^{\eta l_t} l_t^\phi / \lambda_t - w_t} \quad (21)$$

for hours.

3.4 Other conditions

We assume that the country is a small open economy, which has two implications for external links. First, a modified UIP condition holds, where the interest rate on home currency denominated foreign bonds is given by the constant world interest rate plus an endogenous risk premium:

$$\frac{e_t R_t}{E_t e_{t+1}} = \left[\frac{1}{\beta} + \psi (e^{-(B_t - \bar{B})} - 1) \right] e^{\eta_t^{UIP}}. \quad (22)$$

We follow Schmitt-Grohé and Uribe (2003) and make the risk-premium a function of the net foreign asset position B . Second, we posit an ad-hoc export demand equation

$$\frac{y_{x,t}}{y_{x,t-1}^{h_x}} = (p_t^x)^{-\theta_x} Y^w e^{\eta_t^x}, \quad (23)$$

which is subject to habit formation. We include a structural foreign demand shock which has been shown to be important in the case of Hungary.

Factor markets need to clear in equilibrium, which lead to the following conditions:

$$y_t^d = n_t l_t \quad (24)$$

$$y_t^d = y_{d,t}^d + y_{x,t}^d \quad (25)$$

$$k_{t-1} = k_{d,t} + k_{x,t} \quad (26)$$

$$y_t^m = y_{d,t}^m + y_{x,t}^m. \quad (27)$$

Note that the first equation defines the supply of domestic intermediates. In addition, domestic output $y_{d,t}$ must equal its usage as consumption, investment and government spending:

$$y_{d,t} = c_t + i_t + g_t. \quad (28)$$

We treat government spending as completely exogenous and unproductive, which follows a first-order autoregressive path.

Monetary policy is represented by a simple Taylor rule:

$$\hat{r}_t = \zeta_r \hat{r}_{t-1} + (1 - \zeta_r) (\zeta_\pi E_t \hat{\pi}_{t+1} + \xi_e \hat{e}_t) + \eta_t^m. \quad (29)$$

We assume that the monetary authority sets the interest rate, and reacts to expected inflation and the unemployment rate. We allow for interest rate smoothing when $\xi_r > 0$.

Finally, we can rewrite the household budget constraint to get the current account:

$$\frac{B_t}{e_t R_t} - \frac{B_{t-1}}{e_t} = p_t^x y_{x,t} - y_t^m. \quad (30)$$

We assume that the foreign currency price of imported intermediates is exogenously given. This implies that their domestic currency price is given by:

$$p_t^m = p_t^{m*} \frac{e_t}{p_t},$$

where e_t/p_t is the real exchange rate. We can also set measurement units for real variables, and we normalize the steady state level of the domestically sold final good,

$$\bar{y}_d = 1.$$

Equations (5) through (29) describe the equilibrium dynamics of the system. We log-linearize the equations around the non-stochastic steady state, and solve the linearized system. The full list of our log-linearized equations is contained in the Appendix. Note that in addition to the shocks explicitly mentioned up to now, we are also including an error term in the capital accumulation equation in order to account for measurement error, and we add a shock to the arbitrage condition between capital and bond holdings. As the latter one is quantitatively insignificant, we omit it from further discussion.

4 Parameter values

In this section we describe the calibration of the model parameters that are not estimated. Table 1 below contains the actual parameter values. We begin by setting the steady state level of net foreign assets $\bar{B} = 0$, and the steady state level of the exchange rate and the export price to $\bar{e} = 1$ and $\bar{p}^x = 1$. We use (2), (3) and (4) to get

$$\begin{aligned}\bar{R} &= \frac{1}{\beta} \\ \bar{r}^k &= \frac{1}{\beta} - 1 + \delta.\end{aligned}$$

The discount rate is calibrated to match a steady state annualized interest rate of 4%, and the depreciation rate is set to $\delta = 0.025$.

Given the Cobb-Douglas assumption for the final good sectors, we calibrate the share para-

Calibrated other parameters		
Discount factor	β	0.99
Steady state share of capital in real marginal costs, domestic	α_d	0.17
Steady-state share of capital in real marginal costs, export	α_x	0.14
Steady-state share of imported inputs in intermediates, domestic	α_{zd}	0.50
Steady-state share of imported inputs in intermediates, export	α_{zx}	0.64
Depreciation rate	δ	0.025
Markup in final goods (domestic, export)	μ, μ_x	0.2
Investments adjustment cost	$\Phi''(1)$	13.00
Exchange rate elasticity of the policy rule	ζ_e	0.025
Debt elasticity of financial premium	ψ	0.001
Autoregressive learning parameter	ρ_π	0.99
Calibrated labor market parameters		
Matching function elasticity	σ	0.5
Vacancy creation cost	κ	4.252
Labor disutility parameter	Ψ	2.287
Elasticity of labor supply	ϕ	8
Workers' bargaining power	η	0.2
Separation rate	ρ	0.1
Unemployment benefit	b_u	0.1542

Table 1: Calibrated parameter values

meters from the following equations:

$$\alpha_d = \frac{(1 + \bar{\mu}) \bar{r}^k \bar{k}_d}{\bar{y}_d}$$

$$\alpha_x = \frac{(1 + \bar{\mu}_x) \bar{p} \bar{r}^k \bar{k}_x}{\bar{y}_x}$$

$$\alpha_{zd} = \frac{(1 + \bar{\mu}) \bar{p}^m \bar{y}_d^m}{(1 - \alpha_d) \bar{y}_d}$$

$$\alpha_{zx} = \frac{(1 + \bar{\mu}_x) \bar{p} \bar{p}^m \bar{y}_x^m}{(1 - \alpha_x) \bar{y}_x}$$

The steady state mark-ups are set to $\mu = \mu_x = 0.2$.

For the other parameters that are not estimated, we use values from Jakab and Világi (2007). These parameters are the investment adjustment cost ($\Phi''(1) = 13$) and the debt elasticity of the risk premium ($\psi = 0.001$).

We estimate the standard-deviation and autoregressive parameters of the exogenous shocks with observable time series, (namely, the government-spending \tilde{g}_t , the measurement error of

capital accumulation $\tilde{\epsilon}_t^k$ and the import-price \tilde{P}_t^{m*} shocks) by single-equation OLS. Second, the time series of the deterministic part of depreciation $d\bar{e}_t$ is constructed. Using this time series we also estimate the standard-deviation and autoregressive parameters of this shock by OLS. We also fixed ζ_e^{cr} , ζ_e^{it} and ψ . These are technical parameters. Their only role is to assure stationarity of the model. The learning gain parameter was also set fixed and took the value estimated by Jakab and Világi (2007).

4.1 The labor market

First, we choose some parameters and normalizations:

$$\sigma = 0.5$$

$$\eta = 0.2$$

$$\bar{l} = 1$$

The value of σ is standard in the literature, and we do not have any direct observations on it. The value of η indicates our belief that in Hungary employees have a relatively low bargaining power.³ The value of steady state hours is simply a normalization.

The separation rate is difficult to calibrate because we only observe a limited number of transitions out of employment (those who become and stay unemployed for more than one quarter). This data would give us a separation rate of about 1.2%, which is probably much too low. We tried a value close to the standard value used in the literature (0.1).

The official unemployment rate is about 7%, but it does not include those workers who are classified as inactive but are potentially available for work. Thus we take a more indirect route and use data from the public employment agency on transition from unemployment to taking a job.⁴ The job finding probability is 10% per month, which leads us to choose $\bar{s} = 0.3$. We can

³This is because (i) unemployment and inactivity rates are relatively high, (ii) it is relatively easy to hire and fire workers, and (iii) trade unions are (with the exception of a few sectors like railways) are weak or nonexistent.

⁴The numbers are available at [http:// www.afsz.hu/sysres/meoweb/index.html](http://www.afsz.hu/sysres/meoweb/index.html) (Table 1). The data refers to one

calculate the unemployment rate using the definition of \bar{s} :

$$\bar{s} = \frac{\rho(1 - \bar{u})}{\bar{u}},$$

which leads to a steady state total unemployment rate of $\bar{u} = 0.25$. Since inactivity in Hungary is high (the activity rate is about 57%), and a significant part of inactives might also behave as unemployed we feel comfortable with an unemployment rate of about 25%.

We also use the job finding probability to calibrate the replacement rate. The average unemployment spell is simply the inverse of \bar{s} , and in our calibration it is a bit above 3 quarters; we use three quarters in what follows. An unemployed person receives 60% of his/her previous salary for 1 quarter, then 60% of the minimum wage for two more quarters, and 40% of the minimum wage for one more quarter. After one year, an unemployed is eligible only for a welfare payment, which is related to the level of the state minimum pension.⁵ Using our three quarter average unemployment spell estimate, we get a replacement rate of $b_u/\bar{w} = 0.427$.

The vacancy rate is difficult to find data for, since firms only report a fraction of their vacancies to the state authority. Thus we follow Christoffel et. al. (2006) and choose $\bar{q} = 2/3$, which implies a vacancy rate of about 11%. The parameters κ , σ_m and Ψ are calculated from the steady state conditions.

5 Bayesian Estimation

First, it is worth noting that the estimation is still preliminary. The estimation of the DSGE model used Hungarian quarterly data of thirteen macroeconomic variables: real consumption, real investments, real exports, real imports, real government consumption, real wages, employment, capital stock, CPI inflation rate, nominal interest rate, import and export prices denominated in foreign currency and the preannounced rate of the nominal-exchange-rate crawl.

month, between 2007/08/20-2007/09/20, so it may not be representative of the average job finding rate. We are hoping to get a time series in the near future.

⁵The calculation is quite complicated, but the basic idea is to bring the person's income to 90% of the minimum pension. We use this number in our calculations.

Estimation is based on a quarterly data set presented in Benk et al. (2006) and Jakab and Világi (2007). The estimation sample covers the period of 1995:2-2007:2.

We applied a likelihood-based Bayesian method described in An and Schorfheide (2005). After setting up a rational expectations solution of the model, we constructed the likelihood function using a Kalman-filter. Then, this likelihood function is combined with prior distributions and this gives the posterior density function of parameters. Finally, we ran a random-walk Metropolis-Hastings (MH) algorithm to generate the posterior distribution.

In our sample there is one obvious structural break: the change in monetary policy regime in 2001. Monetary policy switched from an exchange rate targeting (the crawling-peg) and inflation targeting regime was introduced. This change was captured by estimating different policy rules in the two subperiods. Our estimation procedure also allowed some other parameters to change between the two regimes. Namely, the parameters of the Phillips curves, risk premium shock and the labor supply shock are time varying. The handling of the two regimes perfectly matches the method of Jakab and Világi (2007).

5.1 Specifying prior distributions

Prior distributions for parameters of non-observed exogenous shocks are displayed in *Table 2*. All the standard deviations of the shocks are assumed to be distributed as an inverted Gamma distribution with a degree of freedom equal to 2. Prior distributions of autoregressive parameters are assumed to follow Beta distributions with mean of 0.8 and standard error of 0.1. The exceptions are the employment shock, the price markup, the monetary policy rule and the capital measurement error. They were assumed to follow white noise processes.

Prior distributions for the rest of estimated parameters are shown in *Table 3*. Calvo and indexation parameters of consumer and export price setting and the indexation of nominal wages were set to be equal to a Beta distribution with means close to that found by Jakab and Világi (2007).

The choice of prior for the parameter of interest rate smoothing ζ_i is different from the literature. We imposed a relatively uninformative Uniform prior distribution on it. Again, the

mean values for the consumption preference parameter ϑ and consumption habits h were set close to that of Jakab and Világi (2007). The adjustment cost parameter of nominal wage setting was again a very problematic parameter: we used a prior of an Inverted Gamma distribution with a mean of 1. This choice gave us flexibility as the distribution guarantees a positive value with a relatively wide domain in the parameter space.

5.2 Estimation results

Table 2 and *3* summarizes our estimation results. One can observe that the standard error of the labor supply shock in both monetary regimes turned out to be high compared to other shocks of the model. This is partly intuitive, in Hungary labor supply and activity movements were rather erratic during the transformation (in the first subsample) and after 2001, government policies (e.g. minimum wage hikes) and large shifts from inactivity to activity occurred. On the other hand, the high volatility of the shocks might also indicate the model cannot be well identified with a limited number of observations on labor market (only employment information is used). An interesting feature is that the autoregressive coefficient of the productivity shock was estimated to be much lower than usually found in other DSGE models.

As far as the structural parameters of the model are concerned, the results are plausible for certain cases. The Calvo price parameters in the domestic sector turned out to be close to the ones usually found in the literature. We found less role for price rigidities in the IT-regime than in the crawling peg. Moreover, domestic price indexation also turned out to be much lower in the IT than in the crawling peg. This reassures the results found by Jakab and Világi (2007). Export prices in the IT regime are estimated to be less rigid than domestic prices. In contrast to Jakab and Világi (2007) we found a high parameter for export price rigidity in the exchange rate targeting (crawling peg) regime. Similarly to Jakab and Világi (2007) indexation of export prices are less relevant than for domestic prices. The price elasticity of export, the export smoothing parameter, the parameters in the monetary reaction function were estimated to be close to the benchmark model of Jakab and Világi (2007).

As far as nominal wage rigidities are concerned, our results point to some but not very large

extent of nominal wage rigidities. Interestingly, the adjustment cost of nominal wage change in the IT regime is estimated to be lower than in the crawling peg. This is in contrast to our prior belief, that during the disinflation wage rigidities should have increased as agents might have not perfectly foreseen the lower inflationary environment. One possible explanation for this is that the presence of adaptive learning mechanism in pricing might already capture this '*credibility*' or '*learning*' effect. Finally, the estimation of the indexation in wages was not yet successful, posterior mode and mean were very close to our priors.

Table 2 Estimated parameters of exogenous shocks

		Prior distribution			Estimated posterior		
		Type	Mean	Stand. err.	Mode	Mean	90% prob. int.
Standard errors							
productivity	σ_A	I.Gam.	0.5	2*	2.098	2.211	[1.85, 2.67]
export demand	σ_x	I.Gam.	0.5	2*	2.407	2.370	[2.00, 2.84]
cons. pref.	σ_c	I.Gam.	0.5	2*	1.340	1.437	[1.00, 1.99]
cons. price markup	σ_p	I.Gam.	0.5	2*	0.372	0.408	[0.34, 0.49]
export price markup	σ_{px}	I.Gam.	0.5	2*	1.665	1.824	[1.39, 2.35]
labor supply, crawl	σ_w^{cr}	I.Gam.	0.5	2*	20.713	25.002	[18.08, 33.36]
labor supply, IT	σ_w^{it}	I.Gam.	0.5	2*	16.356	18.475	[13.91, 24.37]
investments	σ_I	I.Gam.	0.5	2*	0.975	1.012	[0.78, 1.26]
Equity premium	σ_Q	I.Gam.	0.5	2*	0.166	0.353	[0.10, 0.77]
policy rule, crawl	σ_r^{cr}	I.Gam.	0.5	2*	0.574	0.605	[0.48, 0.77]
policy rule, IT	σ_r^{it}	I.Gam.	0.5	2*	0.231	0.246	[0.19, 0.32]
risk premium, crawl	σ_{pr}^{cr}	I.Gam.	0.5	2*	0.197	0.287	[0.12, 0.54]
risk premium, IT	σ_{pr}^{it}	I.Gam.	0.5	2*	0.649	0.827	[0.52, 1.24]
employment	σ_n	I.Gam.	0.5	2*	5.377	5.609	[4.62, 6.86]
Autoregressive coefficients							
productivity	ρ_A	Beta	0.8	0.1	0.657	0.639	[0.54, 0.72]
export demand	ρ_x	Beta	0.8	0.1	0.675	0.658	[0.54, 0.76]
cons. pref.	ρ_c	Beta	0.8	0.1	0.925	0.879	[0.75, 0.96]
labor supply, crawl	ρ_w^{cr}	Beta	0.5	0.2	0.712	0.687	[0.51, 0.85]
labor supply, IT	ρ_w^{it}	Beta	0.5	0.2	0.955	0.863	[0.69, 0.97]
export markup	ρ_x	Beta	0.5	0.2	0.156	0.202	[0.06, 0.40]
investments	ρ_I	Beta	0.8	0.1	0.498	0.485	[0.33, 0.64]
risk premium, crawl	ρ_{pr}^{cr}	Beta	0.8	0.1	0.904	0.863	[0.75, 0.95]
risk premium, IT	ρ_{pr}^{it}	Beta	0.8	0.1	0.808	0.761	[0.64, 0.86]

* For the Inverted Gamma function the degrees of freedom are indicated.

Table 3 Estimated parameters

	Prior distribution				Estimated posterior		
	Type	Mean	Stand. err.	Mode	Mean	90% prob. int.	
Utility function parameters							
consumption	ϑ	Norm.	2.00	0.40	1.647	1.607	[1.02, 2.22]
habit	h	Beta	0.60	0.15	0.507	0.550	[0.41, 0.69]
Price and wage setting param.							
ind. cons. prices	ϑ_p^{cr}	Beta	0.50	0.20	0.809	0.782	[0.61, 0.93]
ind. cons. prices	ϑ_p^{it}	Beta	0.50	0.20	0.365	0.404	[0.19, 0.63]
ind. exp. prices	ϑ_x^{cr}	Beta	0.50	0.20	0.190	0.238	[0.08, 0.45]
ind. exp. prices	ϑ_x^{it}	Beta	0.50	0.20	0.198	0.304	[0.08, 0.64]
ind. wages	ϑ_w^{cr}	Beta	0.50	0.20	0.563	0.514	[0.18, 0.84]
ind. wages	ϑ_w^{it}	Beta	0.50	0.20	0.507	0.473	[0.16, 0.81]
Calvo cons. prices, crawl	γ_p^{cr}	Beta	0.80	0.20	0.943	0.935	[0.91, 0.96]
Calvo cons. prices, IT	γ_p^{it}	Beta	0.80	0.20	0.862	0.863	[0.82, 0.91]
Calvo exp. prices, crawl	γ_x^{cr}	Beta	0.80	0.20	0.990	0.919	[0.81, 0.98]
Calvo exp. prices, IT	γ_x^{it}	Beta	0.80	0.20	0.653	0.731	[0.56, 0.90]
Adjustment cost wages, crawl	γ_w^{cr}	I.Gam.	1.00	2*	0.554	1.330	[0.34, 2.95]
Adjustment cost wages, IT	γ_w^{it}	I.Gam.	1.00	2*	0.477	0.950	[0.30, 2.02]
Other parameters							
exp. elasticity	η	Beta	0.50	0.1	0.486	0.465	[0.35, 0.59]
exp. smooth.	h_x	Beta	0.50	0.15	0.521	0.447	[0.30, 0.59]
ir. smooth.	ζ_i	U(0,1)	0.50	0.29	0.751	0.751	[0.67, 0.82]
policy rule	ζ_π	Norm.	1.50	0.16	1.404	1.428	[1.19, 1.67]

* For the Inverted Gamma function the degrees of freedom are indicated.

6 Results

6.1 Impulse response analysis

We calculated impulse response functions of the calibrated model by allowing for one-period, 1 percentage point shocks to aggregate productivity, labor supply and export demand. The

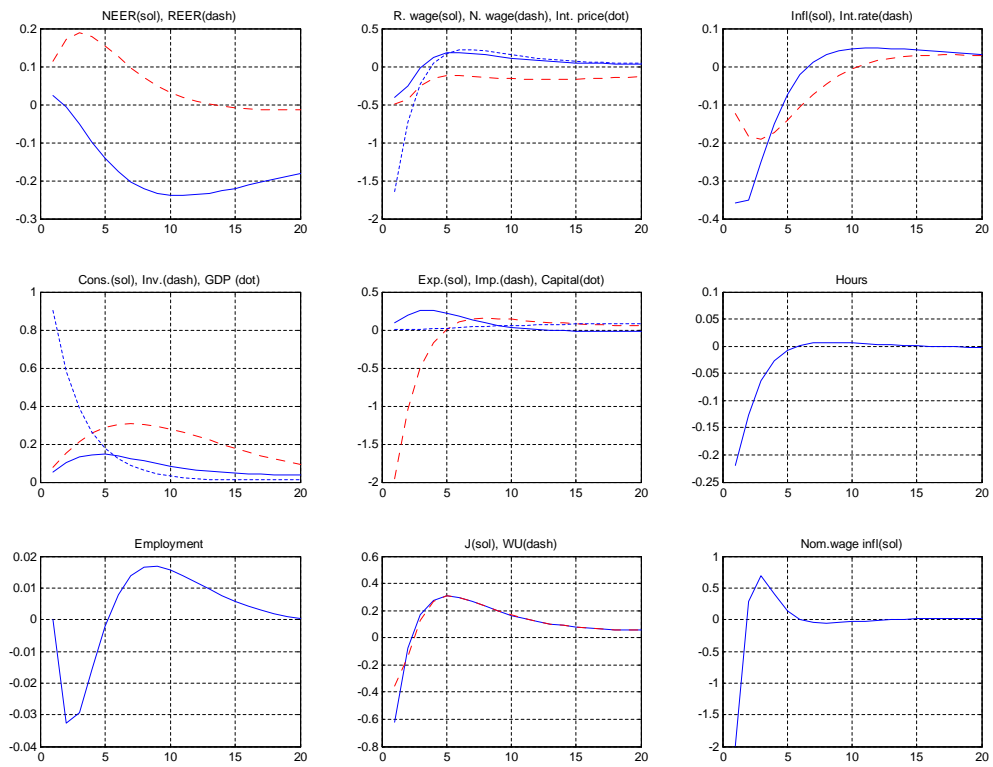


Figure 4: Productivity shock

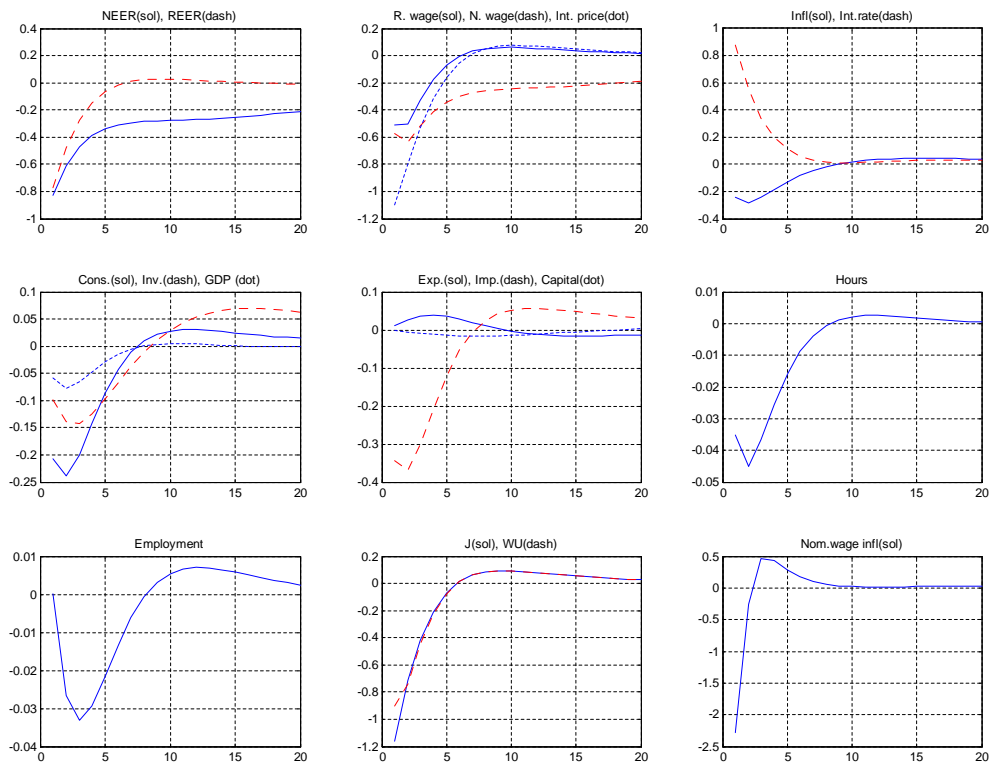


Figure 5: Monetary policy shock

monetary policy shock was set such that the initial impact on nominal interest rate was one-quarter of a percent quarterly (annually 1 percent). The domestic price markup (cost push) shock was calibrated to result in a 0.25 percentage point increase in quarterly consumer price inflation on impact. The risk premium shock was performed so as to arrive at a 1 percent initial depreciation of the nominal exchange rate.

Our model qualitatively reproduces other DSGE models and the one presented by Jakab and Világi (2007). There are, however, some significant differences. Hours typically respond less. Consumption responses are driven by the Euler-condition and all consumers are fully forward looking and do not face financial or liquidity constraints. Therefore, consumption is usually more sensitive to shocks than in the model with non-optimizers such as in the model of Jakab and Világi (2007). Impulse responses are very similar to that in Jakab and Világi (2007) for almost all variables, except for labor market variables (hours, employment and wages). The presence of search-and-matching creates a real friction and thus, there is less limited impact of labor market variables on the other variables of the model. In other words, under search-and-matching frictions the need for nominal wage rigidities is less pronounced to explain movements of inflation and real variables.

Although the estimated nominal wage adjustment cost is small, firms still have an incentive to avoid large changes. Therefore, the responses of nominal wages are smoother than compared to those of the intermediate goods price (p^d). On the other hand, nominal wage inflation usually reacts more heavily than consumer price inflation, thus real wages and nominal wages move very similarly. The exception is the domestic price markup shock, when nominal and real wages have different trajectories. The model thus describes an economy with a rather limited role for nominal wage rigidities.

The fact that the price of the domestic intermediate changes more aggressively than real wages can be explained by the perfect competition assumption of their market. At the same time, the bargaining in the labour market makes the adjustment through three channels, through real wages, hours and employment. Vacancies and hours are usually more sensitive to shocks than unemployment, as firms can more easily adjust by their labor demand. The exceptions are

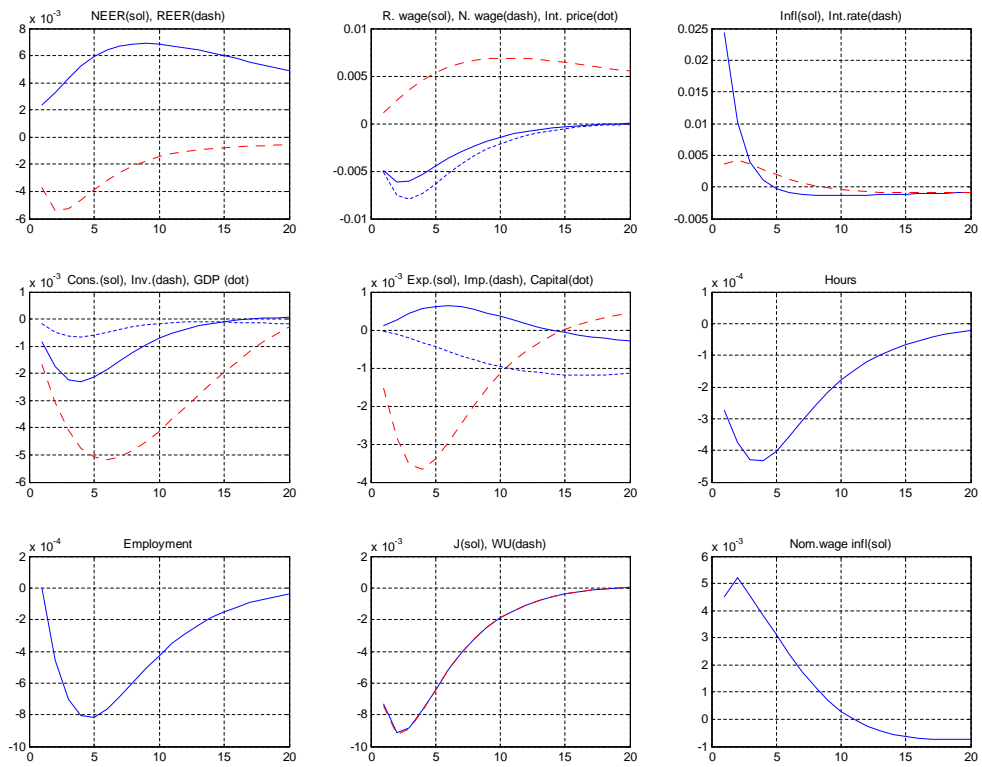


Figure 6: Domestic cost-push shock

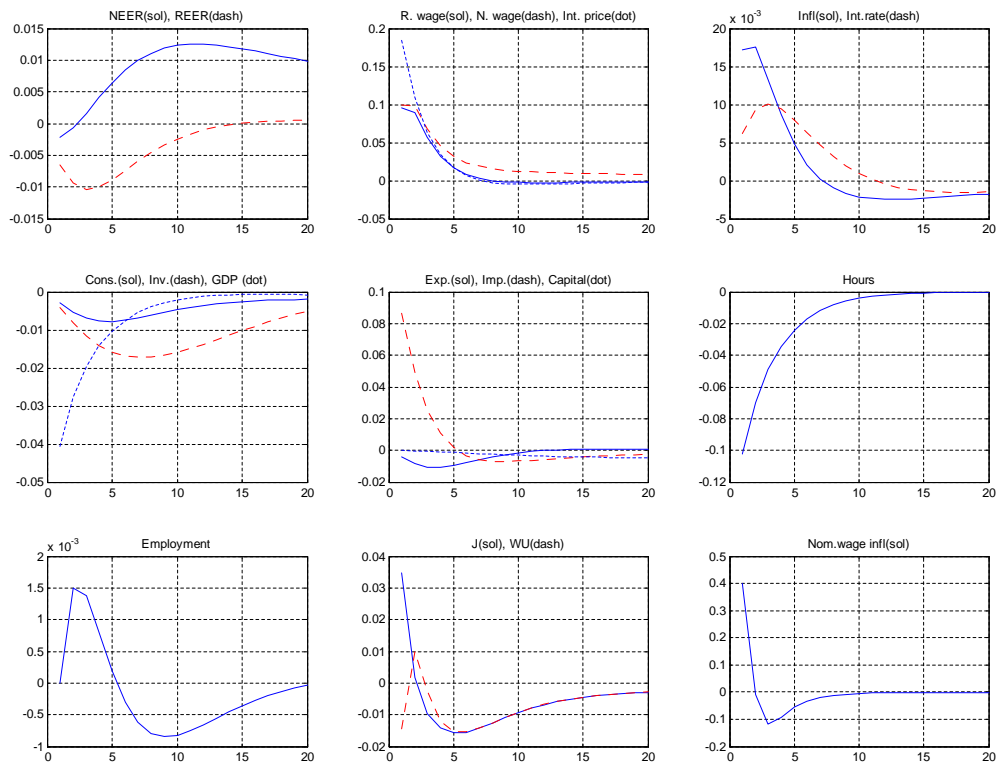


Figure 7: Labor supply shock

the monetary policy and domestic cost-push shocks, for which hours and employment react at almost the same magnitude.

The model replicates a drop in hours after a positive *productivity shock*, which is consistent with the finding of Jakab and Világi (2007) and with the relatively high price stickiness. As prices changing at a lesser extent than nominal wages, a substitution from labor to capital arises. Employment only slightly changes in the case of a productivity shock. Interestingly, real wages decrease on the impact, which can be the result of the strong drop in value of jobs to firms. On the longer run, however, real wages increase and thus consumption increases also in the short run due to the forward-looking behavior of consumers. The price of domestic intermediates drops heavily and this creates a relative price effect for imports (see *Figure 1*).

Under the *monetary policy shock* the responses are generally standard, though the reactions of real variables are generally weaker than in other DSGE models. This, however, conforms to the one observed by Jakab and Világi (2007). Again, nominal wages are quite sensitive. As mentioned employment and hours react similarly. This can be due to the fact that after a monetary tightening consumption also drops leading to a relative decrease in the value of jobs to workers compared to the drop in value of jobs to firms. (see *Figure 2*).

Figure 3 shows the effects of a *domestic cost push shock*. After this shock, prices are higher and output drops. Both hours and employment drop, but again employment is affected more significantly than in the cases of other than monetary policy shocks. Similarly to a negative monetary policy shock, employers' are in a slightly better bargaining position as markups on the goods market increases. Increasing domestic prices also imply a relatively marked decrease in the value of jobs to workers, which induces a decrease in labor supply, as well.

A *labor supply shock* improves the relative bargaining position of employers and value of jobs to firms increases on impact, while the value of jobs to workers decreases. This generates an increase in both real and nominal wages. However, firms demand for hours drops, and thus there is only a slight increase at the extensive margin and employment increases only at a very limited pace. Though under both shocks consumer price inflation is higher, there is a substantial difference compared to the domestic price markup shock with respect to real wages.

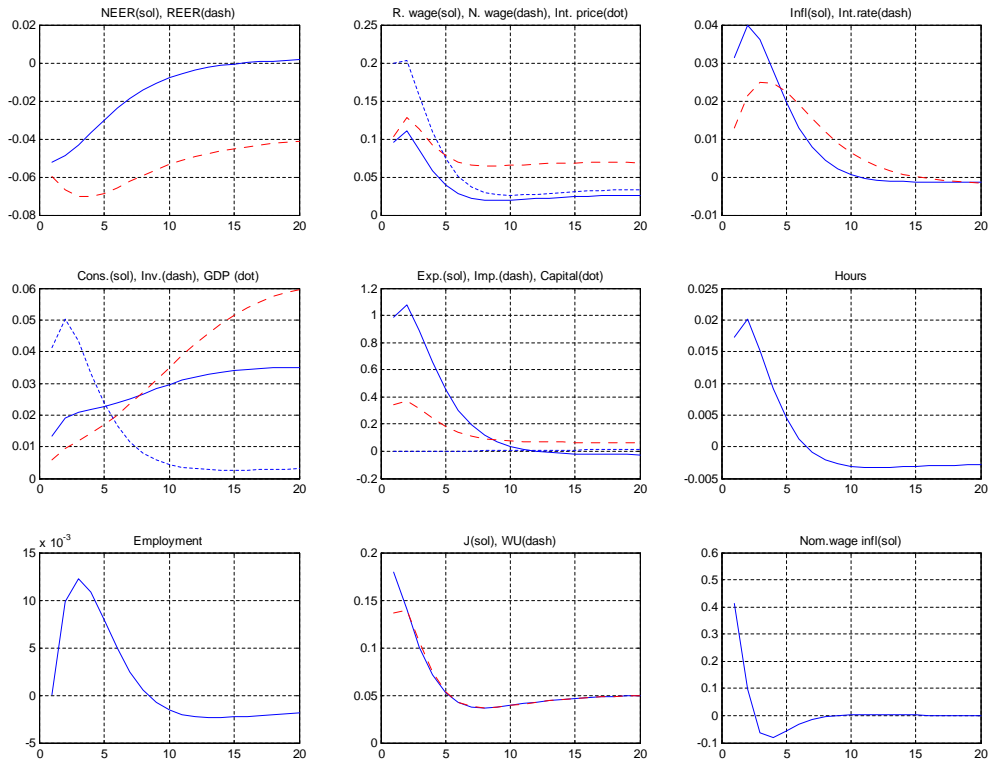


Figure 8: Export demand shock

In both cases nominal wages increase, but real wages have very different path. This is due to the different evolution of relative bargaining powers of employees and employers. (see *Figure 4*).

The open economy aspects of our model can be captured by an export demand shock (see *Figure 5*) and a risk premium shock (*Figure 6*). There is a substantial reaction of hours and employment under an increase in demand for exports. Higher exports pushes up wages which is mostly the result of the higher value of jobs to firms. In the model of Jakab and Világi (2007) with monopolistic competition in the labor market the reaction of real wages is much less pronounced. In the case of a *risk premium shock* our model predicts an increase, then a drop in real wages which is again in contrast to the model with monopolistically competitive labor market which predicts an increase. This can be explained by the similar reactions of value of jobs to firms and employees. If nominal exchange rate depreciates, consumption and

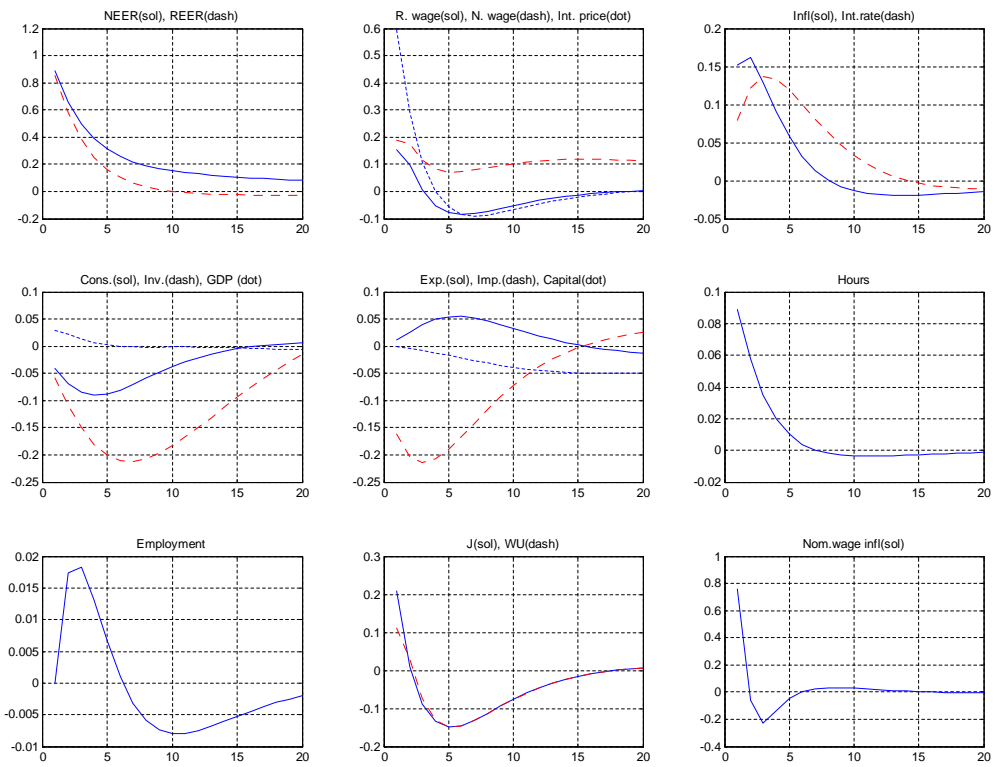


Figure 9: Risk premium shock

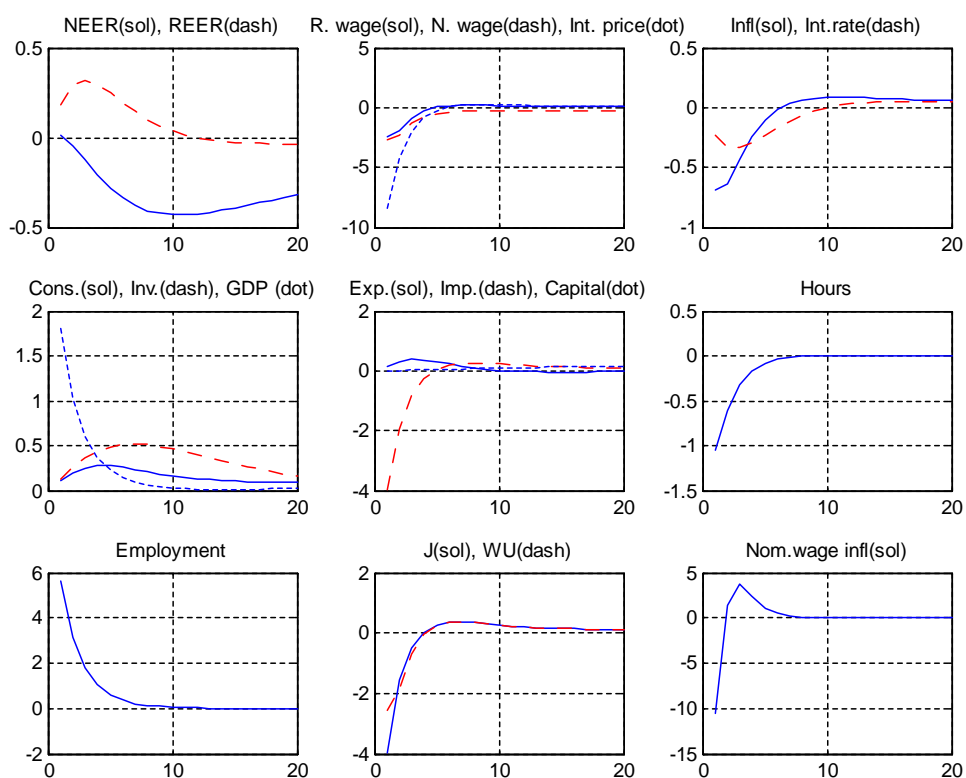


Figure 10: Activity shock

investments drop due to higher interest rates and this compensates for the increase in exports. Thus, output and GDP only slightly increase and the value of jobs to firms starts to drop. We also found that initially hours rather than employment responds, but later employment starts to react, as well.

Finally, we also plot the impulse responses to an activity shock. As we show below, activity shocks are important determinants of not only labor market outcomes, but also other variables. In contrast to the previous figures, the size of the shock is the actual, estimated value. We can see that most variables respond strongly. The nominal exchange rate depreciates, and the real exchange rate appreciates. The nominal wage falls by close to 10%, while inflation also declines by more than 0.5%. Hours fall by 1 %, and imports decline by 4%. As more people work (employment rises by 6%), GDP and consumption rise. Interestingly, imports fall as there are more domestic intermediates being produced.

	Preference	Investment	Technology	Labor supply	UIP	Export demand	Shocks						
							Home markup	Export markup	Monetary policy	Employment	Capital error	Import price	Government spending
Net foreign assets	6.67	3.4	17.25	6.32	8.95	27.75	1.69	4.5	0.26	12.23	1.09	6.7	3.19
Consumption	16.91	1.75	17.81	15.78	8.56	13.14	3.32	2.53	1.74	11.19	2.21	3.19	1.86
Inflation differential	0.21	1.01	12.64	3.42	6	0.17	62.82	0.07	1.38	8.73	0.03	3.1	0.42
Investment	0.5	80.44	3.03	5.14	3.5	0.52	1.65	0.14	0.08	1.64	2.37	0.87	0.12
Capital stock	1.59	60.7	5.79	8.34	3.5	3.02	1.51	0.62	0.04	3.43	9.89	1.1	0.47
Hours	0.19	0.24	2.15	86.03	0.92	0.12	0.05	0.05	0.02	9.45	0.03	0.36	0.42
Employment	0.09	0.11	0.06	0.03	0.05	0.04	0.07	0.01	0.01	99.48	0.02	0.02	0.01
Exchange rate	1.21	4.27	11.08	8.71	41.67	0.21	17.46	0.24	5.01	6.67	0.66	2.44	0.37
Inflation	0.41	2.04	14.18	5.47	7.52	0.24	54.35	0.09	1.9	9.32	0.13	3.94	0.42
Nominal wage inflation	0.26	1.08	9.7	24.44	3.18	0.45	0.51	0.08	2	54.3	0.02	1.87	2.11
Export price	0.59	2.82	10.44	5.13	1.88	2.31	0.3	64.13	0.05	4.63	0.38	7	0.32
Job filling rate	7.45	9.95	8.96	3.51	6.01	2.88	6.16	1.21	0.72	48.38	1.15	2.57	1.04
Interest rate	0.97	4.82	15.01	10.13	20	0.39	12.64	0.16	21.34	8.47	0.38	5.41	0.28
Real exchange rate	0.89	3.9	4.95	7.1	59.87	4.15	6.39	0.44	3.81	2.77	0.64	4.77	0.32
Job finding rate	7.45	9.95	8.96	3.51	6.01	2.88	6.16	1.21	0.72	48.38	1.15	2.57	1.04
Unemployment	0.09	0.11	0.06	0.03	0.05	0.04	0.07	0.01	0.01	99.48	0.02	0.02	0.01
Vacancies	0.29	0.44	0.54	0.18	0.35	0.1	0.25	0.05	0.04	97.52	0.03	0.14	0.06
Real wage	0.81	1.96	7.42	39.95	2.82	2.02	5.24	0.34	1.79	34.84	0.11	1.5	1.2
Exports	0.28	1.36	4.47	2.36	0.89	59.4	0.14	25.63	0.02	1.95	0.18	3.17	0.14
Imports	2.07	4.42	37	6.17	4.01	6.51	0.83	1.02	0.34	28.7	0.21	1.97	6.73

Table 2: Variance decomposition

6.2 Variance decomposition

We investigated how much of the variance of the endogenous variables individual shocks explain. Table 2 contains a variance decomposition based on the estimated parameters of the model. As expected, the technology shock is important for many variables. Markup shocks are most important for price variables, but the domestic markup shock also has a nontrivial influence on some labor market variables: the real wage, the job filling rate and the job finding rate. The external shocks, and the interest premium (or UIP) shock in particular, matter, also (to some extent) for the labor market outcomes. The latter two are specific to the open economy framework, and show that in our baseline Hungarian calibration the openness is quite important to model.

The investment shock is important for some variables: notably, again, for the job finding and job filling rates. The monetary policy shock, on the other hand, does not seem to interact much with the real economy, although it has some impact on the exchange rate. Government spending also seems fairly irrelevant. This does not mean, however, that the government itself is unimportant. It strongly influences the labor market through its policies, as the importance of the activity shock implies.

Indeed, exogenous fluctuations in activity strongly dominate the labor market. Essentially all the movements in employment, unemployment, and vacancy creation are due to this shock;

while half the variance in the job finding rate, job filling rate and nominal wage inflation is explained by activity shifts. But activity is important also for variables outside the labor market. Roughly 10% of inflation variation, 11% of consumption, and 29% of imports are due to this shock. The labor supply shock is also important, notably for consumption, capital, the exchange rate, and (not surprisingly) the real wage and hours.

The main conclusion from this section, therefore, is that while the strong shocks buffeting the labor market dominated other influences, there was a strong feedback from the labor market towards other real and nominal variables. This indicates that the careful modelling of the labor market is important not so much for its own sake, but to understand its role and impact in the broader economy. Our findings suggest that there is probably a large return in incorporating the activity decision into the model, since activity movements are extremely important to understand business cycle facts in Hungary.

7 Conclusion

This paper has developed a small open economy DSGE model with search and matching frictions. Our preliminary results indicate that while most parameter values are sensibly estimated, either wage rigidity (real or nominal) is not present in Hungary or it is difficult to estimate its extent. Since inflation dynamics are similar to what was found in Jakab and Világi (2007), our conjecture is that the intrinsic real rigidities captured by the search-and-matching framework are sufficient to explain the sluggishness of inflation without a need for extra wage rigidity.

Our second result is that activity shocks in Hungary have been important not only in explaining labor market movements, but also more broadly. While in our estimation labor market stocks are autonomously determined by labor market originated shocks, other variables such as the job finding rate, the job filling rate and the real wage react to shocks outside of the labor market. Thus there is an important interaction among labor market and non-labor market variables, with a few shocks playing particularly important roles. Finally, external shocks have a moderate influence on the labor market, but labor market shocks influence external developments

significantly.

The model we described, we believe, is an important step in exploring the role of the labor market in Hungarian macroeconomic developments. There is much that remains to be done. We face severe estimation difficulties, which is keeping us from estimating a model version with the (perhaps more realistic) right-to-manage bargaining assumption. We would also like to experiment with different calibrations, especially on the labor market. This is important, since labor market data is not as reliable as we'd like, and we have to infer key parameters from indirect inference. Thus our next task is to check the robustness of our results in as many directions as we can.

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A Log-linearization

1. Euler equation (λ)

$$\hat{R}_t = \lambda_t - E_t \hat{\lambda}_{t+1} + E_t \hat{\pi}_{t+1}$$

2. Marginal utility of income (c)

$$\hat{\lambda}_t = -\frac{\vartheta}{1-h} (\hat{c}_t - h\hat{c}_{t-1}) + \eta_t^c$$

3. Capital-bond trade-off (Q)

$$\hat{Q}_t = \beta(1-\delta)E_t \hat{Q}_{t+1} + [1-\beta(1-\delta)]E_t \hat{r}_{t+1}^k + E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t + \eta_t^q$$

4. Investment (i)

$$\hat{i}_t = \frac{1}{1+\beta} \hat{i}_{t-1} + \frac{\beta}{1+\beta} E_t \hat{i}_{t+1} + \frac{1}{(1+\beta)\phi''(1)} \hat{Q}_t + \frac{\beta E_t \eta_{t+1}^I - \eta_t^I}{1+\beta}$$

5. Capital accumulation (k)

$$\hat{k}_t = (1-\delta)\hat{k}_{t-1} + \delta\hat{i}_t + \eta_t^k$$

6. Marginal cost in domestic sector (mc_d)

$$\widehat{mc}_{d,t} = \alpha_d \hat{r}_t^k + (1 - \alpha_d) \alpha_{zd} (\hat{e}_t - \hat{p}_t + \hat{p}_t^m) + (1 - \alpha_d) (1 - \alpha_{zd}) \hat{p}_t^d - a_{d,t}$$

7. Marginal cost in export sector (mc_x)

$$\widehat{mc}_{x,t} = \alpha_x \hat{r}_t^k + (1 - \alpha_x) \alpha_{zx} (\hat{e}_t - \hat{p}_t + \hat{p}_t^m) + (1 - \alpha_x) (1 - \alpha_{zx}) \hat{p}_t^d - a_{x,t}$$

8. Capital demand in domestic sector (k_d)

$$\hat{k}_{d,t} = \hat{y}_{d,t} + \widehat{mc}_{d,t} - \hat{r}_t^k$$

9. Capital demand in export sector (k_x)

$$\hat{k}_{x,t} = \hat{y}_{x,t} + \widehat{mc}_{x,t} - \hat{r}_t^k$$

10. Imported intermediate demand in domestic (y_d^m)

$$\hat{y}_{d,t}^m = \hat{y}_{d,t} + \widehat{mc}_{d,t} - \hat{e}_t + \hat{p}_t - \hat{p}_t^m$$

11. Imported intermediate demand in export (y_x^m)

$$\hat{y}_{x,t}^m = \hat{y}_{x,t} + \widehat{mc}_{x,t} - \hat{e}_t + \hat{p}_t - \hat{p}_t^m$$

12. Domestic intermediate demand in domestic (y_d^d)

$$\hat{y}_{d,t}^d = \hat{y}_{d,t} + \widehat{mc}_{d,t} - \hat{p}_t^d$$

13. Domestic intermediate demand in export (y_x^d)

$$\hat{y}_{x,t}^d = \hat{y}_{x,t} + \widehat{mc}_{x,t} - \hat{p}_t^d$$

14. Domestic Phillips curve (π)

$$d\hat{\pi}_t - \vartheta_p d\hat{\pi}_{t-1} = \beta (E_t d\hat{\pi}_{t+1} - \vartheta_p d\hat{\pi}_t) + \frac{(1-\gamma)(1-\beta\gamma)}{\gamma} (\widehat{mc}_{d,t} + \hat{\mu}_{h,t})$$

15. Export Phillips curve (π^x)

$$\hat{\pi}_t^x - \vartheta_x \hat{\pi}_{t-1}^x = \beta (E_t \hat{\pi}_{t+1}^x - \vartheta_x \hat{\pi}_t^x) + \frac{(1-\gamma_x)(1-\beta\gamma_x)}{\gamma_x} (\widehat{mc}_{x,t} - \hat{p}_t^x - \hat{e}_t + \hat{p}_t + \hat{\mu}_{x,t})$$

16. Job filling rate (v)

$$\hat{q}_t = \sigma (\hat{u}_t - \hat{v}_t)$$

17. Job finding rate (s)

$$\hat{s}_t = (1 - \sigma) (\hat{v}_t - \hat{u}_t)$$

18. Job flows (n)

$$\hat{n}_t = (1 - \rho) \hat{n}_{t-1} + \rho \hat{m}_t + \eta_t^n$$

19. Unemployment (u)

$$\hat{u}_t = -\frac{\bar{n}}{\bar{u}} \hat{n}_t$$

20. Value of a job to firm (J)

$$\bar{J}\hat{J}_t = \bar{p}_d (\hat{p}_t^d + \hat{l}_t) - \bar{w} (\hat{w}_t + \hat{l}_t) - \frac{(1-\rho)\kappa}{\bar{\lambda}\bar{q}} (\hat{\lambda}_t + \hat{q}_t)$$

21. Value of a job to worker (WU)

$$\begin{aligned} \overline{WU} \cdot \widehat{WU}_t &= \bar{w} (\hat{w}_t + \hat{l}_t) - \frac{\bar{p}^d}{1 + \phi} \left[(1 + \phi) \hat{l}_t - \hat{\lambda}_t + \eta_t^l \right] \\ &\quad + \beta (1 - \rho - \bar{s}) \overline{WU} \left[E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t - \frac{\bar{s}}{1 - \rho - \bar{s}} \hat{s}_t + \widehat{WU}_{t+1} \right] \end{aligned}$$

22. Wage equation (π^w)

$$\hat{\pi}_t^w - \vartheta_w \hat{\pi}_{t-1}^w = \beta (1 - \rho) E_t (\hat{\pi}_{t+1}^w - \vartheta_w \hat{\pi}_t^w) + \frac{\bar{p}^d}{\gamma_w \bar{w} (\bar{p}^d - \bar{w})} (\hat{p}_t^d + \hat{\lambda}_t - \phi \hat{l}_t - \eta_t^l)$$

23. Real wage (w)

$$\hat{w}_t - \hat{w}_{t-1} = \hat{\pi}_t^w - \hat{\pi}_t$$

24. Hours (l)

$$\hat{j}_t - \widehat{WU}_t = \frac{\bar{p}^d}{\bar{p}^d - \bar{w}} (\hat{p}_t^d - \phi \hat{l}_t + \hat{\lambda}_t - \eta_t^l)$$

25. Job creation (q)

$$\begin{aligned} \hat{q}_t &= \beta (1 - \rho) E_t \hat{q}_{t+1} - [1 - \beta (1 - \rho)] E_t \hat{\lambda}_{t+1} \\ &\quad + \frac{\beta \bar{\lambda} \bar{q}}{\kappa} \left[\bar{w} (E_t \hat{w}_{t+1} + E_t \hat{l}_{t+1}) - \bar{p}^d (E_t \hat{p}_{t+1}^d + E_t \hat{l}_{t+1}) \right] \end{aligned}$$

26. Market for intermediates (p^d)

$$\hat{n}_t + \hat{l}_t = \frac{\bar{y}_d^d}{\bar{y}^d} \hat{y}_{d,t}^d + \frac{\bar{y}_x^d}{\bar{y}^d} \hat{y}_{x,t}^d$$

27. Market for domestic sector

$$y_{d,t} = \frac{\bar{c}}{\bar{y}_d} \hat{c}_t + \frac{\bar{l}}{\bar{y}_d} \hat{l}_t + \frac{\bar{g}}{\bar{y}_d} \hat{g}_t$$

28. Current account (b)

$$\beta db_t - db_{t-1} = \bar{p}^x \bar{y}_x (\hat{p}_t^x + \hat{y}_{x,t}) - \bar{y}^m \hat{y}_t^m$$

29. Export demand (x)

$$\hat{y}_{x,t} = h_x \hat{y}_{x,t-1} - \theta_x \hat{p}_t^x + \eta_t^x$$

30. Taylor rule (R)

$$\hat{R}_t = \xi_r \hat{R}_{t-1} + (1 - \xi_r) \xi_\pi E_t \hat{\pi}_{t+1} + \eta_t^m$$

31. UIP (e)

$$\hat{R}_t = E_t \hat{e}_{t+1} - \hat{e}_t - \beta \psi db_t + \eta_t^{uip}$$

32. Export price (P^x)

$$\hat{\pi}_t^x = \hat{p}_t^x - \hat{p}_{t-1}^x$$