A DSGE Model for the Slovenian Economy: Model Estimates and Application[*]

ANDREJ KUŠTRIN[1]

ABSTRACT: *The paper presents the estimation of a dynamic stochastic general equilibrium (DSGE) model for the Slovenian economy and its applications. The model, which is built in the tradition of New Keynesian models, closely follows the structure of the model developed by Adolfson et al. (2007) and Masten (2010). We estimate the model using a Bayesian method on quarterly Slovenian macroeconomic data covering the period 1995-2014. Beyond evaluating the properties of the estimated model, we discuss the role of various shocks in explaining macroeconomic fluctuations in the Slovenian economy to illustrate the model's potential in structural business cycle analysis.*

INTORDUCTION

New-Keynesian dynamic stochastic general equilibrium (DSGE) models have recently become a standard tool for macroeconomic analysis. The key feature of this class of models is that they are derived from the microeconomic foundations meaning that they assume optimizing agents which usually form rational expectations and maximize their objective functions subject to their respective constraints in the presence of imperfect competition and nominal rigidities.[2] In recent years there have been many theoretical and empirical contributions developing and estimating DSGE models. The most influential papers in this area include Clarida et al. (1999, 2001), Beningo & Beningo (2003), Galí & Monacelli (2005), Christiano et al. (2005), Smets & Wouters (2003, 2007), Adolfson et al. (2007) and many others.

---

[1] University of Ljubljana, Faculty of Economics, Young Researcher, Ljubljana, Slovenia, e-mail: andrej.kustrin@ef.uni-lj.si.

[2] For further information on the New-Keynesian models, see Galí (2008) and Woodford (2003).

Although the literature on the estimation of DSGE models and the subsequent use of these models to study macroeconomic fluctuations in various countries has rapidly expanded in recent years, no attempt has as yet been made to estimate a New-Keynesian DSGE model for Slovenia, at least to the best of our knowledge.[2.1] This paper therefore seeks to fill this gap by presenting an estimated DSGE model for the Slovenian economy.

The model that we use was inspired in the work of Adolfson et al. (2007) and Masten (2010). Masten (2010) extended the baseline model of Adolfson et al. (2007) in two directions, namely by (i) adapting the model to the small open economy case within the euro area and (ii) enriching the fiscal block of the model. We use a Bayesian approach to estimate key model parameters on 15 time series for Slovenia: GDP, consumption, investment, exports, imports, government consumption, real effective exchange rate, real wage, employment, GDP deflator, CPI price index, short-run interest rate, and three foreign variables (that is output, inflation and interest rate), which refer to the first 12 euro area countries.

With this paper we want to contribute to the large literature on estimated DSGE models by applying the Bayesian method to the estimation of the DSGE model for the Slovenian economy and therefore presenting evidence for an additional country on the estimates of the structural parameters, and by identifying the shocks responsible for the recent recession and the key sources of macroeconomic fluctuations in Slovenia.

After the estimation, we first present our estimates of the structural parameters. We then perform several checks of the model's empirical performance. Specifically, we evaluate how well the model fits the data. To do so, we compare the actual data with the one-sided predicted values from the model. Next, we calculate statistics of the data generated by the estimated model and compare them with those based on the actual data. Finally, we look at the smoothed estimates of the shock innovation paths to check whether they look stationary. In the last part of the paper, we apply the estimated DSGE model to analyse the contribution of the structural shocks on business cycle fluctuations in the Slovenian economy. We proceed here in three steps. First, using traditional impulse response analysis, we look at the partial effects of the most important shocks included in the model on key

---

[2.1] Despite their wide use, DSGE models have also certain drawbacks. The most problematic issues which are currently much discussed in the literature are mainly concerned with: (i) unrealistic assumptions (e.g. Ricardian equivalence, rational expectations hypothesis, infinitely-lived households, ...), (ii) unconvincing method of estimation (which is a combination of calibration and Bayesian estimation), (iii) questionable assumption about the structural parameters that are assumed to be invariant to policy changes, (iv) issue related with the use of revised or real-time data when estimating the model, and (v) poor performance during the recent crisis. For more detailed discussion of these issues, see Romer (2016), Blanchard (2016) and the other contributions (see Blanchard (2017) for an extensive list of references). Despite these shortcomings, we decided to use a DSGE framework as we believe that it is flexible enough to be used for our purposes, while other models are more limited in terms of their ability to fully address the research questions under study.

macroeconomic variables. Second, to assess how much of the volatility of the observed variables can be explained by the shocks included in the model, we also produce variance decomposition analysis. Finally, we compute historical decompositions of GDP growth and its main components in terms of various structural shocks of the model to examine the importance of respective shocks in explaining the observed macroeconomic dynamics over the sample period, with particular attention to the recent recessionary periods.

Previewing the results, we find that investment-specific technology shocks mostly accounted for a significant portion of the drop in output growth from 2008 onwards. This result accords with a drop in foreign and domestic orders followed by a decline in investment (mostly at the beginning of the crisis) and the large amount of losses of the corporate sector that accumulated on balance sheets of the banks in the form of non-performing bad loans, further contributing to a contraction of lending activity, which in turn reduced investment and impeded economic activity. Furthermore, consumption preference and export mark-up shocks were another sources that contributed negatively to GDP growth, most likely reflecting the reduction in households' income (in combination with the precautionary saving) and the fall in exports due to the deterioration of external competitiveness, as wages increased faster than productivity before the crisis years, respectively. The results also suggest that fiscal shocks had a stimulating impact during the first stage of the crisis. However, starting from 2010 there was a turnaround in fiscal policy due to austerity measures adopted to consolidate public finances. The slowdown in GDP growth was also accompanied by permanent (unit-root) technology shocks that could be considered as associated with the lack of productivity-enhancing and other structural reforms in the run-up to the crisis. By contrast, the historical decomposition suggests that transitory (stationary) technology shocks were stimulative for GDP growth from 2013 onwards, which may be interpreted as resulting from a temporary greater tendency of the corporate sector to take restructuring measures in response to the crisis to enhance its technology and production efficiency. Finally, our results show that the recovery phase after 2013 is explained in our model mainly by consumption preference shocks, which could be explained by the increased consumer confidence, resolution of banking system problems, as well as by the improvement in the labour market situation.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 presents the estimation methodology and discusses the calibration of the model, the choice of priors and presents the data used in the estimation. Section 4 contains the estimation results and evaluation, which are followed by an analysis of the impulse responses of the various structural shocks and their contribution to the developments in the Slovenian economy in Section 5. Section 6 concludes with a summary of the main findings.

2   THE MODEL

As mentioned in the introduction, to describe the Slovenian economy we use a DSGE model presented in Adolfson et al. (2007) and Masten (2010), which is an extended ver-

sion of basic closed-economy new-Keynesian models, including the benchmark models
of Christiano et al. (2005), Altig et al. (2011), and Smets & Wouters (2003, 2007). The
model economy consists of households, domestic goods producing firms, importing con-
sumption and importing investment firms, exporting firms, a government which conducts
fiscal policy, and an exogenous foreign economy. As it is common in the DSGE literature,
the model incorporates several real and nominal rigidities, such as habit persistence in con-
sumption, variable capacity utilization of capital and investment adjustment costs, as well
as the price and wage stickiness. The stochastic dynamics of the model is driven by sixteen
exogenous structural shocks. The shocks considered are: permanent (unit-root) technol-
ogy, transitory (stationary) technology, investment-specific technology, markup shocks
(domestic, imported consumption, imported investment and export markup shocks), con-
sumption preference and labour supply shocks, asymmetric technology, risk premium, for-
eign VAR shocks (foreign output, inflation and interest rate shocks) and fiscal shocks (rate
of transfers to households and government spending shocks). One feature of the model
worth noting is that it includes a stochastic unit-root technology shock, which implies a
common trend in the real variables of the model. Consequently, the model can be esti-
mated with raw data without any pre-filtering. In the following we summarize the main
features of the model. To this end we follow quite closely the mode of presentation from
Section 2 of Adolfson et al. (2014).[3]

2.1.   Supply side of the economy

2.1.1.   Domestic firms

The domestic firms use labour together with capital to produce intermediate goods Y_i,
which are sold to the final good producer. The production function of the final good firm
is of the Dixit-Stiglitz form:

$$Y_t^d = \left[\int_0^1 \left(Y_{i,t}^d \right)^{\frac{1}{\lambda_t^d}} di \right]^{\lambda_t^d}, \quad \lambda_t^d \geq 1, \tag{1}$$

where $\lambda_{d,t}$ is a stochastic process determining the time-varying markup in the domestic
goods market. The final good producers operate in a perfectly competitive environment,
taking the prices of the intermediate goods $P_{i,t}^d$ and final goods P_t^d as given. The pro-
duction function for each intermediate good firm i which operates under monopolistic
competition is of the Cobb-Douglas type:

$$Y_{i,t} = z_t^{1-\alpha} \epsilon_t K_{i,t}^\alpha H_{i,t}^{1-\alpha} - z_t \phi, \tag{2}$$

where $H_{i,t}$ denotes homogeneous labour input hired by firm i, and $K_{i,t}$ is the amount of
capital services used by firm i, which can differ from capital stock since the model assumes

---

[3]The detailed description of the model (including the first order conditions) is available in Adolfson et al.
(2007).

a variable capital utilization rate. Furthermore, z_t is a permanent (unit-root) technology shock, whereas ϵ_t is a transitory (stationary) technology shock. The term $z_t\phi$ indicates fixed costs, which grow with the technology rate. Fixed costs are set in such a way that profits are zero in steady state. Cost minimization yields the following nominal marginal cost function for intermediate firm i:

$$MC_t^d = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} \left(R_t^k\right)^{\alpha} W_t^{1-\alpha} \frac{1}{z_t^{1-\alpha}} \frac{1}{\epsilon_t}, \tag{3}$$

where R_t^k is the gross nominal rental rate per unit of capital, R_t is the gross nominal interest rate, and W_t is the nominal wage rate per unit of aggregate, homogeneous labour $H_{i,t}$. Besides solving the cost minimization problem, intermediate good firms have to decide on price for their output. The model assumes the Calvo type staggered-price setting. This means that at each period, each firm faces a random probability $(1 - \xi_d)$ that it can reoptimize its price. The reoptimized price is denoted $P_t^{d,opt}$. With probability ξ_d a firm is not allowed to set its prices optimally, and its price is then set according to the following indexation rule (Smets & Wouters, 2003):

$$P_{t+1}^d = \left(\pi_t^d\right)^{\kappa_d} P_t^d,$$

where $\pi_t^d = P_t^d/P_{t-1}^d$ is the (gross) inflation rate and κ_d is an indexation parameter. The optimization problem of a firm setting a new price in period t is the following:

$$\max_{P_t^{d,opt}} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\xi_d)^s \upsilon_{t+s} \left[\begin{array}{c} \left(\pi_t^d \pi_{t+1}^d ... \pi_{t+s-1}^d\right)^{\kappa_d} P_t^{d,opt} Y_{i,t+s}^d \\ -MC_{i,t+s}^d \left(Y_{i,t+s}^d + z_{t+s}\phi\right) \end{array} \right], \tag{4}$$

where $(\beta\xi_d)^s \upsilon_{t+s}$ denotes the stochastic discount factor, which is used to make profits conditional upon utility. β is the discount factor, and υ_t denotes the marginal utility of households' nominal income in period $t + s$, which is exogenous to the intermediate firms.

2.1.2.   *Importing and exporting firms*

The importing sector consists of two types of firms: firms which import consumption goods and firms which import investment goods. There is a continuum of importing firms, indexed by $i \in (0, 1)$. These firms buy a homogeneous good in the world market at price P_t^* and transform it into a differentiated consumption $C_{i,t}^m$ or investment good $I_{i,t}^m$. In addition, there is also a continuum $i \in (0, 1)$ of exporting firms that buy a homogeneous good on the domestic market and transform it into a differentiated exported good which is sold on the foreign market. The marginal cost of importing and exporting firms are P_t^* and P_t, respectively. The aggregate import consumption, import investment and export good is a composite of a continuum of i differentiated imported consumption, imported investment and exported goods, each supplied by a different firm, which follows the CES function:

$$C_t^m = \left[\int_0^1 \left(C_{i,t}^m\right)^{\frac{1}{\lambda_t^{m,c}}} di\right]^{\lambda_t^{m,c}}, \quad I_t^m = \left[\int_0^1 \left(I_{i,t}^m\right)^{\frac{1}{\lambda_t^{m,i}}} di\right]^{\lambda_t^{m,i}},$$

$$X_t = \left[\int_0^1 (X_{i,t})^{\frac{1}{\lambda_t^x}} di \right]^{\lambda_t^x}, \tag{5}$$

where $1 \leq \lambda_t^j < \infty$ for $j = \{mc, mi, x\}$ is the time-varying flexible-price mark-up in the import consumption (mc), import investment (mi) and export (x) sector. The model assumes monopolistic competition among importers and exporters and Calvo-type staggered price setting. The price setting problems are completely analogous to that of the domestic firms in Equation (4). From the optimization problems four specific Phillips curves, determining inflation in the domestic, import consumption, import investment and export sectors, can be derived.

2.2.   Demand side of the economy

2.2.1.   Households

In the model economy there is also a continuum of households $j \in (0, 1)$, which attain utility from consumption and leisure. The households decide on their current level of consumption and their domestic and foreign bond holdings. They also choose the level of capital services provided to the firms, their level of investment and their capital utilization rate. The households can increase their capital stock by investing in additional physical capital, taking one period to come in action, or by directly increasing the utilization rate of the capital at hand. The jth household's utility function is:

$$\mathbb{E}_0^j \sum_{t=0}^\infty \beta^t \left[\zeta_t^c \ln (C_{j,t} - b C_{j,t-1}) - \zeta_t^h A_L \frac{(h_{j,t})^{1+\sigma_L}}{1 + \sigma_L} \right], \tag{6}$$

where $C_{j,t}$ and $h_{j,t}$ denotes levels of real consumption and labour supply of household j, respectively. A_L is a constant representing the weight that the worker attaches to disutility of work. The model also allows for habit formation in consumption by including $b C_{j,t-1}$. ζ_t^c and ζ_t^h are preference shocks, consumption preference shock and labour supply shock, respectively. The aggregate consumption C_t is a CES index of domestic C_t^d and imported C_t^m consumption goods:

$$C_t = \left[(1 - \omega_c)^{1/\eta_c} \left(C_t^d \right)^{(\eta_c - 1)/\eta_c} + \omega_c^{1/\eta_c} \left(C_t^m \right)^{(\eta_c - 1)/\eta_c} \right]^{\eta_c/(\eta_c - 1)}, \tag{7}$$

where ω_c is the share of imported consumption goods in total consumption, and η_c is the elasticity of substitution between domestic and imported consumption goods. The corresponding consumer price index is given by:

$$P_t^c = \left[(1 - \omega_c)^{1/\eta_c} \left(P_t^d \right)^{1 - \eta_c} + \omega_c^{1/\eta_c} \left(P_t^{m,c} \right)^{1 - \eta_c} \right]^{1/(1 - \eta_c)}. \tag{8}$$

The model also assumes that households can purchase investment goods in order to increase their capital stock. The law of motion of capital is given by:

$$\bar{K}_{t+1} = (1 - \delta) \bar{K}_t + \Upsilon_t F (I_t, I_{t-1}) + \Delta_t, \tag{9}$$

where $\bar{K}_t$ is a physical capital stock, δ is the depreciation rate of capital stock, $F(I_t, I_{t-1})$ is a function that transforms investment into capital. Following Christiano et al. (2005), $F(I_t, I_{t-1})$ is of the following form:

$$F(I_t, I_{t-1}) = \left[1 - \tilde{S}(I_t, I_{t-1})\right] I_t, \tag{10}$$

where $\tilde{S}$ determines the investment adjustment costs through the estimated parameter $\tilde{S}''$. Υ_t denotes the investment-specific technology shock and Δ_t represents either newly bought capital if it is positive or sold capital if it is negative. The investment (I_t) is a bundle between domestic and imported investment goods (I_t^d and I_t^m, respectively):

$$I_t = \left[(1 - \omega_i)^{1/\eta_i} \left(I_t^d\right)^{(\eta_i - 1)/\eta_i} + \omega_i^{1/\eta_i} \left(I_t^m\right)^{(\eta_i - 1)/\eta_i}\right]^{\eta_i/(\eta_i - 1)}, \tag{11}$$

where ω_i denotes the share of imported investment goods in total investment, and η_i is elasticity of substitution between domestic and imported investment goods. It is worth noting that domestically produced consumption and investment goods have the same price P_t^d. The aggregate investment price index is therefore given by:

$$P_t^i = \left[(1 - \omega_i) \left(P_t^d\right)^{1-\eta_i} + \omega_i \left(P_t^{m,i}\right)^{1-\eta_i}\right]^{1/(1-\eta_i)}. \tag{12}$$

Furthermore, the model assumes that each household is a monopolistic supplier of differentiated labour service, which implies that they can determine their own wage. Each household sells its labour $h_{j,t}$ to a firm which transforms it into a homogeneous input good H_t according to the following production function:

$$H_t = \left[\int_0^1 (h_{j,t})^{\frac{1}{\lambda_w}} dj\right]^{\lambda_w}, \ \lambda_w \geq 1, \tag{13}$$

where λ_w is the wage markup. The demand function for each differentiated labour service is given by:

$$h_{j,t} = \left[\frac{W_{j,t}}{W_t}\right]^{\frac{\lambda_w}{1-\lambda_w}} H_t. \tag{14}$$

Following Erceg et al. (2000) and Christiano et al. (2005), the households are subject to the Calvo wage rigidities, which means that in every period each household faces a random probability $1 - \xi_w$ that it can change its nominal wage. If a household is allowed to re-optimize its wage, it will set its wage to W_t^{opt} taking into account the probability ξ_w that the wage will not be re-optimized in the future. The households that cannot re-optimize set their wages according to the following indexation rule:

$$W_{j,t+1} = (\pi_t^c)^{\kappa_w} \mu_{z,t+1} W_{j,t}, \tag{15}$$

where κ_w is an indexation parameter, π_t^c is the inflation rate measured by the consumer price index, and $\mu_{z,t} = z_t/z_{t-1}$ is the growth rate of the unit-root technology shock. The

household j that can re-optimize solves the following optimization problem:

$$\max_{W^{opt}_{j,t}} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\xi_w)^s \left\{ \begin{array}{c} -\zeta^h_{t+s} A_L \frac{(h_{j,t+s})^{1+\sigma_L}}{1+\sigma_L} \\ +v_{t+s}\left(1-\tau^y+\tau^{tr}_{t+s}\right)\left(\pi^c_t \ldots \pi^c_{t+s-1}\right)^{\kappa_w} \\ \times \left(\mu_{z,t+1} \ldots \mu_{z,t+s}\right) W^{opt}_{j,t} h_{j,t+s} \end{array} \right\}, \quad (16)$$

where τ^y is a labour income tax and τ^{tr}_t is a time-varying rate of social transfers to households defined in more detail in Subsection 2.4.

2.3. Monetary policy

The monetary policy is modelled in a highly simplified way. It is assumed that the domestic interest rate (R_t) depends on the exogenously given foreign interest rate (R^*_t) adjusted for the risk premium on foreign bonds $(\Phi\left(a_t, \tilde{\phi}_t\right))$:[4]

$$R_t = R^*_t \Phi\left(a_t, \tilde{\phi}_t\right), \quad (17)$$

where the risk premium, which is defined through the following function:

$$\Phi\left(a_t, \tilde{\phi}_t\right) = e^{-\tilde{\phi}_a(a_t-\bar{a})+\tilde{\phi}_t}, \quad (18)$$

depends on the aggregate net foreign asset position of the domestic economy (a_t) and exogenous risk premium shocks $(\tilde{\phi}_t)$.[5] The inclusion of risk premium is necessary to ensure a well-defined steady state in the model (Schmitt-Grohé & Uribe, 2003).

---

[4]In Adolfson et al. (2007), the interest rate is determined according to a simple rule (expressed in log-linear form):

$$\hat{R}_t = \rho_R\hat{R}_{t-1} + (1-\rho_R)\left(\hat{\bar{\pi}}^c_t + r_\pi\left(\hat{\pi}^c_{t-1} - \hat{\bar{\pi}}^c_t\right) + r_y\hat{y}_{t-1} + r_x\hat{x}_{t-1}\right) + r_{\Delta\pi}\Delta\hat{\pi}^c_t + r_{\Delta y}\Delta\hat{y}_t + \varepsilon_{R,t},$$

where $\hat{R}_t$ is the short-rate interest rate, $\hat{\pi}^c_t$ the CPI inflation rate, $\hat{\bar{\pi}}^c_t$ a time-varying inflation target, $\hat{y}_t$ the output gap, $\hat{x}_t$ denotes the real exchange rate, and $\varepsilon_{R,t}$ is an interest rate shock.

[5] Besides joining the European Monetary Union (EMU) in 2007, Slovenia went through different monetary regimes since its independence in 1991: money based stabilization policy (1991-1995), price and real exchange rate stability dual targeting policy (1996-2001), and exchange rate based stabilization policy and accession to ERM 2 exchange rate mechanism and EMU (2001-2007) (Caprirolo & Lavrač, 2003). Because these would be very difficult to implement in the model, we are not modelling any break in the conduct of monetary policy when estimating the model. Rather, we follow an uncomplicated way of monetary policy inclusion into the model structure. That is, we keep only a modified UIP condition (17) on the monetary side without specifying any particular form of monetary rule for the period before 2007, when Slovenia run an independent monetary policy. Of course, for the years before 2007 (or at least 2004Q3, when Slovenia entered the ERM 2), an additional term, $-\Delta S_{t+1}$, capturing the nominal exchange rate fluctuations, must be added on the right-hand side of Equation (17). In addition, the terms of trade channel would be affected by the nominal exchange rate. In such a setting the endogenously determined nominal exchange rate may reduce or amplify the impact of structural shocks, depending on their nature. Based on the findings presented in Cúrdia et al. (2012), applying a more adequate approach to modelling monetary policy may also improve the fit of the model. We initially included exchange rate as an additional variable into the model, but due to model solvability problems (i.e., more variables than equations) we again restricted with the simple version, as described above. In other words, in order to guarantee solvability of the model, an explicit monetary policy rule must be incorporated into the model structure. Despite

2.4.   Fiscal policy

The government in this economy collects taxes, issues debt and uses revenues for government consumption, transfers to households and interest on outstanding debt. The resulting government budget constraint can be expressed as:

$$B_{t+1} + T_t = R_{t-1} B_t + T R_t + P_t^d G_t \Leftrightarrow B_{t+1} = B_t + DEF_t, \tag{19}$$

where B_t denotes the public debt and DEF_t is the government deficit, which is defined as the difference between the government expenditures GEX_t and total tax revenues T_t:

$$DEF_t = GEX_t - T_t. \tag{20}$$

The government tax revenues consist of taxes on private consumption, as well as on labour income and capital income:

$$
\begin{aligned}
T_t = \ & \tau^c P_t^c C_t + \tau^y W_t H_t \\
& + \tau^k \left[(R_{t-1} - 1) B_t + R_t^k K_t + \left(R_{t-1}^* \Phi \left(a_{t-1}, \tilde{\phi}_{t-1} \right) - 1 \right) B_t^* + \Pi_t \right],
\end{aligned}
\tag{21}
$$

with τ^c, τ^y and τ^k being the tax rates on private consumption, labour income and capital income, respectively, which are assumed to be fixed. In the above expression, Π_t are total profits, which are equal to the sum of profits earned by domestic, importing and exporting firms, Π_t^d, Π_t^m and Π_t^x, respectively:

$$\Pi_t = \Pi_t^d + \Pi_t^m + \Pi_t^x, \tag{22}$$

where:

$$
\begin{aligned}
\Pi_t^d = \ & P_t^d \left(C_t^d + I_t^d + G_t \right) + P_t^d \left(C_t^x + I_t^x \right) \\
& - MC_t^d \left(C_t^d + I_t^d + G_t + C_t^x + I_t^x \right) - MC_t^d z_t \phi
\end{aligned}
\tag{23}
$$

$$\Pi_t^m = P_t^{m,c} C_t^m + P_t^{m,i} I_t^m - P_t^* \left(C_t^m + I_t^m \right) \tag{24}$$

and:

$$\Pi_t^x = P_t^x \left(C_t^x + I_t^x \right) - P_t^d \left(C_t^x + I_t^x \right). \tag{25}$$

these simplifications, the model in such a structure fits the data, including the short-term nominal interest rates, reasonably well. It is also worth noting that similar approach neglecting existence of diverse monetary policies and flexible exchange rates prior to the EMU-start was used in the literature (see, for example, Adolfson et al. (2007), Almeida (2009), Smets & Wouters (2003), Marcellino & Rychalovska (2014) among others). The authors estimated their models under implicit assumption that, even before the establishment of the currency area there was a common monetary policy in the European Union. Finally, as a robustness check we re-estimated our model using the data for the period 2004Q3 onwards, when Slovenia entered the ERM 2. Our analysis reveals that in this case parameter estimates do not substantially vary from the estimates reported in Tables 3 and 4 in the main text. But what is more important, we find that our main results reported in the paper (e.g., those of the historical decompositions) persist. We choose not to report this robustness check in the paper to save space, but it is available upon request from the author.

Furthermore, the government expenditures are given by:

$$GEX_t = TR_t + P_t^d G_t + (R_{t-1} - 1) B_t, \tag{26}$$

where TR_t denotes transfers to households, G_t is government consumption of goods and services and $(R_{t-1} - 1) B_t$ stands for public debt interest payments. We assume that transfers to households are indexed to wages W_t and hours worked H_t with an exogenously given rate of transfers τ_t^{tr} according to the following expression (D'Auria et al., 2009):

$$TR_t = \tau_t^{tr} W_t H_t. \tag{27}$$

For the rate of transfers to households it is simply assumed that follow an AR(1) process (in deviations from its steady state):

$$\hat{\tau}_t^{tr} = \rho_{\tau^{tr}} \hat{\tau}_{t-1}^{tr} + \varepsilon_{\tau^{tr},t}. \tag{28}$$

Finally, government consumption follows the log-linear rule of the following form:[6]

$$\hat{g}_t = \rho_g \hat{g}_{t-1} - \phi_\pi \hat{\pi}_t^c - \phi_y \hat{y}_t - \phi_b \hat{b}_t - \phi_d \widetilde{def}_t + \varepsilon_{g,t}. \tag{29}$$

In this equation, $\hat{g}_t$ is the percentage deviation of real government consumption (stationarized with the unit-root technology level, z_t) from its steady state level, $\hat{\pi}_t^c$ is the CPI inflation, $\hat{y}_t$ reflects the output gap, $\hat{b}_t$ is the public debt and $\widetilde{def}_t$ denotes the government deficit which is expressed as a difference from its steady state, that is, $\widetilde{def}_t = def_t - def$. $\varepsilon_{g,t}$ defines the exogenous shock aimed at capturing discretionary changes in government consumption. ϕ_π, ϕ_y, ϕ_b and ϕ_d denote the feedback coefficients towards inflation, output gap, public debt and government deficit deviations, respectively. ρ_g reflects the degree of government consumption smoothing.

2.5. Market equilibrium

In equilibrium all markets clear. The market clearing condition for the domestic goods market is given by:

$$C_t^d + I_t^d + G_t + C_t^x + I_t^x \le z_t^{1-\alpha} \epsilon_t K_t^\alpha H_t^{1-\alpha} - z_t \phi - a(u_t) \bar{K}_t, \tag{30}$$

where C_t^x and I_t^x are the foreign demand for export goods which follow CES aggregates with elasticity η_f. Furthermore, the net foreign assets' market clears when domestic investment in foreign bonds (denoted by B_t^*) equals the net position of exporting/importing firms:

$$B_t^* = P_t^x (C_t^x + I_t^x) - P_t^* (C_t^m + I_t^m) + R_{t-1}^* \Phi\left(a_t, \tilde{\phi}_t\right) B_t^*. \tag{31}$$

---

[6]Our specification for the fiscal rule is similar to those used by Erceg & Lindé (2013), with the only exception that they do not include the inflation rate.

2.6.   Foreign economy

Since the domestic economy is a small open economy, we assume that the foreign economy is exogenous. In particular, foreign output ($\hat{y}_t^*$), foreign inflation ($\hat{\pi}_t^*$) and foreign interest rate ($\hat{R}_t^*$) are exogenously modelled as an identified VAR model with two lags:[7]

$$\Phi_0 X_t^* = \Phi_1 X_{t-1}^* + \Phi_2 X_{t-2}^* + S_{x^*}\varepsilon_{x^*,t}, \tag{32}$$

where $X_t^* \equiv \left(\hat{\pi}_t^*, \hat{y}_t^*, \hat{R}_t^*\right)'$, $\varepsilon_{x^*,t} \sim \mathcal{N}\left(0, I_{x^*}\right)$, S_{x^*} is a diagonal matrix with standard deviations and $\Phi_0^{-1} S_{x^*}\varepsilon_{x^*,t} \sim \mathcal{N}\left(0, \Sigma_{x^*}\right)$.

2.7.   Structural shocks

In total, the dynamics of the model is driven by 16 exogenous shock processes that are assumed to be characterized in log-linearized form by the univariate representation:

$$\hat{\xi}_t = \rho_\xi \hat{\xi}_{t-1} + \varepsilon_{\xi,t}, \quad \varepsilon_{\xi,t} \overset{iid}{\sim} N\left(0, \sigma_\xi^2\right), \tag{33}$$

where $\xi_t = \left\{\mu_{z,t}, \epsilon_t, \lambda_t^j, \zeta_t^c, \zeta_t^h, \Upsilon_t, \tilde{\phi}_t, \tilde{z}_t^*, \tau_t^{tr}, \varepsilon_{g,t}\right\}$ for $j = \{d, mc, mi, x\}$. $\varepsilon_{g,t}$ is assumed to be a white noise process (that is, $\rho_{\varepsilon_g} = 0$). There are also three foreign shocks (that is, foreign output, foreign inflation and foreign interest rate shock) provided by the exogenous (pre-estimated) foreign VAR model.

3   MODEL SOLUTION AND ESTIMATION

In this section, we present how the DSGE model is solved and estimated.

---

[7]The foreign VAR model is estimated for the first 12 Euro area countries over the period 1995Q1-2014Q4 and includes the following variables: output (GDP at market prices, chain linked volumes (2005), million units of national currency); GDP deflator (GDP at market prices, price index (implicit deflator), 2005=100, national currency); interest rate (12-month money market interest rate in percent). To make the observed data consistent with the model's concepts, we adjusted the data before entering the VAR model. Specifically, we used HP-detrended log of GDP (we set the smoothing parameter to 1600, which is typically used with quarterly data), the demeaned first difference of the log of GDP deflator and the demeaned interest rate which is divided by 400. All data series are seasonally adjusted and adjusted by working days. The lag order of the VAR model was chosen using the Hannan-Quinn information criterion, which suggests an optimal lag order of two periods (Lütkepohl & Krätzig, 2004). We also removed variables with lowest t-ratios until all remaining variables had t-ratios greater than 2, which is often used in applied work. The estimated foreign VAR model is, therefore, given by:

$$\hat{\pi}_t^* = 0.028\hat{y}_{t-1}^* + 0.121\hat{\pi}_{t-1}^* + 0.279\hat{\pi}_{t-2}^* + \varepsilon_{\pi^*,t}$$
$$\hat{y}_t^* = 1.667\hat{y}_{t-1}^* - 0.698\hat{y}_{t-2}^* + \varepsilon_{y^*,t}$$
$$\hat{R}_t^* = 1.190\hat{R}_{t-1}^* + 0.321\hat{y}_{t-1}^* - 0.306\hat{y}_{t-2}^* - 0.271\hat{R}_{t-2}^* + \varepsilon_{R^*,t}.$$

.

3.1.   Model solution

The model presented in the previous section consists of a set of optimality conditions and laws of motion of the shock processes. Since the model comprises the unit-root technology shock that induces a stochastic trend in the levels of the real variables, the first step prior to model solution is rendering the model stationary. To this end all real variables are divided with the trend level of technology z_t. The resulting stationary variables are then denoted by lower-case letters, that is, $x_t = \frac{X_t}{z_t}$ for a generic variable x_t. We then proceed with the log-linearisation[8] to the model's equations of the transformed model around the deterministic steady state[9], where the variables are expressed as logarithmic deviations from their steady state values, that is, $\hat{x}_t = \frac{x_t - x}{x} \approx \ln x_t - \ln x$, where x denotes the steady state value of a generic variable x_t. Once the model has been stationarized and log-linearized, it can be written in the following compact form:

$$\mathbb{E}_t \left\{ \alpha_0 \Gamma_{t-1} + \alpha_1 \Gamma_t + \alpha_2 \Gamma_{t+1} + \beta_2 \Psi_{t+1} + \beta_1 \Psi_t \right\} = 0, \tag{34}$$

where Γ_t is a vector of endogenous variables, Ψ_t is a vector of exogenous variables, and $\alpha_0, \alpha_1, \alpha_2, \beta_1$ and β_1 are coefficient matrices. It is assumed that Ψ_t evolves according to:

$$\Psi_t = \rho \Psi_{t-1} + \varepsilon_t \quad \varepsilon_t \sim N\left(0, \Sigma\right). \tag{35}$$

We use Dynare 4.4.3[10] to solve the model. The solution of the model takes the form:[11]

$$\Gamma_t = A\Gamma_{t-1} + B\Psi_t. \tag{36}$$

3.2.   Data and measurement equations

For estimation purposes the solved model can be written in the following state-space form (Hamilton, 1994):

$$\xi_{t+1} = F\xi_t + \upsilon_{t+1} \tag{37}$$

and:

$$\tilde{Y}_t = A'x_t + H'\xi_t + \omega_t. \tag{38}$$

---

[8] However, it is important to notice that dynamics in the log-linearized model is only approximation of the true non-linear dynamics. Therefore, studying the log-linearized models is only valid for small deviations from the model's steady state. For a complete list of the log-linearized equations of the model, see Appendix A.

[9] We compute the non-stochastic steady state of the model following the procedure described in Adolfson et al. (2007). It is important to note that the steady state also depends on estimated parameters. For this reason, when estimating the model, it is of great importance to take into account parameter dependence by using model-local variables. For further discussion, see Pfeifer (2014a), Remark 4 (Parameter dependence and the use of model-local variables).

[10] Dynare is a software package for solving and estimating DSGE models. For more information regarding Dynare refer to the official Dynare web page http://www.dynare.org and see Mancini Griffoli (2011), as well as Adjemin, Bastani, Karamé, Juillard, Maih, Mihoubi, Perendia, Pfeifer, Ratto & Villemot (2014).

[11] Dynare uses solution algorithms proposed by Klein (2000) and Sims (2002). For a detailed look at what exactly is going on behind the scenes of Dynare's computations, the interested reader is referred to Villemot (2011).

The first equation is called the state equation, whereas the second is called the observation (measurement) equation. The symbols appearing in (37) and (38) have the following meaning: $\tilde{Y}_t$ is an $(n \times 1)$ vector of observed variables at time t, ξ_t is an $(r \times 1)$ vector of unobserved variables at time t (also referred to as state vector) and x_t is a $(k \times 1)$ vector with exogenous or predetermined variables (e.g. a constant). Furthermore, F, A' and H' are matrices of dimension $(r \times r)$, $(n \times k)$ and $(n \times r)$, respectively. The $(r \times 1)$ vector v_t and the $(n \times 1)$ vector ω_t are uncorrelated, normally distributed white noise vectors, therefore:

$$\mathbb{E}\left(v_t v_\tau'\right) = \left\{ \begin{array}{ll} Q & \text{for } \tau = t \\ 0 & \text{otherwise} \end{array} \right.$$

$$\mathbb{E}\left(\omega_t \omega_\tau'\right) = \left\{ \begin{array}{ll} R & \text{for } \tau = t \\ 0 & \text{otherwise}, \end{array} \right.$$

where Q and R are $(r \times r)$ and $(n \times n)$ matrices, respectively. The disturbances v_t and ω_t are assumed to be uncorrelated at all lags:

$$\mathbb{E}\left(v_t, \omega_\tau'\right) = 0 \quad \text{for all } t \text{ and } \tau. \tag{39}$$

In what follows, we describe how the raw data were converted to the form used in estimation. In addition, we present the exact measurement equations that are employed to relate the observed data to the model state variables. The estimates are based on quarterly Slovenian macroeconomic data covering the period 1995Q1-2014Q4. We employ the following 14 variables as observables:[12] the GDP deflator (P_t^d), the real wage (W_t/P_t^d), consumption (C_t), investment (I_t), government consumption (G_t), the real exchange rate (x_t), the short-run interest rate (R_t), employment[13] (E_t), GDP (Y_t), exports (X_t), imports (M_t), the CPI price index (P_t^c), foreign output (for the first 12 euro area countries) (Y_t^*), the foreign GDP deflator (for the first 12 euro area countries) (P_t^*) and the foreign interest rate (12-month money market interest rate of the euro area) (R_t^*). Regarding the foreign variables, GDP for the first 12 euro area countries is used for foreign output, and the GDP deflator for the first 12 euro area countries is used for foreign inflation, while the foreign interest rate refers to the 12-month money market interest rate of the euro area. Data come from four different sources. Data on the employment and gross wages are taken from the Statistical Office of the Republic of Slovenia. The sources for domestic interest rate are the Bank of Slovenia and the Institute of Macroeconomic Analysis and Development of the Republic of Slovenia. The rest of the data are taken from Eurostat. Since the model comprises a stochastic unit root technology shock that induces a common stochastic trend in the real variables of the model, we use first differences to make these variables stationary. When estimating the model, the following variables are matched in growth rates

---

[12]A detailed description of the data used in the estimation together with their sources is provided in Appendix B. Additionally, the data are plotted in Appendix D.

[13]We assume that the employment variable ($\hat{E}_t$) is related to the hours worked variable ($\hat{H}_t$) by an auxiliary equation (expressed as a percentage deviation from the steady state):

$$\Delta \hat{E}_t = \frac{\beta}{1+\beta} \mathbb{E}_t \Delta \hat{E}_{t+1} + \frac{(1-\xi_e)(1-\beta\xi_e)}{(1+\beta)\xi_e} \left(\hat{H}_t - \hat{E}_t \right).$$

The Calvo parameter, ξ_e, representing the fraction of firms that in any period is able to adjust employment to its desired total labour input, is estimated.

measured as quarter-to-quarter log-differences: GDP, consumption, investment, exports, imports, government consumption, real wage, GDP deflator, CPI price index, foreign output and foreign GDP deflator. The rest of the variables are used in levels: domestic and foreign interest rate, employment and real exchange rate. The real wage is calculated as the nominal gross wage per employee deflated by the GDP deflator. All interest rates are divided by 4 to express them in quarterly rates consistent with the variables in the model. The stationary variables, x_t and E_t, are measured as follows: we take the logarithm of real exchange rate and remove a linear trend, so that it is expressed in percentage deviations from the trend, consistently with the model concepts, that is $\hat{x}_t^{data} = \frac{x_t - x}{x}$, while the employment is measured as deviation around the mean, that is $\hat{E}_t^{data} = \frac{E_t - E}{E}$. Furthermore, in order to align the data with the model-based definitions, some additional transformations are made. First, since the model assumes that all real variables are growing at the same rate as output, we match the sample growth rates of private consumption, investment, government consumption, exports, imports and real wage with the sample growth rate of real GDP by removing the remaining growth rate differentials. Second, the model assumes that in steady-state, the interest rates (that is, domestic and foreign interest rate) as well as different measures of inflation (that is, domestic, CPI and foreign inflation) are identical, that is $R = R^*$ and $\pi^d = \pi^c = \pi^*$, respectively. This assumption is clearly rejected by the data. To circumvent this issue, we demean all these time series before the model estimation and add the sample mean of domestic interest rate to the foreign interest rate and the sample mean of domestic inflation to the CPI and foreign inflation, so that the data match the model assumptions. All variables (except the nominal interest rates) are seasonally adjusted and adjusted by working days. The vector of observable variables, $\tilde{Y}_t$, is then given by:

$$
\begin{aligned}
\tilde{Y}_t = \Big[& \Delta \ln P_t^{d,data} \quad \Delta \ln \left(W_t / P_t^d \right)^{data} \quad \Delta \ln \tilde{C}_t^{data} \quad \Delta \ln \tilde{I}_t^{data} \quad \hat{x}_t^{data} \ldots \\
& R_t^{data} \quad \hat{E}_t^{data} \quad \Delta \ln Y_t^{data} \quad \Delta \ln \tilde{X}_t^{data} \quad \Delta \ln \tilde{M}_t^{data} \ldots \quad\quad (40) \\
& \Delta \ln G_t^{data} \quad \Delta \ln P_t^{c,data} \quad \Delta \ln Y_t^{*,data} \quad \Delta \ln P_t^{*,data} \quad R_t^{*,data} \Big]',
\end{aligned}
$$

where Δ is the first difference operator. The corresponding measurement equation that matches observed data with model's variables is:

$$
\tilde{Y}_t =
\begin{bmatrix}
\Delta \ln P_t^{d,data} \\
\Delta \ln \left(W_t / P_t^d \right)^{data} \\
\Delta \ln \tilde{C}_t^{data} \\
\Delta \ln \tilde{I}_t^{data} \\
\hat{x}_t^{data} \\
R_t^{data} \\
\hat{E}_t^{data} \\
\Delta \ln Y_t^{data} \\
\Delta \ln \tilde{X}_t^{data} \\
\Delta \ln \tilde{M}_t^{data} \\
\Delta \ln G_t^{data} \\
\Delta \ln P_t^{c,data} \\
\Delta \ln Y_t^{*,data} \\
\Delta \ln P_t^{*,data} \\
R_t^{*,data}
\end{bmatrix}
=
\begin{bmatrix}
\left(\pi^d - 1 \right) \\
\ln \mu_z \\
\ln \mu_z \\
\ln \mu_z \\
0 \\
4R \left(R - 1 \right) \\
0 \\
\ln \mu_z \\
\ln \mu_z \\
\ln \mu_z \\
\ln \mu_z \\
\left(\pi^d - 1 \right) \\
\ln \mu_z \\
\left(\pi^d - 1 \right) \\
4R \left(R - 1 \right)
\end{bmatrix}
+
\begin{bmatrix}
\hat{\pi}_t^d \\
\Delta \hat{\tilde{w}}_t + \hat{\mu}_{z,t} \\
\Delta \hat{\tilde{c}}_t + \hat{\mu}_{z,t} \\
\Delta \hat{\tilde{i}}_t + \hat{\mu}_{z,t} \\
\hat{x}_t \\
4R\hat{R}_t \\
\hat{E}_t \\
\Delta \hat{y}_t + \hat{\mu}_{z,t} \\
\Delta \hat{\tilde{x}}_t + \hat{\mu}_{z,t} \\
\Delta \hat{\tilde{m}}_t + \hat{\mu}_{z,t} \\
\Delta \hat{g}_t + \hat{\mu}_{z,t} \\
\hat{\pi}_t^c \\
\Delta \hat{y}_t^* + \Delta \hat{\tilde{z}}_t^* + \hat{\mu}_{z,t} \\
\hat{\pi}_t^* \\
4R\hat{R}_t^*
\end{bmatrix}
+
\begin{bmatrix}
\varepsilon_{\pi^d,t}^{me} \\
\varepsilon_{\tilde{w},t}^{me} \\
\varepsilon_{\tilde{c},t}^{me} \\
\varepsilon_{\tilde{i},t}^{me} \\
\varepsilon_{x,t}^{me} \\
\varepsilon_{R,t}^{me} \\
\varepsilon_{E,t}^{me} \\
\varepsilon_{y,t}^{me} \\
\varepsilon_{\tilde{x},t}^{me} \\
\varepsilon_{\tilde{m},t}^{me} \\
\varepsilon_{g,t}^{me} \\
\varepsilon_{\pi^c,t}^{me} \\
\varepsilon_{y^*,t}^{me} \\
\varepsilon_{\pi^*,t}^{me} \\
\varepsilon_{R^*,t}^{me}
\end{bmatrix}, \quad (41)
$$

where $\varepsilon_{i,t}^{me}$ denotes the measurement error for the respective variable. The standard deviation of specific measurement error is calibrated at 10% of the standard deviation of the corresponding observed domestic variables, while the measurement errors for the foreign variables are set to 0, as in Adolfson et al. (2007).

3.3. Estimation methodology

Structural parameters of the model are either calibrated or estimated. The values for the parameters that are calibrated (and thus kept fixed throughout the estimation) are chosen in accordance with the practice in the literature calibrating small open-economy models. Their values are discussed in Subsection 3.4. All remaining parameters are estimated with a Bayesian estimation method, which has become a standard econometric technique for estimating DSGE models.[14] In the following, we briefly describe the main features of the method. The key idea of the Bayesian estimation method[15] is that it combines the prior belief of the parameters with empirical data to form the posterior distributions of the parameters. The posterior distributions are obtained by using the Bayes theorem:

$$
p \left(\theta | \tilde{Y}_t \right) = \frac{p \left(\tilde{Y}_t | \theta \right) p \left(\theta \right)}{p \left(\tilde{Y}_t \right)}, \quad (42)
$$

[14]All estimates are performed using Dynare version 4.4.3 in Matlab R2012b.

[15]A detailed explanation of the estimation method can be found in An & Schorfheide (2007), Adolfson et al. (2007), Canova (2007), Fernández-Villaverde (2010) and Smets & Wouters (2003, 2007) among many others. The reader is also referred to Dynare Manual for additional explanation of the estimation method.

where θ is a vector of the parameters to estimate, $p\left(\theta|\tilde{Y}_t\right)$ is the density of the parameters conditional on data (the posterior), $p\left(\tilde{Y}_t|\theta\right)$ is the density of the data conditional on the parameters (the likelihood), $p\left(\theta\right)$ is the unconditional density of the parameters (the prior) and $p\left(\tilde{Y}_t\right)$ is the marginal density of the data.[16] Given that the marginal density of the data is a constant term or equal for any parameter, equation (42) can be rewritten as:

$$p\left(\theta|\tilde{Y}_t\right) \propto p\left(\tilde{Y}_t|\theta\right) p\left(\theta\right) \equiv \mathcal{K}\left(\theta|\tilde{Y}_t\right), \qquad (43)$$

where $\mathcal{K}\left(\theta|\tilde{Y}_t\right)$ is the posterior kernel. Taking logs of (43), we get:

$$\ln \mathcal{K}\left(\theta|\tilde{Y}_t\right) = \ln p\left(\tilde{Y}_t|\theta\right) + \ln p\left(\theta\right) = \ln \mathcal{L}\left(\tilde{Y}_t|\theta\right) + \ln p\left(\theta\right). \qquad (44)$$

Before the estimation can begin, we need to specify the priors for the parameters to be estimated and evaluate the likelihood function of the observed data. The choice of priors is discussed in Subsection 3.5. The likelihood function of the observed data is evaluated by generating forecasts from the state-space system, (37) and (38), with the use of the Kalman filter. Conceptually, the Kalman filter consists of calculating the sequence $\left\{\xi_{t+1|t}\right\}_{t=1}^{T}$ and $\left\{\Sigma_{t+1|t}^{\xi}\right\}_{t=1}^{T}$, where $\xi_{t+1|t}$ denotes the optimal forecast of ξ_{t+1} based on observation of $\mathbf{y}_t \equiv \left(\tilde{Y}_t', \tilde{Y}_{t-1}', \tilde{Y}_{t-2}', \ldots, \tilde{Y}_1', x_t', x_{t-1}', x_{t-2}', \ldots, x_1'\right)'$ and $\Sigma_{t+1|t}^{\xi}$ denotes the mean squared error of this forecast. The algorithm works forward in time and is conducted as follows:[17] For $t = 1$, the algorithm needs to be provided with initial values for a one-step ahead forecast of time t states, $\xi_{t|t-1}$, and respective forecast error variance-covariance matrix, $\Sigma_{t|t-1}^{\xi}$. Based on this a one-step ahead forecast of time t data, $\tilde{Y}_{t|t-1}$ and respective variance-covariance matrix, $\Sigma_{t|t-1}^{\tilde{Y}}$ are computed. The algorithm then updates the forecasts of time t states, $\xi_{t|t}$, and a respective variance-covariance matrix, $\Sigma_{t|t}^{\xi}$. The final step is to compute a one-step ahead forecast of time $t+1$ states, $\xi_{t+1|t}$, and respective variance-covariance matrix, $\Sigma_{t+1|t}^{\xi}$. These steps are iterated for $t = 2, 3, 4, \ldots, T$. The log-likelihood function (based on the data up to time t) can be written as follows (Hamilton, 1994):

$$\sum_{t=1}^{T} \ln \mathcal{L}\left(\tilde{Y}_t|x_t, \mathbf{y}_{t-1}, F, A', H', Q, R\right)$$

$$= -\sum_{t=1}^{T}\left[\begin{array}{c} \frac{n}{2}\log 2\pi + \frac{1}{2}\log |\Sigma_{t|t-1}^{\tilde{Y}}| \\ +\frac{1}{2}\sum_{t=1}^{T}\left(\tilde{Y}_t - \tilde{Y}_{t|t-1}\right)'\left(\Sigma_{t|t-1}^{\tilde{Y}}\right)^{-1}\left(\tilde{Y}_t - \tilde{Y}_{t|t-1}\right) \end{array}\right]. \qquad (45)$$

---

[16]It is defined as:

$$p\left(\tilde{Y}_t\right) = \int_{\Theta} p\left(\theta, \tilde{Y}_t\right) d\theta,$$

where $p\left(\theta, \tilde{Y}_t\right)$ denotes the joint density of the parameters and the data.

[17]The presentation here follows Hamilton (1994).

Finally, the posterior distribution is obtained in two steps: first, by maximizing the log posterior density with respect to θ, the posterior mode θ^m and an approximate covariance matrix, based on the inverse Hessian matrix evaluated at the posterior mode, $\Sigma_{\theta^m} = H\left(\theta^m|\tilde{Y}\right)^{-1}$, is obtained and second, the posterior distribution is simulated by using the Monte-Carlo Markov-Chain (MCMC) sampling method, specifically the Metropolis-Hastings (MH) algorithm. The idea behind this algorithm is the following (Mancini Griffoli, 2013): first, the algorithm chooses a starting point (posterior mode), then it draws a candidate value θ^* from an arbitrary candidate (or jumping) distribution:

$$J\left(\theta^*|\theta_{i-1}\right) \sim N\left(\theta_{i-1}, c\Sigma_{\theta^m}\right), \tag{46}$$

where θ_{i-1} is the last accepted draw, Σ_{θ^m} denotes the inverse of the Hessian computed at the posterior mode, and c is the scale factor, which is chosen to ensure an appropriate acceptance rate. In the next step, the algorithm computes the acceptance ratio:

$$\alpha = \min\left[\frac{\mathcal{K}\left(\theta^*|\tilde{Y}_t\right)}{\mathcal{K}\left(\theta_{i-1}|\tilde{Y}_t\right)}, 1\right]. \tag{47}$$

The algorithm then accepts or discards the proposal θ^* according to the following rule:

$$\theta_i = \begin{cases} \theta^* & \text{with probability } \alpha \\ \theta_{i-1} & \text{otherwise} \end{cases}.$$

If the parameter value is accepted, the mean of the distribution is updated with the new draw θ_i. These algorithm steps are repeated many times to simulate the posterior distribution.

3.4.   Calibrated parameters

In this section, we present the calibrated parameters of the model.[18] Their values are taken mainly from Adolfson et al. (2007) unless otherwise stated. The discount factor, β, is fixed to 0.993, implying a steady-state interest rate of 11%,[19] which matches the average interest rate in the sample period. The share of capital in production, α, is calibrated to 0.30. The depreciation rate of capital, δ, is set to 0.013. We calibrate the capital utilization cost parameter, σ_a, to 10^6. The elasticity of substitution between domestic and foreign goods, η_c, is calibrated to 5. Labour disutility constant, A_L, is calibrated to 7.5. As in Christiano, Eichenbaum and Evans (2005), we set the labour supply elasticity, σ_L, to 1, and the wage mark-up, λ_w, to 1.05. The steady state mark-ups are calibrated at: 1.222 in the domestic goods market (λ^d), 1.633 in the imported consumption goods market ($\lambda_{m,c}$) and 1.275 in the imported investment goods market ($\lambda^{m,i}$). The steady state foreign terms of trade, γ^f, is calibrated to 1. The rest of the parameters, as well as the steady state relationships, are

---

[18] It is important to note that a time period is taken to be a quarter.

[19] This follows from the first order condition of the households' bond holdings, $R = \frac{\pi \mu_z - \tau^k \beta}{(1-\tau^k)\beta}$.

calibrated using the averages of Slovenian data for the period 1995Q1-2014Q4. The shares of imports in consumption and investment, ω_c and ω_i, are set to 0.67 and 0.40, respectively. The steady state rate of transfers to households, τ^{tr}, is calibrated to 0.50. The ratios of government expenditures ($\frac{gex}{y}$), taxes ($\frac{t}{y}$), government consumption ($\frac{g}{y}$), and debt services ($\frac{r}{y}$) in GDP are 0.37, 0.36, 0.19, and 0.02, respectively. Further, the share of government consumption, social transfers and debt services in total government expenditures, $\frac{g}{gex}$, $\frac{tr}{gex}$ and $\frac{r}{gex}$, are set to 0.51, 0.44 and 0.05, respectively. The target value of debt-to-GDP ratio, b_y^*, is assumed to be 240% in the steady state, which is consistent with the reference value of public debt established by the Maastricht Treaty, which equals 60% of yearly output. The steady state quarterly gross inflation rate, π^d, is equal to 1.01. Finally, the average effective tax rates on consumption, labour income and capital income, τ^c, τ^y and τ^k, amount to 0.17, 0.48 and 0.22, respectively. An overview of the calibrated parameters is found in Table 1, while Table 2 provides an overview of the steady state relationships.

Table 1: *Calibrated parameters of the model*

Parameter	Description	Calibrated value
β	Households' discount factor	0.993
α	Capital share in production	0.30
η_c	Substitution elasticity between C_t^d and C_t^m	5
σ_a	Capital utilization cost parameter	10^6
A_L	Labour disutility constant	0.3776
σ_L	Labour supply elasticity	1
δ	Depreciation rate of physical capital	0.013
λ_w	Wage mark-up	1.05
λ^d	Mark-up in the domestic goods market	1.168
$\lambda^{m,c}$	Mark-up in the imported consumption goods market	1.619
$\lambda^{m,i}$	Mark-up in the imported investment goods market	1.226
ω_i	Share of imports in investment	0.40
ω_c	Share of imports in consumption	0.67
τ_c	Consumption tax rate	0.114
τ_y	Labour income tax rate	0.48
τ_k	Capital tax rate	0.22
τ^{tr}	Rate of transfers to households	0.50

3.5.   Prior distributions of the estimated parameters

Before the Bayesian estimation method starts, the prior distributions of the estimated parameters need to be specified. As the name suggests, prior distribution describes the available information about the parameters prior to observing the data used in the estimation. The observed data is then used to update the prior, through the Bayes theorem, to the posterior distribution of the model's parameters. In specifying the prior distributions we mainly

Table 2: *Steady state relationships*

Parameter	Description	Value
π^d	Steady state quarterly gross inflation rate	1.01
$\frac{gex}{y}$	Share of government expenditures in GDP	0.37
$\frac{t}{y}$	Share of taxes in GDP	0.36
$\frac{g}{y}$	Share of government consumption in GDP	0.19
$\frac{g}{gex}$	Share of government consumption in government expenditures	0.51
$\frac{r}{y}$	Share of debt services in GDP	0.02
$\frac{r}{gex}$	Share of debt services in government expenditures	0.05
$\frac{tr}{gex}$	Share of social transfers in government expenditures	0.44
b^*_y	Target value of debt-to-GDP ratio	2.4

rely on choices from Adolfson et al. (2007).

Throughout the analysis we use four main distributions: beta distribution, inverse gamma distribution, normal distribution and gamma distribution. For the parameters bounded between 0 and 1 we choose beta distribution. Parameters belonging to this group are nominal stickiness parameters ξ, indexation parameters κ, the habit persistence b and the persistence parameters of the shock processes ρ. We set the mean of prior distributions for the price stickiness parameters to 0.5 with standard deviation 0.2, while the mean for the indexation parameters is set to 0.4 with standard deviation 0.1. However, there are three exceptions. For the Calvo parameter for domestic firms we set the prior mean to 0.85 with a standard deviation of 0.1, while for the Calvo parameter for exporting firms we choose a prior mean equal to 0.75 with a standard deviation of 0.1. For the wage indexation parameter we impose a prior mean of 0.5 with a standard deviation of 0.2. The prior on habit persistence has a mean of 0.65 and a standard deviation of 0.2. With the exception of the shocks to the unit-root technology, stationary technology and government consumption, we set the prior means of the persistence parameters for the structural shocks equal to 0.5 with a standard deviation of 0.2. For the unit-root technology, stationary technology and government consumption shocks we choose a mean of 0.6 and a standard deviation of 0.2.

We use inverse gamma distribution to describe our priors about the parameters that are assumed to be positive. These parameters are the standard deviations of shocks and the substitution elasticities between goods, η. We set the prior mean of the substitution elasticity between domestic and foreign investment goods, η_i, equal to 0.8, while the prior mean of the substitution elasticity among goods in the foreign economy, η_f, is set to 1.5. Continuing with the standard deviations of shocks[20], we set the standard deviation of the stationary technology shock, σ_ϵ, to 0.007, and the standard deviation of the unit-root technology shock, σ_{μ_z}, is assumed to be 0.002, which is the value used by Altig et al. (2011).

---

[20]In order to decrease the degree of non-linearity when estimating the model, the mark-up shocks in the Phillips curves, as well as the investment-specific technology shock, the labour supply shock and the consumption preference shock enter into the equations in an additive way.

The size of the risk premium shock, $\sigma_{\tilde{\phi}}$, and the prior on the risk premium parameter related to net foreign assets, $\tilde{\phi}$, are set to 0.0005 and 0.045, respectively. Based on the residuals from a first-order autoregression of the series obtained when substracting the HP-trend in domestic output from the HP-trend in foreign output, we set the size of the asymmetric technology shock, $\sigma_{\tilde{z}^*}$, to 0.003. The consumption preference, labour supply and investment-specific technology shocks, σ_{ζ_c}, σ_{ζ_h} and σ_Υ, respectively, are assumed to have the prior mean of 0.002, which is similar to Adolfson et al. (2007). Since we have little information about the properties of these shocks, we choose very loose priors with infinite variances. Regarding the foreign shocks, there are three standard deviations of shocks which need to be specified, namely the standard deviation of the foreign output shock, foreign inflation shock and foreign interest rate shock. We fix their values at the standard deviations of residuals obtained from a pre-estimated foreign VAR model. The standard deviation for the foreign output shock, σ_{y^*}, is, therefore, set to 0.004, the foreign inflation shock, σ_{π^*}, is assumed to have a standard deviation of 0.002, while the standard deviation for the foreign interest rate shock, σ_{R^*}, is set to 0.003.

Finally, turning to the parameters of the fiscal rule, the prior on the persistence parameter (ρ_g) follows a beta distribution with a mean of 0.6 and a standard deviation of 0.2. The priors on the feedback coefficients are assumed to be gamma distributed. We set their values as follows: the prior mean of the feedback coefficient on inflation (ϕ_π) and output gap (ϕ_y) is set to 0.25 with a standard deviation of 0.15, while the prior on the feedback coefficient on public debt (ϕ_b) and government deficit (ϕ_d) is somewhat lower and has a mean equal to 0.05 and a standard deviation of 0.01. For the steady state quarterly gross growth rate, μ_z, we choose normal distribution with prior mean centred around 1.006, implying an annual growth rate of about 2.4%.

4   ESTIMATION RESULTS AND EVALUATION

In this section, we present and evaluate the estimation results.

4.1.   Posterior distributions of the estimated parameters

In total we estimated 50 parameters: 17 friction parameters, 5 policy parameters and 28 shock processes parameters. The posterior mode and an approximate covariance matrix, based on the inverse Hessian matrix evaluated at the mode, have been computed by using a standard numerical optimisation routine, namely Christopher Sims' optimizer csminwel, on the log posterior density. After having optimized the log posterior density, the draws from the posterior distribution have been obtained by simulating two parallel Markov chains of 300,000 draws of the Metropolis-Hastings algorithm, ignoring the first 50% of draws as burn-in. The average acceptance rate is roughly 32% across the two Metropolis-Hastings blocks used.

After the estimation, we performed several diagnostic tests to assess the quality of the estimated model. More precisely, we (i) looked at the quality of the posterior kernel optimization, (ii) assessed the convergence of the Markov chains by using both the univariate convergence diagnostics proposed by Brooks & Gelman (1998) as well as the multivariate convergence diagnostics, and (iii) compared the plots of the prior and posterior distributions. This latter diagnostic can be found in Appendix C. To have sensible estimates, the patterns of the prior and posterior distributions should be reasonably distinct. If the posterior looks like the prior, either the prior is a very accurate reflection of the information in the data or, more usually, the parameter under consideration is only weakly identified and the data does not provide much information to update the prior (Canova, 2007). On the other hand, if the prior and posterior distribution are far away from each other, this typically indicates that there is a disagreement between the information provided by the data and the prior knowledge about the true parameter value. In addition, the posterior distribution should be approximately normal in shape, which is in line with the asymptotic properties of Bayesian estimation, and the mode should be in the center of the posterior distribution.

As seen in these plots, the most of the estimated parameters are well identified as their posterior distribution is reasonably different from the prior distribution. Moreover, for the majority of the parameters, the variance of the posterior is lower compared to the prior distribution, indicating that data are quite informative. The mode check plots (not presented here) indicate that the optimization procedure was able to precisely find a robust maximum for the posterior kernel. Finally, both univariate and multivariate convergence graphs (also not presented here) confirm that the parameters are generally characterized by good convergence.[21]

The estimation results are summarized in Table 3, which provides prior distributions, posterior estimations and 90% confidence intervals of the estimated parameters. Let us now briefly discuss the estimation results. Beginning with the Calvo price stickiness parameters, we find that the domestic price stickiness parameter ξ_d is estimated at 0.90, which implies the average duration of prices of about 10 quarters.[22] The values for the other sectors ($\xi_{m,c}$, $\xi_{m,i}$ and ξ_x) are estimated as follows: the estimated price stickiness parameter for the imported consumption, $\xi_{m,c}$, is equal to 0.71, suggesting that prices remain on average unchanged for 3 quarters. Furthermore, the posterior mean of the price stickiness parameter for the imported investment, $\xi_{m,i}$, is estimated at 0.52. The average duration of prices in this sector is therefore 2 quarters. The export price stickiness parameter, ξ_x, in turn, is estimated at 0.87, corresponding to an average price duration of 7 quarters. The posterior mean of the Calvo wage stickiness parameter, ξ_w, is nearly 0.56. This value implies that wages are reset as frequent as twice a year. Considering next the indexation parameters, we find that the posterior mean of the degree of wage indexation, κ_w, is estimated at 0.60, while the remaining indexation parameters (κ_d, $\kappa_{m,c}$, $\kappa_{m,i}$, κ_x) are estimated at a lower value. The posterior mean of the habit persistence parameter in consumption, b, is

---

[21] Due to space limitations these graphs are not presented here, but they are available from the author upon request.

[22] Average duration of prices comes from $\frac{1}{1-\xi_d}$.

estimated at 0.94. Furthermore, our estimates suggest the substitution elasticity between domestic and foreign investment goods, η_i, of around 0.29, while the posterior mean for the substitution elasticity among goods in the foreign economy, η_f, is estimated at 1.37. The investment adjustment cost parameter, $\tilde{S}''$, is estimated to be equal to 8.65. The posterior mean of the risk premium parameter related to net foreign assets, $\tilde{\phi}_a$, is 0.03.

Regarding the parameters in the fiscal policy rule, we find that the feedback coefficient of government consumption to inflation, ϕ_π, is estimated at 0.22, the estimated feedback coefficient of output gap, ϕ_y, is 0.08, while the estimated feedback coefficients of public debt and government deficit, ϕ_b and ϕ_d, are equal to 0.06 and 0.05, respectively. It is worth noting that the latter two parameters are driven by a prior. This can be explained by the fact that we do not use the data on public debt and government deficit in the estimation. The persistence parameter in the fiscal rule, ρ_g, is estimated to be 0.50, which indicates a moderate degree of persistence in government consumption.

Finally, we consider the parameters associated with the persistence and volatility of shock processes (see Table 4). We find that the autoregressive parameters are estimated to lie between 0.22 for the consumption preference shock and 0.96 for the unit-root technology shock. In general, the level of persistence of stochastic processes is not very high, indicating that the model contains a sufficiently persistent endogenous propagation mechanism. Turning to the estimated standard deviations of shocks, we find that the most volatile are the imported investment mark-up shocks and the investment-specific technology shock, with standard deviations of 0.3345 and 0.0309, respectively, while the least volatile is the unit-root technology shock with a standard deviation equal to 0.0013.

Table 3: *Prior and posterior distribution of structural parameters*

Description	Parameter	Prior distribution			Posterior distribution				
		Type	Mean	Std. Dev./Df	Mode	Std. Dev.	Mean	5 %	95 %
Friction parameters									
Calvo wages	ξ_w	Beta	0.500	0.200	0.5775	0.0881	0.5568	0.4173	0.6918
Calvo domestic prices	ξ_d	Beta	0.850	0.100	0.9044	0.0206	0.9018	0.8639	0.9365
Calvo import consumption prices	$\xi_{m,c}$	Beta	0.500	0.200	0.7569	0.0957	0.7051	0.5352	0.8673
Calvo import investment prices	$\xi_{m,i}$	Beta	0.500	0.200	0.6293	0.1099	0.5195	0.2910	0.7509
Calvo export prices	ξ_{x}	Beta	0.750	0.100	0.8954	0.0439	0.8655	0.7689	0.9702
Calvo employment	ξ_{e}	Beta	0.500	0.200	0.8112	0.0319	0.8232	0.7762	0.8757
Indexation wages	κ_w	Beta	0.500	0.200	0.5927	0.1770	0.6016	0.3491	0.8291
Indexation domestic prices	κ_d	Beta	0.400	0.100	0.2013	0.0643	0.2181	0.1064	0.3172
Indexation import consumption prices	$\kappa_{m,c}$	Beta	0.400	0.100	0.3379	0.1110	0.3510	0.1951	0.5056
Indexation import investment prices	$\kappa_{m,i}$	Beta	0.400	0.100	0.3250	0.0957	0.3349	0.1814	0.4848
Indexation export prices	κ_{x}	Beta	0.400	0.100	0.3293	0.0996	0.3309	0.1786	0.4764
Investment adjustment cost	$\tilde{S}^*$	Normal	7.694	1.500	8.6319	1.2547	8.6526	6.5778	10.6581
Habit formation	b	Beta	0.650	0.200	0.9442	0.0214	0.9413	0.9081	0.9761
Substitution elasticity investment	η_i	Inv. Gamma	0.800	inf	0.2860	0.0552	0.2925	0.2001	0.3847
Substitution elasticity foreign	η_f	Inv. Gamma	1.500	2	1.1934	0.4019	1.3696	0.6160	2.1375
Technology growth	μ_z	Beta	1.006	0.005	1.0061	0.0005	1.0061	1.0054	1.0068
Risk premium	$\tilde{\phi}_a$	Beta	0.045	0.02	0.0234	0.0103	0.0296	0.0115	0.0460
Policy parameters									
Policy rule: lagged gov. consumption	ρ_g	Beta	0.600	0.200	0.5149	0.1585	0.4987	0.3314	0.6619
Policy rule: inflation	ϕ_π	Gamma	0.25	0.15	0.1900	0.0990	0.2234	0.0623	0.3765
Policy rule: output gap	ϕ_y	Gamma	0.25	0.15	0.0649	0.0491	0.0834	0.0148	0.1451
Policy rule: public debt	ϕ_b	Gamma	0.05	0.01	0.0508	0.0160	0.0553	0.0381	0.0716
Policy rule: gov. deficit	ϕ_{def}	Gamma	0.05	0.01	0.0495	0.0101	0.0514	0.0339	0.0674

Table 4: *Prior and posterior distribution of shock processes*

Description	Parameter	Type	Prior distribution		Posterior distribution				
			Mean	Std. Dev./Df	Mode	Std. Dev.	Mean	5 %	95 %
Persistence parameters									
Unit-root technology shock	$\rho_{\mu z}$	Beta	0.600	0.200	0.9707	0.0167	0.9577	0.9272	0.9899
Stationary technology shock	ρ_{ϵ}	Beta	0.600	0.200	0.8697	0.1096	0.7887	0.6071	0.9613
Investment-specific technology shock	ρ_{Υ}	Beta	0.500	0.200	0.2872	0.1381	0.2775	0.0823	0.4677
Asymmetric technology shock	$\rho_{\tilde{z}*}$	Beta	0.500	0.200	0.9872	0.0091	0.9822	0.9678	0.9971
Consumption preference shock	ρ_{ζ_c}	Beta	0.500	0.200	0.1938	0.0979	0.2228	0.0773	0.3700
Labour supply shock	ρ_{ζ_h}	Beta	0.500	0.200	0.5307	0.3261	0.5435	0.2473	0.8126
Risk premium shock	$\rho_{\tilde{\phi}}$	Beta	0.500	0.200	0.9329	0.0153	0.9317	0.9076	0.9577
Domestic mark-up shock	ρ_{λ_d}	Beta	0.500	0.200	0.4599	0.0988	0.4742	0.3051	0.6394
Import consumption mark-up shock	$\rho_{\lambda_{m,c}}$	Beta	0.500	0.200	0.4727	0.2155	0.5425	0.2412	0.8520
Import investment mark-up shock	$\rho_{\lambda_{m,i}}$	Beta	0.500	0.200	0.1670	0.1219	0.3121	0.0500	0.5801
Export mark-up shock	ρ_{λ_x}	Beta	0.500	0.200	0.2893	0.1458	0.3566	0.0859	0.6103
Rate of transfers shock	$\rho_{\tau tr}$	Beta	0.500	0.200	0.6550	0.1105	0.5941	0.3635	0.8286
Standard deviations									
Unit-root technology shock	$\sigma_{\mu z}$	Inv. Gamma	0.002	inf	0.0011	0.0002	0.0013	0.0008	0.0017
Stationary technology shock	σ_{ϵ}	Inv. Gamma	0.007	inf	0.0126	0.0056	0.0210	0.0071	0.0380
Investment-specific technology shock	σ_{Υ}	Inv. Gamma	0.002	inf	0.0304	0.0040	0.0309	0.0246	0.0367
Asymmetric technology shock	$\sigma_{\tilde{z}*}$	Inv. Gamma	0.003	inf	0.0037	0.0005	0.0038	0.0030	0.0047
Consumption preference shock	σ_{ζ_c}	Inv. Gamma	0.002	inf	0.0044	0.0006	0.0044	0.0035	0.0054
Labour supply shock	σ_{ζ_h}	Inv. Gamma	0.002	inf	0.0010	0.0005	0.0015	0.0006	0.0023
Risk premium shock	$\sigma_{\tilde{\phi}}$	Inv. Gamma	0.0005	inf	0.0030	0.0003	0.0032	0.0026	0.0036
Domestic mark-up shock	σ_{λ_d}	Inv. Gamma	0.003	inf	0.0024	0.0003	0.0024	0.0018	0.0030
Import consumption mark-up shock	$\sigma_{\lambda_{m,c}}$	Inv. Gamma	0.003	inf	0.0026	0.0004	0.0028	0.0019	0.0037
Import investment mark-up shock	$\sigma_{\lambda_{m,i}}$	Inv. Gamma	0.003	inf	0.2533	0.0756	0.3345	0.1470	0.5169

| Description | Parameter | Prior distribution | | | Posterior distribution | | | |
		Type	Mean	Std. Dev./Df	Mode	Std. Dev.	Mean	5 %	95 %
Export mark-up shock	σ_{λ_x}	Inv. Gamma	0.003	inf	0.0112	0.0043	0.0113	0.0044	0.0184
Government consumption shock	σ_g	Inv. Gamma	0.002	inf	0.0049	0.0006	0.0050	0.0041	0.0058
Rate of transfers shock	$\sigma_{\tau^{tr}}$	Inv. Gamma	0.002	inf	0.0018	0.0005	0.0016	0.0007	0.0023

4.2.   Assessing the empirical performance of the model

After having presented and evaluated the estimation results, we now proceed with the assessment of the empirical performance of the estimated model. This is done in three directions. First, we evaluate the absolute (in-sample) fit of the model. Second, we compare the unconditional second moments in the estimated DSGE model with those based on the actual data. Finally, we look at the smoothed estimates of the innovation component of structural shocks.

In Figure D.1 in Appendix D we first plot the actual series used in the estimation along with filtered variables obtained by the one-sided Kalman filter for each of the fifteen observable variables. The thin red line depicts the mean estimate of the one step ahead forecast of the endogenous variables (best guess for the endogenous variables at time $t + 1$ given information up to the current observations t), derived from the Kalman filter, whereas the thick black line represents the actual data (Pfeifer, 2014b). As it can be seen from the subplots, the in-sample fit of the model is satisfactory in most of the cases since the model predictions closely follow the path of the observed historical data. However, the model is not good at capturing government consumption.

The common practice in the DSGE literature is to analyse how well the model's moments match those from the actual data. As a next step we therefore compare the second moments in the data (for the period 1995Q2-2014Q4) with those in the model (calculated at the posterior mean). The results are presented in Table 5. The first column presents the standard deviations of the selected observed variables and their counterparts implied by the estimated model. The second column reports the first order autocorrelation coefficients. The last two columns show correlations with GDP growth rates and domestic inflation, respectively. Several results are worth highlighting here. First, our model is able to replicate quite well the volatilities of some observables, in particular those of the growth rate of GDP and government consumption, but generates much high volatile consumption growth rates as compared to the data. Consumption growth in the model is three times more volatile than in the data. Furthermore, we can observe that the model replicates quite closely the positive correlation of investment and government consumption growth rates with GDP growth rates. The correlation between investment and GDP growth rates is 0.67 in the model, while it is 0.77 in the data. These numbers are respectively 0.09 and 0.14 for the correlation of government consumption. On the other hand, the correlation of imports and exports seems to be underestimated by the model (0.77 in the data and 0.40 in the model for imports, 0.70 in the data and 0.41 in the model for exports), while the correlation of consumption is slightly overestimated by the model (0.42 in the data and 0.64 in the model). Furthermore, the model is quite successful in predicting the persistence of the observables, except the persistence of consumption, investment and imports that is overpredicted compared to their empirical counterparts. From the table we can also see that the model is less successful in replicating the observed correlations between the respective variables and inflation.

Finally, Figures (E.1a)-(E.1b) in Appendix E plot the estimated structural shocks of the model. The values plotted are obtained using the two-sided Kalman filter and represent the most likely values for the respective shock in a particular period, whereas the green areas provide the highest posterior density intervals (HPDI) (Pfeifer, 2014b). For the estimates to be sensible, they should be stationary around zero. As can clearly be seen from the figures, the estimates tend to fluctuate around zero over time and look clearly stationary, which gives some positive indication on the statistical validity of the estimated model.

Table 5: *Unconditional second moments in the data (1995Q2–2014Q4) and in the model*

	Standard dev.		Autocorrelation		Corr with $\Delta \ln Y_t$		Corr with $\Delta \ln P_t^d$	
	Data	Model	Data	Model	Data	Model	Data	Model
$\Delta \ln P_t^d$	0.95	0.75	0.62	0.74	0.03	-0.46	1	1
$\Delta \ln \left(W_t / P_t^d \right)$	1.09	1.17	0.49	0.59	0.74	0.46	-0.01	-0.38
$\Delta \ln \tilde{C}_t$	1.51	4.91	-0.09	0.67	0.42	0.64	0.11	-0.75
$\Delta \ln \tilde{I}_t$	7.06	8.28	-0.15	0.35	0.77	0.67	-0.13	-0.22
$\hat{E}_t$	3.17	5.13	0.99	0.99	-0.36	0.02	-0.42	0.03
$\Delta \ln Y_t$	1.18	1.43	0.49	0.47	1	1	0.03	-0.46
$\Delta \ln \tilde{X}_t$	2.80	3.13	0.45	0.50	0.70	0.41	-0.07	-0.05
$\Delta \ln \tilde{M}_t$	3.97	4.34	-0.02	0.30	0.77	0.40	-0.13	-0.05
$\Delta \ln G_t$	0.76	0.78	0.22	0.29	0.14	0.09	0.47	0.14

Notes: Standard deviations are in percent. Values implied by the model are calculated at the posterior mean estimates of the model's parameters.

5   APPLICATION: WHAT STRUCTURAL SHOCKS DRIVE THE SLOVENIAN ECONOMY?

After having verified the empirical performance of the model, we use the estimated DSGE model to analyse historical contributions of structural shocks to the business cycle developments in the Slovenian economy. In particular, we focus our attention to analyse the main driving forces behind the real GDP growth and its components during the sample period with special focus on the recent recessions. Before proceeding to such analyses, it is useful to discuss the impulse response functions and variance decompositions to understand the reaction and properties of the shocks.

5.1.   Impulse response analysis

This section briefly discusses the impulse response functions of some selected variables[23] from shocks that appear to be, based on a historical decomposition of the data (discussed in more detail in Subsection 5.3), the most important in driving macroeconomic fluctuations in Slovenia. The results are reported in Figures F.1-F.9 in Appendix F, displaying impulse responses up to 20 quarters. These figures portray a Bayesian version of the impulse responses which are presented in terms of mean responses of endogenous variables (solid line) together with the 5% and 95% posterior intervals (dashed lines). Notice that all quantities are reported as log deviations from the steady state (i.e. percentage deviations).

We first focus on the impulse responses to a permanent (unit-root) technology shock that captures permanent shifts in total factor productivity (see Figure F.1). As can be seen in the figure, this shock induces all variables (except the real exchange rate and private consumption) to rise. After the initial drop, it has also a positive impact on private consumption.

Figure F.2 plots the impulse responses to a transitory (stationary) technology shock. As expected, this shock has expansionary effects on the economy. When such a shock hits the economy, marginal cost of domestic firms decreases, which reduces domestic inflation and increases domestic output. Since the increase of output outperforms the decrease in inflation, government consumption is decreased by the government. One noticeable observation is that the model predicts negative response for employment. The reason for this is that the model includes various rigidities that restrict the increase in aggregate demand, which further induces a fall in employment as firms have become more productive.

Next, we present the impulse response functions to an investment-specific technology shock (also referred to as a shock to the marginal efficiency of investment), which affects the transformation of investment into physical capital (see Figure F.3). A positive realiza-

---

[23] Although the model includes 81 endogenous variables, we restrict our attention to key variables only. These variables include the GDP and its main components, domestic inflation, CPI inflation, real wages, employment and real exchange rate.

tion of this shock is associated with an increase in investment. This induces an increase in aggregate demand and output in the economy. Interestingly, domestic inflation slightly decreases after this shock, while private consumption increases. Further, if we look at the impulse responses of government consumption, we can see that the government reduces its consumption to dampen demand. The expansion in the economy drives up imports, while exports suffer from higher prices caused by increasing domestic marginal costs.

Figure F.4 refers to the case when the economy is hit by a consumption preference shock. This shock causes an increase in consumption, investment and output. To meet the higher demand, firms increase capital utilisation and employment. Firms therefore face rising marginal costs, and they respond by increasing prices. Higher domestic prices drive up CPI inflation. This, in turn, induces the government to decrease its consumption to counter the expansion in the economy.

Next, we present the impulse responses to a negative labour supply shock (i.e., an increase in the disutility of working, ζ_t^h). The impulse responses are presented in Figure F.5. This shock leads to a decline in hours worked and to an increase in the real wage. This increase in the real wage leads to an increase in marginal cost and inflation. Through the usual aggregate demand effects, the result is a recession in the economy.

In the following, we discuss the impulse responses to four mark-up shocks. Figure F.6 depicts the impulse responses to a domestic mark-up shock. As a consequence of this shock, domestic inflation increases. Higher domestic prices lead to a decrease in demand of domestic consumption and investment goods. Consumption demand is also shifted towards imported goods that are cheaper than domestic production. Volumes of imports therefore increase. As a consequence, lower domestic production has a negative impact on both hours worked and wages. Higher domestic prices also negatively affect the competitiveness of exports. All these factors cause a decrease in the GDP growth rate. Government consumption, which follows a fiscal rule, decreases on impact in response to the increase in inflation.

Figures F.7 and F.8 contains the impulse response functions to an imported consumption and investment shock, respectively. After the imported consumption shock, the prices of imported consumption goods increase. This leads households to buy fewer of these goods. The increase in imported consumption inflation also drives up CPI inflation. Because imported consumption goods are now more expensive relative to the domestic ones, expenditure switching towards domestic goods works to expand the economy. As domestic firms see marginal costs go up, they increase their prices and domestic inflation increases. This has a negative effect on exports. Nevertheless, output increases because of increased domestic demand. The government therefore reduces demand in the economy by decreasing its consumption.

Figure F.8 shows impulse response functions to an imported investment mark-up shock. Following this shock, the prices of imported investment goods rise up. As a consequence, the resulting relative price effects induce investment to fall whereas consumption increases.

Decrease in demand for imported investment goods causes a reduction in imports. Domestic inflation rises up. Due to higher domestic prices, export decreases. Because of reduced exports, production in the economy falls and thus output decreases. To stimulate the economy, the government increases its consumption.

Finally, in Figure F.9 we present the dynamics of the economy following an export mark-up shock. After this shock prices of exported goods rise up. This leads to a fall in exports and consequently domestic firms produce less output. Lower production forces firms to reduce demand for labour and capital services, pushing down wages and rental rate of capital. This reduces marginal costs, allowing domestic firms to reduce prices on domestic goods. The fall in domestic inflation also works to reduce CPI inflation. Consequently, this has a positive effect on domestic demand. Since the increase in domestic demand is not sufficient to off-set the fall in exports, output falls. Fiscal policy therefore responds by raising government consumption.

5.2.   Variance decompositions

In this section, we use the estimated model to decompose the unconditional variances of the observable variables into the contributions of the structural shocks. Although the primary interest of this paper is to investigate the background of the GDP (and its main components) fluctuations, we also present results for some other macroeconomic aggregates. The results are presented in Table 6, where we report the unconditional variance decomposition analysis (i.e., evaluated at the infinite horizon)[24] computed at the posterior mean for selected observable variables.

To facilitate the presentation, we divide the shocks into five categories. The first contains technology shocks: the stationary ($\varepsilon_{\epsilon,t}$), unit-root ($\varepsilon_{\mu_z,t}$), investment-specific ($\varepsilon_{\Upsilon,t}$), and asymmetric technology ($\varepsilon_{\tilde{z}^*,t}$) shocks. The second category includes supply shocks: the labour supply shock ($\varepsilon_{\zeta^h,t}$) and shocks to the mark-ups of the domestic ($\varepsilon_{\lambda^d,t}$), imported consumption ($\varepsilon_{\lambda^{mc},t}$), imported investment ($\varepsilon_{\lambda^{mi},t}$), and export ($\varepsilon_{\lambda^x,t}$) goods. The third category contains the domestic demand shock: the consumption preference shock ($\varepsilon_{\zeta^c,t}$). The fourth category includes foreign shocks: the uncovered interest rate parity ($\varepsilon_{\tilde{\phi},t}$), foreign output ($\varepsilon_{y^*,t}$), foreign inflation ($\varepsilon_{\pi^*,t}$) and foreign interest rate ($\varepsilon_{R^*,t}$) shocks. Finally, we have the fiscal policy shocks: the government spending ($\varepsilon_{g,t}$) and rate of transfers to households ($\varepsilon_{\tau^{tr},t}$) shocks.

It is evident from the table that technology shocks play the most important role in fluctuation of the GDP and investment growth. Our results show that roughly 50% and 80%

---

[24]In general, Dynare allows for two types of variance decompositions. The first one is the variance decomposition that is obtained under stoch_simul command and is calculated at the calibrated parameter combination, e.g., at the posterior mean (at the average over the parameters), while the second one is the so-called Bayesian variance decomposition, which is the average of the variance decomposition over the parameter draws. Furthermore, Dynare distinguishes between the conditional and unconditional variance decomposition. The first one is at a particular time horizon, while the second one is at horizon infinity.

of fluctuations in GDP and investment growth rates, respectively, are due to technology shocks. In this context, the most important technology shocks are the investment-specific technology shocks. Among the 50% (80%) of fluctuations of GDP (investment) growth rates explained by technology shocks, investment-specific technology shocks account for around 38% (78%). Furthermore, we can observe that supply shocks are the main drivers of fluctuations in the domestic inflation, real wages, consumption, exports and imports. More specifically, domestic inflation is mainly driven by domestic mark-up shocks. In our case they account for 41% of the total variation. Moreover, domestic mark-up and imported consumption mark-up shocks appear to have a leading role in explaining consumption growth fluctuations. They explain about 28% of total volatility. The shocks most responsible for the variability of real wages are labour supply shocks (34%). The export mark-up shocks turn out to be the key drivers for the exports, contributing to approximately 91% of total volatility, while the imported investment mark-up shocks play the most important role in accounting for the variation in imports, explaining about 54% of total volatility in that variable. Next, our estimates suggest that demand shocks have some importance in our framework in the sense that they explain about 15% of the variance in GDP growth rates, but their contribution to the remaining variables is negligible. Finally, we can observe that foreign and fiscal shocks explain a small fraction of variability in all variables and thus do not play an important role in explaining the Slovenian business cycle.[25]

---

[25] The small impact of foreign shocks may be due to the simplified representation of the foreign block, which is modelled as a VAR model.

Table 6: *Variance decompositions (in %) evaluated at the infinite horizon*

Variable	Technology	Supply	Demand	Foreign	Fiscal
$\ln P_t^d$	33.70	57.01	0.27	7.34	0.10
$\Delta\left(\ln W_t/P_t^d\right)$	36.95	60.59	0.19	1.03	0.38
$\Delta\ln\tilde{C}_t$	27.52	66.27	3.45	2.59	0.07
$\Delta\ln\tilde{I}_t$	79.82	16.03	0.24	2.90	0.01
$\hat{E}_t$	60.30	32.25	4.56	2.45	0.06
$\Delta\ln Y_t$	49.60	33.26	14.84	0.98	0.62
$\Delta\ln\tilde{X}_t$	4.13	92.52	0	2.54	0
$\Delta\ln\tilde{M}_t$	41.70	55.11	0.17	2.19	0
$\Delta\ln G_t$	35.88	5.44	0.27	1.62	55.85

Notes: The unconditional variance decomposition is performed at the posterior mean estimates of the model's parameters. Shocks are aggregated as explained in the main text.

5.3. Historical decompositions

The economic developments in Slovenia in recent years have been characterized by one of the biggest decline in economic growth in the European Union. Since 2008, Slovenia has experienced a double-dip recession. After a significant decline in GDP over the 2008-2009 period, the period of short-lived recovery began, but in the last quarter of 2011 Slovenia again dropped into recession. The question that arises is, what were the main driving forces behind the decline in GDP during the recent recession? To answer this question, we calculate historical decompositions that allow us to investigate the role of shocks in explaining the movement of observable variables over the sample period. In discussing the results, we focus on four variables: GDP, private consumption, investment, import and export. All variables are in real terms. The historical decomposition of real GDP growth is provided in Figure 1, while the remaining graphs are presented in Appendix G. In all graphs the bold black line represents the estimate of the smoothed observed variables[26] (best guess for the observed variables given all observations) derived from the Kalman smoother, while the coloured bars correspond to the contribution of the respective smoothed shock to the deviation of the smoothed observable variable from its steady state (Pfeifer, 2014b). Bars above the horizontal axis represent positive shock contributions, while bars below the horizontal axis show negative contributions.

Figure 1 decomposes the growth rate of real GDP dynamics over the underlying period. Prior to the crisis, Slovenia was characterized by a very high growth rate of the GDP. During the period 1996-2005, the annual growth rate of real GDP averaged 4%. The highest growth rate of GDP was achieved in the years 2006-2008, reaching its peak in 2007, when it was 6.7%. The historical decomposition results show that while domestic mark-up

---

[26]The smoothed series results from the Kalman smoother. They are the best guess of the variables given the information for the whole sample. Given that they are observed, their best guess is the actual value. Hence, there should be no difference unless one assumes they are observed only with measurement error (Pfeifer, 2014b).

shocks had a positive effect on economic growth in this period, stationary technology and labour supply shocks had a negative one. The intuition behind this result can be explained as follows: During this period domestic, mark-up shocks appear to have contributed significantly to lower inflation, which in turn stimulated the economy. This could be contributed to the entrance of Slovenia to the EMU, since this process was characterized by the efforts aimed to achieve sufficiently low inflation to satisfy the euro adoption, as well as by the convergence of previously high Slovenian interest rates towards lower interest rates in the Euro Area. This enabled the Slovenian banks to get access to low interest rate credits from abroad, which were mainly intended for the corporate sector. The competition among banks has further induced a decrease in effective interest rates and thus reduced borrowing costs for a business. At the same time, negative transitory (stationary) technology and labour supply shocks that resulted in lower efficiencies of production and higher wages, caused an upward inflationary pressures, which affected GDP growth negatively.

Since the first quarter of 2008, the GDP growth has experienced persistent declines until reaching the bottom in the first quarter of 2009. In that quarter, the GDP declined by about 5% relative to the previous quarter. As the model's estimates suggest, this negative dynamics was mainly driven by investment-specific technology, consumption preference and export mark-up shocks. Investment-specific technology shocks to a large extent reflect a drop in foreign and domestic orders, followed by a decline in investment. This effect was further compounded by tougher access to financial resources. Consumption preference and export mark-up shocks also contributed to the slowdown in economic activity in the 2008-2009 period. It is likely that consumption preference shocks reflect the reduction in households' income (in combination with the precautionary saving) while export mark-up shocks could capture the loss of external competitiveness from an increase in wages, reflected in a series of negative labour supply shocks identified right before the crisis. The analysis also points out that fiscal and foreign shocks played a smaller but nevertheless noticeable role in driving the Slovenian business cycle. According to the model, fiscal shocks have contributed positively over the whole pre-crisis period. The positive effect was still visible in the early stages of the crisis, when loose fiscal policy mitigated the economic slowdown, although during the ongoing recession fiscal tightening (as a result of austerity measures adopted to consolidate public finances) was suppressing GDP. However, it should be noted that the impact of fiscal policy shocks was small compared to other shocks, which suggests a relatively minor significance of changes in fiscal policy for cyclical fluctuations in GDP growth. The results regarding the effects of foreign shocks show that the direction of foreign shocks has reversed its course in 2010, from having a negative effect on GDP growth during the period 2008-2010 to having a positive influence by the middle of 2010, where the latter can be attributed to improvements in the economic situation in Slovenia's main trading partners. Moreover, the historical decomposition also suggests that investment-specific technology shocks continued to be the main sources of blocking recovery in more recent years, especially in the years 2012-2013, when Slovenia fell into its second recession, in which GDP declined by about -2% (quarter-on-quarter) in real terms. This result is obviously connected to banking system problems. Namely, the Slovenian banking system has accumulated a large amount of non-performing bad loans in the last years, resulting in a credit crunch which in turn caused a cutback in

corporate investment and impeded economic activity. The model also identifies the important role of permanent (unit-root) technology shocks in explaining the movements of real GDP growth, from having a small but positive impact on GDP growth dynamics in the pre-crisis period to having negative one in recessionary periods, in particular between 2012-2013, and whose negative effects also lasted during the recovery phase. This result could be considered as associated with the lack of productivity-enhancing and other structural reforms in the run-up to the crisis. On the other hand, transitory (stationary) technology shocks have had a positive impact on economic growth, especially from 2013 onwards. This result may be interpreted as resulting from a temporary greater tendency of corporate sector to take restructuring measures in response to the crisis to enhance its production efficiency. If we compare the two recessionary periods, we can observe that in contrast to the first period (2008-2009), when investment-specific technology shocks were accompanied by consumption preference and export mark-up shocks, in the second period (2012-2013), export mark-up shocks made virtually no contribution to the downturn, pointing to a recovery in exports thanks to improving foreign demand, and more importantly, to wage moderation and productivity gains, which translated into considerable competitiveness gains and strong export performance. According to the results obtained, it can also be observed that at the end of the sample period, when the recovery officially began, consumption preference shocks were the main contributors to the pace of economic recovery, presumably due to the increased consumer confidence, resolution of banking system problems, and the improvement in the labour market situation.

Turning now to the main components of GDP, Figure G.1 in Appendix G shows the historical decomposition of consumption growth. As can be seen from the figure, the movement of consumption growth was affected by a variety of structural shocks. Consistent with the variance decomposition results, the shocks most important for explaining dynamics of consumption growth rates over the sample period were stationary technology shocks, investment-specific technology shocks, domestic mark-up shocks and imported consumption mark-up shocks. Figures G.2-G.3 (see Appendix G) plot the historical decomposition results for investment and imports, respectively. As can be seen from the figures, the investment-specific technology shocks and the imported investment mark-up shocks explained most of the variation in these two variables. Finally, Figure G.4 (see Appendix G) portrays historical decomposition of the growth rates of exports. As illustrated in the figure, almost all historical variation in exports was due to export mark-up shocks.

Figure 1: *Historical decomposition of GDP growth in terms of structural shocks*
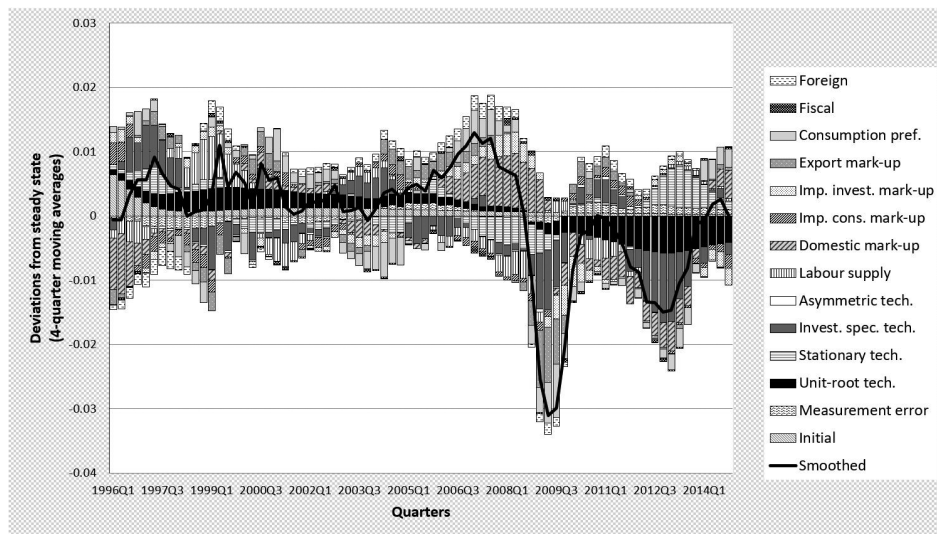
Notes: The smoothed observed time series is plotted excluding its mean.

6   CONCLUSION

The main objective of this paper is to present and estimate an open-economy DSGE model for the Slovenian economy. The model we use closely follows that of Adolfson et al. (2007) and Masten (2010). Using a data set that extends from 1995Q1 to 2014Q4 for Slovenia, we estimate the model using Bayesian estimation techniques and compute the contribution of structural shocks to the cyclical variation of key macroeconomic variables.

After the estimation, we first describe the estimation results and perform several tests on the quality of the estimation process. Further, we evaluate the model's empirical performance. Overall, the estimation results are satisfactory. The diagnostic tests indicate that the estimation is robust in what concerns the quality of the numerical posterior kernel optimization and the convergence of the MCMC procedure. Furthermore, the majority of the parameters appear to be well identified by the data and the data fit of the model is good. The obtained estimates for the structural parameters of interest are generally in line with the literature and, in most cases, seem to make sense from an economic point of view.

In the last part of the paper, the empirical importance of various types of structural shocks in explaining macroeconomic fluctuations in the Slovenian economy is studied using impulse responses, variance and shock decompositions. Our main findings can be summarized as follows. The variance decomposition results show that the investment-specific technology shock is the major driving force of the growth rates of GDP and investment.

Moreover, domestic mark-up shocks are estimated to have a leading role in explaining consumption growth and inflation fluctuations. The labour supply shocks explain the majority of the variance of real wages. The variance of imports growth rates is explained mainly by imported investment mark-up shocks, while the exported mark-up shocks account for most of the variation in exports growth rates. The effect of consumption preference shocks on the economy is estimated to be rather limited, with the largest influence on the GDP and consumption growth rates. Finally, fiscal and foreign shocks are estimated to have a negligible effect in our framework.

Last, using historical decompositions, we estimate the individual contributions of each structural shock to the movements in GDP growth rates (and its main components) over the sample period, focusing mainly on the two recessionary periods: 2008-2009 and 2012-2013. Our results suggest that investment-specific technology shocks accounted for a significant portion of the drop in output from 2008 onwards. This result accords with a drop in foreign and domestic orders followed by a decline in investment (mostly at the beginning of the crisis), as well as with a significant tightening of credit availability, thereby reducing expenditures on investment, which produced a decrease in the aggregate demand and output. Consumption preference and export mark-up shocks were another important sources that contributed to the slowdown in economic activity, especially in the first recession (2008-2009), most likely reflecting the reduction in households' income (in combination with the precautionary saving) and the fall in exports, mainly due to the deterioration of external competitiveness as wages increased faster than productivity before the crisis years, respectively. A noticeable but smaller impact was also exerted by foreign and fiscal shocks. Furthermore, the results show that permanent (unit-root) technology shocks also contributed to the developments of GDP growth rates during the analysed period. While in the pre-crisis period these shocks had a small but positive impact on GDP growth rates, in periods of the crisis, they contributed importantly to the GDP decline. This result could be considered as associated with the lack of productivity-enhancing and other structural reforms in the run-up to the crisis. On the contrary, transitory (stationary) technology shocks had a stimulating impact, especially from 2013 onwards. This finding may capture the effect of measures adopted to improve production efficiency. The comparison between the two recessions also shows that the role of export mark-up shocks decreased in 2010, from having a significantly negative effect on GDP growth during the period 2008-2009 to making virtually no contribution to the economic downturn between 2012-2013, pointing to a recovery in exports thanks to improving foreign demand, but more importantly, to wage moderation and productivity gains, which translated into considerable competitiveness gains and strong export performance. In addition, consumption preference also importantly contributed to the surge in GDP growth in the most recent years, which could be interpreted as a consequence of the increased consumer confidence, the resolution of banking system problems and the recovery in the labour market.

REFERENCES

Adjemin, S., Bastani, H., Karamé, F., Juillard, M., Maih, J., Mihoubi, F., Perendia, G., Pfeifer, J., Ratto, M., & Villemot, S. (2014). Dynare: Reference Manual Version 4 (Working Paper No. 1). Retrieved May 10, 2015, from `http://www.dynare.org/wp-repo/dynarewp001.pdf`

Adolfson, M., Laseén, S., Lindé, J., & Villani, M. (2007). Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through. *Journal of International Economics, 72*(2), 481-511.

Adolfson, M., Laseén, S., Lindé, J., & Svensson, L. E. O. (2014). Monetary Policy Trade-Offs in an Estimated Open-Economy DSGE Model. *Journal of Economic Dynamics & Control, 42*(C), 33-49.

Almeida, V. (2009). Bayesian Estimation of a DSGE Model for the Portuguese Economy. *Bank of Portugal Working Papers Series No. 14.* Retrieved April 12, 2018, from `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1535285`

Altig, D., Christiano L., Eichenbaum, M., & Linde, J. (2011). Firm-Specific Capital, Nominal Rigidities and the Business Cycle. *Review of Economic Dynamics, 14*(2), 225-247.

An, S., & Schorfheide, F. (2007). Bayesian Analysis of DSGE Models. *Econometric Review, 26*(2-4), 113-172.

Benigno, G., & Benigno, P. (2003). Price Stability in Open Economies. *Review of Economic Studies, 70*(4), 743-764.

Blanchard, O. (2016). *Do DSGE Models Have a Future?.* Retrieved February 8, 2017, from `https://piie.com/system/files/documents/pb16-11.pdf`

Blanchard, O. (2017). *Further Thoughts on DSGE Models.* Retrieved February 8, 2017, from `https://piie.com/blogs/realtime-economic-issues-watch/further-thoughts-dsge-models`

Brooks, S., & Gelman, A. (1998). General Methods for Monitoring Convergence of Iterative Simulations. *Journal of Computational and Graphical Statistics, 7*(4), 434-455.

Calvo, G. (1983). Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics, 12*(3), 383-398.

Canova, F. (2007). Bayesian Analysis of DSGE Models by S. An and F. Schorfheide. *Econometric Reviews, 26*(2-4), 187-192.

Caprirolo, G., & Lavrač, V. (2003). Monetary and Exchange Rate Policy in Slovenia. *Ezoneplus Working Paper No. 17G.* Retrieved April 12, 2018, from `https://www.econstor.eu/bitstream/10419/31944/1/480746710.pdf`

Christiano, L., Eichenbaum, M., & Evans, C. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy, 113*(1), 1-45.

Clarida, R., Galí, J., & Gertler, M. (1999). The Science of Monetary Policy: A New Keynesian Perspective. *Journal of Economic Literature, 37*(2), 1661-1707.

Clarida, R., Galí, J., & Gertler, M. (2001). Optimal Monetary Policy in Open vs. Closed Economies: An Integrated Approach. *American Economic Review, 91*(2), 248-252.

Cúrdia, V., Ferrero, A., Cee Ng, G., & Tambalotti, A. (2012). *Interest Rate Rules in DSGE Models: Tracking the Efficient Real Interest Rate.* Retrieved April 12, 2018, from `https://www.newyorkfed.org/medialibrary/media/research/economists/tambalotti/Draft_20130322_Web.pdf`

D'Auria, F., Pagano, A., Ratto, M., & Varga, J. (2009). A Comparison of Structural Reform Scenarios Across the EU Member States: Simulation-Based Analysis Using the QUEST Model with Endogenous Growth (Economic Papers 392). Brussels: European Commission.

Erceg, C., Henderson, D., & Levin, A. (2000). Optimal Monetary Policy with Staggered Wage and Price Contracts. *Journal of Monetary Economics, 46*(2), 281-313.

Erceg, C., & Lindé, J. (2013). Fiscal Consolidation in a Currency Union: Spending Cuts vs. Tax Hikes. *Journal of Economic Dynamics & Control, 37*(2), 422-445.

Fernández-Villaverde, J. (2010). The Econometrics of DSGE Models. *SERIEs, 1*(1-2), 3-49.

Galí, J., & Monacelli, T. (2005). Monetary Policy and Exchange Rate Volatility in a Small Open Economy. *Review of Economic Studies, 72*(3), 707-734.

Galí, J. (2008). *Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework.* Princeton: Princeton University Press.

Hamilton, J. (1994). *Time Series Analysis.* Princeton University Press.

Klein, P. (2000). Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model. *Journal of Economic Dynamics & Control, 24*(10), 1405-1423.

Lütkepohl, H., & Krätzig, M. (2004). *Applied Time Series Econometrics.* New York, NY: Cambridge University Press.

Mancini Griffoli, T. (2013). *DYNARE User Guide: An Introduction to the Solution & Estimation of DSGE Models.* Retrieved May 10, 2015, from `http://www.dynare.org/documentation-and-support/user-guide/Dynare-UserGuide-WebBeta.pdf/view`

Marcellino, M., & Rychalovska, Y. (2014). Forecasting with a DSGE Model of a Small Open Economy within the Monetary Union. *Journal of Forecasting, 33*(5), 315-338.

Masten, I. (2008). Optimal Policy in Presence of Balassa-Samuelson-Type Productivity Shocks. *Journal of Comparative Economics, 36*(1), 120-141.

Masten, I. (2010). *Dinamični stohastični model splošnega ravnovesja Slovenije SLODSGE 1.0.* Retrieved May 15, 2014, from `https://www.dlib.si/stream/URN:NBN:SI:DOC-FVPZR20C/f89623bf-3439-4bba-8c89-a9f92a58dc0e/PDF`

Pfeifer, J. (2014a). *A Guide to Specifying Observation Equations for the Estimation of DSGE Models.* Retrieved May 10, 2015, from `https://sites.google.com/site/pfeiferecon/dynare`

Pfeifer, J. (2014b). *An Introduction to Graphs in Dynare.* Retrieved May 10, 2015, from `https://sites.google.com/site/pfeiferecon/dynare`

Romer, P. (2016). *The Trouble with Macroeconomics.* Retrieved June 10, 2017, from `https://ccl.yale.edu/sites/default/files/files/The%20Trouble%20with%20Macroeconomics.pdf`

Schmitt-Grohé, S. & Uribe, M. (2003). Closing Small Open Economy Models. *Journal of International Economics, 61*(1), 163-185.

Sims, C. A. (2002). Solving Linear Rational Expectations Models. *Computational Economics, 20* (1-2), 1-20.

Smets, F., & Wouters, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association, 1*(5), 1123-1175.

Smets, F., & Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review, 97*(3), 586-606.

Villemot, S. (2011). Solving Rational Expectations Models at First Order: What Dynare Does (Working Paper No. 2). Retrieved May 10, 2015, from `http://www.dynare.org/wp-repo/dynarewp002.pdf`

Woodford, M. (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton: Princeton University Press.

APPENDICES

A   COMPLETE MODEL IN LOG-LINEARIZED FORM

This appendix presents the log-linearized equations of the model. In what follows, a variable with a hat denotes the log deviation from steady-state values ($\hat{x}_t = \frac{x_t - x}{x} \approx \ln x_t - \ln x$ for any variable x_t, where x is the steady-state level), while the overhead tilde indicates that a variable is measured as difference from its steady-state value, i.e. $\tilde{x}_t \equiv x_t - x$. Because the model comprises the unit-root technology shock, all real variables have to be scaled with the trend level of technology z_t in order to render them stationary. The resulting stationary variables are denoted by lower-case letters, that is, $x_t = \frac{X_t}{z_t}$.

Domestic Phillips curve:

$$\hat{\pi}_t^d = \frac{\beta}{1 + \beta \kappa_d} \mathbb{E}_t \hat{\pi}_{t+1}^d + \frac{\kappa_d}{1 + \beta \kappa_d} \hat{\pi}_{t-1}^d + \frac{(1 - \xi_d)(1 - \beta \xi_d)}{\xi_d (1 + \beta \kappa_d)} \left(\widehat{mc}_t + \hat{\lambda}_t^d \right). \quad (48)$$

Phillips curve for the imported consumption goods:

$$\begin{aligned} \hat{\pi}_t^{m,c} &= \frac{\beta}{1 + \beta \kappa_{m,c}} \mathbb{E}_t \hat{\pi}_{t+1}^{m,c} + \frac{\kappa_{m,c}}{1 + \beta \kappa_{m,c}} \hat{\pi}_{t-1}^{m,c} \\ &\quad + \frac{(1 - \xi_{m,c})(1 - \beta \xi_{m,c})}{\xi_{m,c} (1 + \beta \kappa_{m,c})} \left(\widehat{mc}_t^{m,c} + \hat{\lambda}_t^{m,c} \right). \end{aligned} \quad (49)$$

Real marginal cost for domestic firms:

$$\widehat{mc}_t = \alpha \hat{r}_t^k + (1 - \alpha) \hat{\bar{w}}_t - \hat{\epsilon}_t \quad (50)$$

Rental rate of capital:

$$\hat{r}_t^k = \hat{\mu}_{z,t} + \hat{\bar{w}}_t + \hat{H}_t - \hat{k}_t \quad (51)$$

Phillips curve for the imported investment goods:

$$\begin{aligned} \hat{\pi}_t^{m,i} &= \frac{\beta}{1 + \beta \kappa_{m,i}} \mathbb{E}_t \hat{\pi}_{t+1}^{m,i} + \frac{\kappa_{m,i}}{1 + \beta \kappa_{m,i}} \hat{\pi}_{t-1}^{m,i} \\ &\quad + \frac{(1 - \xi_{m,i})(1 - \beta \xi_{m,i})}{\xi_{m,i} (1 + \beta \kappa_{m,i})} \left(\widehat{mc}_t^{m,i} + \hat{\lambda}_t^{m,i} \right). \end{aligned} \quad (52)$$

Real marginal cost for the importing firms (consumption goods):

$$\widehat{mc}_t^{m,c} = -\widehat{mc}_t^x - \hat{\gamma}_t^{x,*} - \hat{\gamma}_t^{mc,d}. \quad (53)$$

Real marginal cost for the importing firms (investment goods):

$$\widehat{mc}_t^{m,i} = -\widehat{mc}_t^x - \hat{\gamma}_t^{x,*} - \hat{\gamma}_t^{mi,d}. \tag{54}$$

Phillips curve for the exporting firms:

$$\hat{\pi}_t^x = \frac{\beta}{1 + \beta \kappa_x} \mathbb{E}_t \hat{\pi}_{t+1}^x + \frac{\kappa_x}{1 + \beta \kappa_x} \hat{\pi}_{t-1}^x + \frac{(1 - \xi_x)(1 - \beta \xi_x)}{\xi_x(1 + \beta \kappa_x)} \left(\widehat{mc}_t^x + \hat{\lambda}_t^x \right). \tag{55}$$

Real marginal cost for the exporting firms:

$$\widehat{mc}_t^x = \widehat{mc}_{t-1}^x + \hat{\pi}_t^d - \hat{\pi}_t^x. \tag{56}$$

Real wage equation:

$$\mathbb{E}_t \left[\begin{array}{c} \alpha_0 \hat{\bar{w}}_{t-1} + \alpha_1 \hat{\bar{w}}_t + \alpha_2 \hat{\bar{w}}_{t+1} + \alpha_3 \left(\hat{\pi}_t^d - \hat{\bar{\pi}}_t^c \right) + \alpha_4 \left(\hat{\pi}_{t+1}^d - \rho_{\bar{\pi}^c} \hat{\bar{\pi}}_t^c \right) \\ + \alpha_5 \left(\hat{\pi}_{t-1}^c - \hat{\bar{\pi}}_t^c \right) + \alpha_6 \left(\hat{\pi}_t^c - \rho_{\bar{\pi}^c} \hat{\bar{\pi}}_t^c \right) \\ + \alpha_7 \hat{\psi}_{z,t} + \alpha_8 \hat{H}_t + \alpha_9 \hat{\zeta}_t^h + \alpha_{10} \hat{\tau}_t^b \end{array} \right] = 0, \tag{57}$$

where:

$$\begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \\ \alpha_8 \\ \alpha_9 \\ \alpha_{10} \end{pmatrix} = \begin{pmatrix} b_w \xi_w \\ \sigma_L \lambda_w - b_w \left(1 + \beta \xi_w^2 \right) \\ b_w \beta \xi_w \\ -b_w \xi_w \\ b_w \beta \xi_w \\ b_w \xi_w \kappa_w \\ -b_w \beta \xi_w \kappa_w \\ (1 - \lambda_w) \\ -(1 - \lambda_w) \sigma_L \\ -(1 - \lambda_w) \\ (1 - \lambda_w) \frac{\tau^b}{(1 - \tau^y + \tau^b)} \end{pmatrix}$$

and:

$$b_w = \frac{[\lambda_w \sigma_L - (1 - \lambda_w)]}{[(1 - \beta \xi_w)(1 - \xi_w)]}.$$

Euler equation for consumption:

$$\mathbb{E}_t \left[\begin{array}{c} -b \beta \hat{c}_{t+1} + \left(\mu_t^2 + b^2 \beta \right) \hat{c}_t - b \mu_z \hat{c}_{t-1} + b \mu_z \left(\hat{\mu}_{z,t} - \beta \hat{\mu}_{z,t+1} \right) \\ + (\mu_z - b \beta)(\mu_z - b) \hat{\psi}_{z,t} + (\mu_z - b \beta)(\mu_z - b) \hat{\gamma}_t^{c,d} \\ - (\mu_z - b) \left(\mu_z \hat{\zeta}_t^c - b \beta \hat{\zeta}_{t+1}^c \right) \end{array} \right] = 0. \tag{58}$$

First order condition w.r.t. i_t:

$$\mathbb{E}_t \left\{ \hat{P}_{k',t} + \hat{\Upsilon}_t - \mu_z^2 \tilde{S}'' \left[\left(\hat{i}_t - \hat{i}_{t-1} \right) - \beta \left(\hat{i}_{t+1} - \hat{i}_t \right) + \hat{\mu}_{z,t} - \beta \hat{\mu}_{z,t+1} \right] \right\} = 0. \tag{59}$$

First order condition w.r.t. b_{t+1}:

$$
\mathbb{E}_t \left[
\begin{array}{c}
-\hat{\psi}_{z,t} + \dfrac{\pi \mu_z - \tau^k \beta}{\mu_z \pi} \left(\hat{\psi}_{z,t+1} - \hat{\mu}_{z,t+1} - \hat{\pi}^d_{t+1} + \hat{R}_t \right) \\[2mm]
+ \beta \dfrac{\tau^k}{\mu_z \pi} \left(\hat{\psi}_{z,t+1} - \hat{\mu}_{z,t+1} - \hat{\pi}^d_{t+1} \right)
\end{array}
\right] = 0.
\tag{60}
$$

First order condition w.r.t. $\bar{k}_{t+1}$:

$$
\mathbb{E}_t \left[
\begin{array}{c}
\hat{\psi}_{z,t} + \hat{\mu}_{z,t+1} - \hat{\psi}_{z,t+1} - \dfrac{\beta(1-\delta)}{\mu_z} \hat{P}_{k',t+1} + \hat{P}_{k',t} \\[2mm]
- \dfrac{\mu_z - \beta(1-\delta)}{\mu_z} \hat{r}^k_{t+1}
\end{array}
\right] = 0.
\tag{61}
$$

Law of motion for capital:

$$
\hat{\bar{k}}_{t+1} = (1-\delta) \frac{1}{\mu_z} \hat{\bar{k}}_t - (1-\delta) \frac{1}{\mu_z} \hat{\mu}_{z,t} + \left[1 - (1-\delta) \frac{1}{\mu_z} \right] \hat{\Upsilon}_t
$$
$$
+ \left[1 - (1-\delta) \frac{1}{\mu_z} \right] \hat{i}_t.
\tag{62}
$$

Capacity utilization rate:

$$
\hat{u}_t = \hat{k}_t - \hat{\bar{k}}_t = \frac{1}{\sigma_a} \hat{r}^k_t.
\tag{63}
$$

Aggregate resource constraint:

$$
(1 - \omega_c) \left(\gamma^{c,d} \right)^{\eta_c} \frac{c}{y} \left(\hat{c}_t + \eta_c \hat{\gamma}^{c,d}_t \right) + (1 - \omega_i) \left(\gamma^{i,d} \right)^{\eta_i} \frac{i}{y} \left(\hat{i}_t + \eta_i \hat{\gamma}^{i,d}_t \right) + \frac{g}{y} \hat{g}_t
$$
$$
+ \frac{y^*}{y} \left(\hat{y}^*_t - \eta_f \hat{\gamma}^{x,*}_t + \hat{\bar{z}}^*_t \right)
$$
$$
= \lambda^d \left[\hat{\epsilon}_t + \alpha \left(\hat{k}_t - \hat{\mu}_{z,t} \right) + (1 - \alpha) \hat{H}_t \right]
$$
$$
- \left(1 - \tau^k \right) r^k \frac{\bar{k}}{y} \frac{1}{\mu_z} \left(\hat{k}_t - \hat{\bar{k}}_t \right).
\tag{64}
$$

Equilibrium law of motion for net foreign assets:

$$
\hat{a}_t = - y^* \widehat{mc}^x_t - \eta_f y^* \hat{\gamma}^{x,*}_t + y^* \hat{y}^*_t + y^* \hat{\bar{z}}^*_t + (c^m + i^m) \hat{\gamma}^f_t
$$
$$
- c^m \left[-\eta_c (1 - \omega_c) \left(\gamma^{c,d} \right)^{-(1-\eta_c)} \hat{\gamma}^{mc,d}_t + \hat{c}_t \right]
$$
$$
+ i^m \left[-\eta_i (1 - \omega_i) \left(\gamma^{i,d} \right)^{-(1-\eta_i)} \hat{\gamma}^{mi,d}_t + \hat{i}_t \right] + \frac{R}{\pi \mu_z} \hat{a}_{t-1}.
\tag{65}
$$

CPI inflation:

$$\hat{\pi}_t^c = \left[(1 - \omega_c) \left(\gamma^{d,c} \right)^{1-\eta_c} \right] \hat{\pi}_t^d + \left[(\omega_c) \left(\gamma^{mc,c} \right)^{1-\eta_c} \right] \hat{\pi}_t^{m,c}. \tag{66}$$

Investment price inflation:

$$\hat{\pi}_t^i = \left[(1 - \omega_i) \left(\gamma^{d,i} \right)^{1-\eta_i} \right] \hat{\pi}_t^d + \left[(\omega_i) \left(\gamma^{mi,i} \right)^{1-\eta_i} \right] \hat{\pi}_t^{m,i}. \tag{67}$$

Gross domestic product:

$$\hat{y}_t = \lambda^d \left[\hat{\epsilon}_t + \alpha \left(\hat{k}_t - \hat{\mu}_{z,t} \right) + (1 - \alpha) \hat{H}_t \right]. \tag{68}$$

Real effective exchange rate:

$$\hat{x}_t = -\omega_c \left(\gamma^{c,mc} \right)^{-(1-\eta_c)} \hat{\gamma}_t^{mc,d} - \hat{\gamma}_t^{x,*} - \widehat{mc}_t^x. \tag{69}$$

Employment equation:

$$\Delta \hat{E}_t = \frac{\beta}{1 + \beta} \mathbb{E}_t \Delta \hat{E}_{t+1} + \frac{(1 - \xi_e)(1 - \beta \xi_e)}{(1 + \beta) \xi_e} \left(\hat{H}_t - \hat{E}_t \right). \tag{70}$$

Domestic interest rate:

$$\hat{R}_t = \hat{R}_t^* + \hat{\tilde{\phi}}_t - \tilde{\phi}_a \hat{a}_t. \tag{71}$$

Government budget constraint:

$$b\hat{b}_t + t\hat{t}_t = \frac{Rb}{\pi^d \mu_z} \left(\hat{R}_{t-1} + \hat{b}_{t-1} - \hat{\pi}_t^d - \hat{\mu}_{z,t} \right) + tr\widehat{tr}_t + g\hat{g}_t. \tag{72}$$

Government expenditures:

$$\begin{aligned} \widehat{gex}_t = {} & \frac{tr}{gex} \widehat{tr}_t + \frac{g}{gex} \hat{g}_t + \frac{r}{gex} \frac{R}{\pi \mu_z (R-1)} \hat{R}_{t-1} + \frac{r}{gex} \frac{\hat{b}_{t-1}}{\pi \mu_z} - \frac{r}{gex} \frac{\hat{\pi}_t}{\pi \mu_z} \\ & - \frac{r}{gex} \frac{\hat{\mu}_{z,t}}{\pi \mu_z}. \end{aligned} \tag{73}$$

Transfers to households:

$$\widehat{tr}_t = \widehat{\tau}_t^{tr} + \hat{\tilde{w}}_t + \hat{H}_t. \tag{74}$$

Fiscal policy rule for government consumption:

$$\hat{g}_t = \rho_g \hat{g}_{t-1} - \phi_\pi \hat{\pi}_t^c - \phi_y \hat{y}_t - \phi_b \hat{b}_t - \phi_d \widetilde{def}_t + \varepsilon_{g,t}. \tag{75}$$

Tax on consumption:

$$\hat{t}_t^a = \omega_c \left(\gamma^{c,mc} \right)^{-(1-\eta_c)} \hat{\gamma}_t^{mc,d} + \hat{c}_t. \tag{76}$$

Taxes and contributions on wages:

$$\hat{t}_t^b = \hat{\bar{w}}_t + \hat{H}_t. \tag{77}$$

Public debt interest payments:

$$\tilde{t}_t^c = \frac{Rb}{\pi \mu_z} \hat{R}_{t-1} + \frac{(R-1)\,b}{\pi \mu_z} \hat{b}_{t-1} - \frac{(R-1)\,b}{\pi \mu_z} \hat{\pi}_t - \frac{(R-1)\,b}{\pi \mu_z} \hat{\mu}_{z,t}. \tag{78}$$

Interest on the amount of the capital services:

$$\tilde{t}_t^d = \frac{r^k k}{\mu_z} \left(\hat{r}_t^k + \hat{k}_t - \hat{\mu}_{z,t} \right). \tag{79}$$

Interest on the amount of foreign bond holdings:

$$\tilde{t}_t^e = \frac{R-1}{\pi \mu_z} \tilde{a}_{t-1}. \tag{80}$$

Profit of domestic firms:

$$\hat{\tilde{\Pi}}_t^d = y \left(\frac{\lambda^d - 1}{\lambda^d} \right) \hat{y}_t - \frac{1}{\lambda^d} \left(y + \phi \right) \left[\alpha \left(\hat{\mu}_{z,t} + \hat{H}_t - \hat{k}_t \right) + \hat{\bar{w}}_t - \hat{\epsilon}_t \right]. \tag{81}$$

Profit of importing firms:

$$
\begin{aligned}
\hat{\tilde{\Pi}}_t^m &= \left\{ c^m \left(\gamma^{mc,d} - \frac{1}{\lambda^d} \right) \eta_c \left[-(1-\omega_c) \left(\frac{1}{\gamma^{c,mc}\gamma^{mc,d}} \right)^{1-\eta_c} \right] + \gamma^{mc,d} c^m \right\} \hat{\gamma}_t^{mc,d} \\
&\quad + c^m \left(\gamma^{mc,d} - \frac{1}{\lambda^d} \right) \hat{c}_t \\
&\quad + \left\{ i^m \left(\gamma^{mi,d} - \frac{1}{\lambda^d} \right) \eta_i \left[-(1-\omega_i) \left(\frac{1}{\gamma^{i,mi}\gamma^{mi,d}} \right)^{1-\eta_i} \right] + \gamma^{mi,d} i^m \right\} \hat{\gamma}_t^{mi,d} \\
&\quad + i^m \left(\gamma^{mi,d} - \frac{1}{\lambda^d} \right) \hat{i}_t \\
&\quad + \frac{1}{\gamma^f} \left[\left(\frac{\eta^{m,c}}{\eta^{m,c} - 1} \right) c^m + \left(\frac{\eta^{m,i}}{\eta^{m,i} - 1} \right) i^m \right] \hat{\gamma}_t^f.
\end{aligned}
\tag{82}
$$

Profit of exporting firms:

$$\widetilde{\overline{\Pi}}_t^x = -y^* \widehat{mc}_t^x. \tag{83}$$

Total tax revenue:

$$\hat{t}_t = \frac{\tau^c t^a}{t} \hat{t}_t^a + \frac{\tau^y t^b}{t} \hat{t}_t^b + \frac{\tau^k}{t} \left(\tilde{t}_t^c + \tilde{t}_t^d + \tilde{t}_t^e + \tilde{t}_t^f \right). \tag{84}$$

Deficit:

$$\widetilde{def}_t = gex \widehat{gex}_t - t\hat{t}_t. \tag{85}$$

Debt-to-GDP ratio:

$$\hat{b}_{y,t} = \hat{b}_t - \hat{y}_t. \tag{86}$$

Deficit-to-GDP ratio:

$$\widetilde{def}_{y,t} = \frac{\widetilde{def}_t}{y} - \frac{def}{y} \hat{y}_t. \tag{87}$$

Relative prices:

$$\hat{\gamma}_t^{mc,d} = \hat{\gamma}_{t-1}^{mc,d} + \hat{\pi}_t^{m,c} - \hat{\pi}_t^d \tag{88}$$

$$\hat{\gamma}_t^{mi,d} = \hat{\gamma}_{t-1}^{mi,d} + \hat{\pi}_t^{m,i} - \hat{\pi}_t^d \tag{89}$$

$$\hat{\gamma}_t^{x,*} = \hat{\gamma}_{t-1}^{x,*} + \hat{\pi}_t^x - \hat{\pi}_t^* \tag{90}$$

$$\hat{\gamma}_t^f = \widehat{mc}_t^x + \hat{\gamma}_t^{x,*} \tag{91}$$

$$\hat{\gamma}_t^{c,d} = \omega_c \left(\gamma^{mc,c} \right)^{(1-\eta_c)} \hat{\gamma}_t^{mc,d} \tag{92}$$

$$\hat{\gamma}_t^{i,d} = \omega_i \left(\gamma^{mi,i} \right)^{(1-\eta_i)} \hat{\gamma}_t^{mi,d} \tag{93}$$

Exogenous shock processes:

$$\hat{\xi}_t = \rho_\xi \hat{\xi}_{t-1} + \varepsilon_{\xi,t}, \quad \varepsilon_{\xi,t} \overset{iid}{\sim} N\left(0, \sigma_\xi^2\right), \tag{94}$$

where $\xi_t = \left\{ \mu_{z,t}, \epsilon_t, \lambda_t^j, \zeta_t^c, \zeta_t^h, \Upsilon_t, \tilde{\phi}_t, \tilde{z}_t^*, \tau_t^{tr}, g_t \right\}$ for $j = \{d, mc, mi, x\}$.

B   DATA SOURCES AND DESCRIPTION

Table B.1: *List of variables used in the estimation and their sources*

Symbol	Description	Country	Source
Y_t	*GDP.* Gross domestic product in millions of euro, chain-linked volumes, reference year 2005, SA	Sl	Eurostat
C_t	*Private consumption.* Household and NPISH final consumption expenditure in millions of euro, chain-linked volumes, reference year 2005, SA	Sl	Eurostat
I_t	*Investment.* Gross fixed capital formation in millions of euro, chain-linked volumes, reference year 2005, SA	Sl	Eurostat
G_t	*Government consumption.* Final consumption expenditure of general government in millions of euro, chain-linked volumes, reference year 2005, SA	Sl	Eurostat
X_t	*Exports.* Exports of goods and services in millions of euro, chain-linked volumes, reference year 2005, SA	Sl	Eurostat
M_t	*Imports.* Imports of goods and services in millions of euro, chain-linked volumes, reference year 2005, SA	Sl	Eurostat
W_t	*Gross wages and salaries.* Gross wages and salaries (income structure of GDP), current prices, millions of euro, SA	Sl	SORS
E_t	*Employment.* Employment (domestic concept), persons (in 1000), SA	Sl	SORS
P_t^d	*GDP deflator.* Price index, reference year 2005, SA	Sl	Eurostat
P_t^c	*CPI index.* Consumer price index, current month/average of the year 2005, not SA	Sl	Eurostat/ECB
x_t	*Real exchange rate.* Real effective exchange rate, consumer price index deflator, reference year 2005, 28 trading partners	Sl	Eurostat
R_t	*Domestic interest rate.* Monetary interest rate on new loans to non-financial corporations in domestic currency in percent	Sl	BS/IMAD
Y_t^*	*Foreign GDP.* Gross domestic product in millions of euro, chain-linked volumes, reference year 2005, SA	EA12	Eurostat
P_t^*	*Foreign GDP deflator.* Price index, reference year 2005, SA	EA12	Eurostat
R_t^*	*Foreign interest rate.* 12-month money market interest rate in percent	EA12	Eurostat

Notes: SA: seasonally adjusted; SORS: Statistical Office of the Republic of Slovenia; IMAD: Institute of Macroeconomic Analysis and Development of the Republic of Slovenia; BS: Bank of Slovenia

C   PRIOR AND POSTERIOR DISTRIBUTIONS

Figure C.1a: *Prior and posterior distributions of the structural parameters, friction parameters*
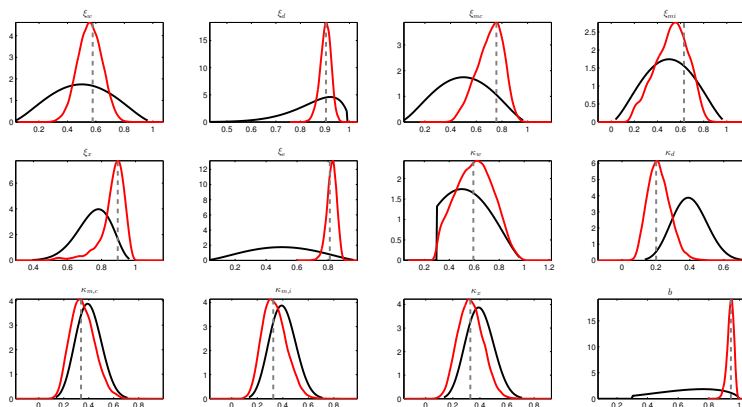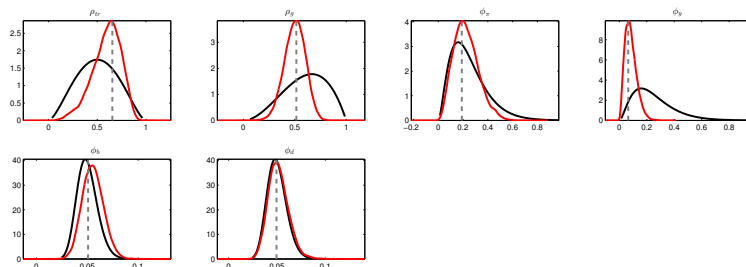

 Notes: Prior (black) vs. posterior (red) distributions for the estimated structural parameters. The gray dashed vertical line is the posterior mode obtained from the posterior kernel maximization. Estimates obtained from Bayesian estimation of the DSGE model using Slovenian macroeconomic data from 1995Q1-2014Q4.

Figure C.1b: *Prior and posterior distributions of the structural parameters, friction parameters (cont.)*
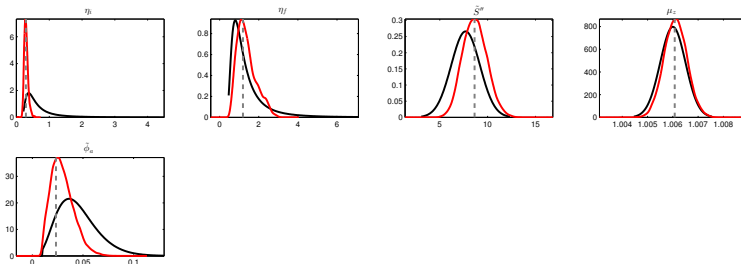
 Notes: Prior (black) vs. posterior (red) distributions for the estimated structural parameters. The gray dashed vertical line is the posterior mode obtained from the posterior kernel maximization. Estimates obtained from Bayesian estimation of the DSGE model using Slovenian macroeconomic data from 1995Q1-2014Q4.

Figure C.1c: *Prior and posterior distributions of the structural parameters, shock processes parameters*
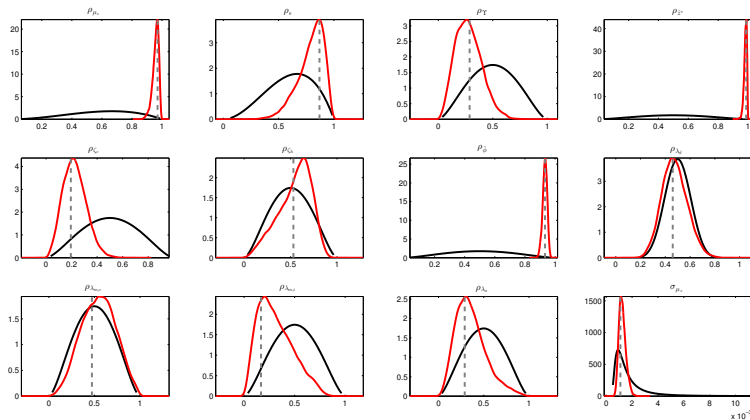
 Notes: Prior (black) vs. posterior (red) distributions for the estimated structural parameters. The gray dashed vertical line is the posterior mode obtained from the posterior kernel maximization. Estimates obtained from Bayesian estimation of the DSGE model using Slovenian macroeconomic data from 1995Q1-2014Q4.

Figure C.1d: *Prior and posterior distributions of the structural parameters, shock processes parameters (cont.)*
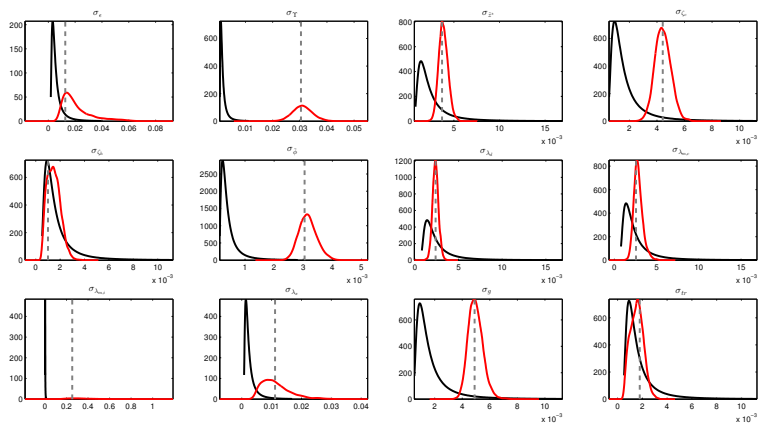
Notes: Prior (black) vs. posterior (red) distributions for the estimated structural parameters. The gray dashed vertical line is the posterior mode obtained from the posterior kernel maximization. Estimates obtained from Bayesian estimation of the DSGE model using Slovenian macroeconomic data from 1995Q1-2014Q4.

Figure C.1e: *Prior and posterior distributions of the structural parameters, policy parameters*

 Notes: Prior (black) vs. posterior (red) distributions for the estimated structural parameters. The gray dashed vertical line is the posterior mode obtained from the posterior kernel maximization. Estimates obtained from Bayesian estimation of the DSGE model using Slovenian macroeconomic data from 1995Q1-2014Q4.

D   DATA AND ONE-SIDED PREDICTED VALUES FROM THE MODEL

Figure D.1: *Data (thick black) and one-sided Kalman-filtered predictions (thin red)*
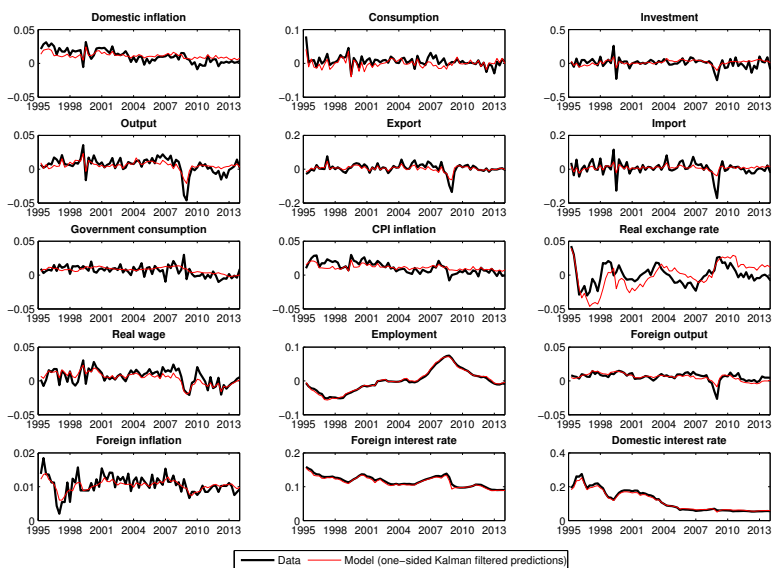
Notes: The plot shows deviations from steady state/trend.

E   SMOOTHED SHOCKS

Figure E.1a: *Smoothed (two-sided Kalman filtered) estimates of the structural shocks (deviations from steady state)*
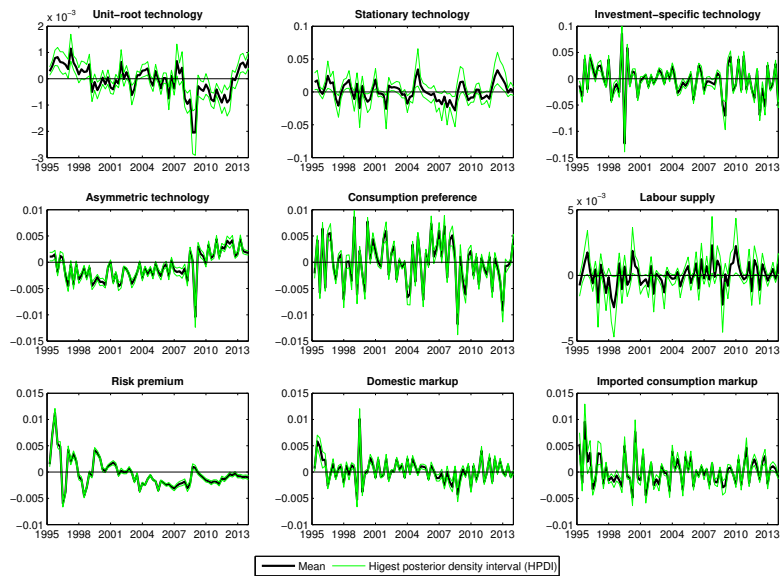
Notes: The plot shows deviations from steady state.

Figure E.1b: *Smoothed (two-sided Kalman filtered) estimates of the structural shocks (deviations from steady state) (cont.)*
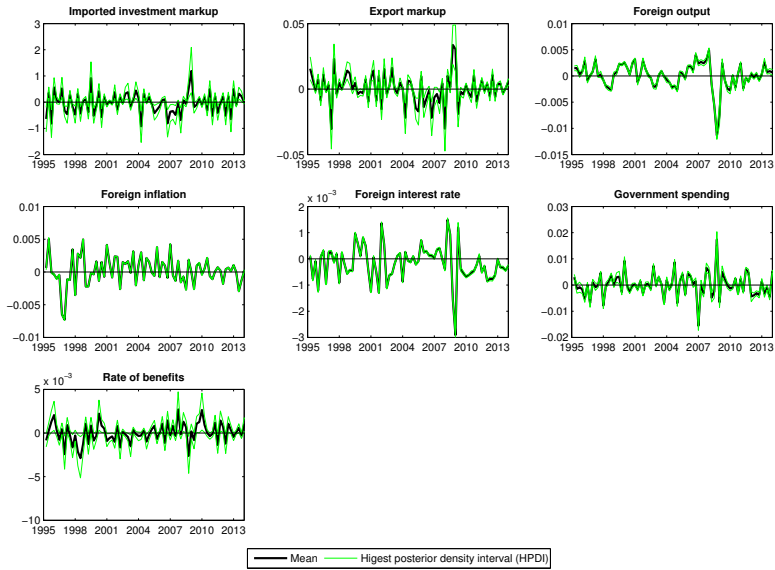
Notes: The plot shows deviations from steady state.

F   IMPULSE RESPONSE FUNCTIONS

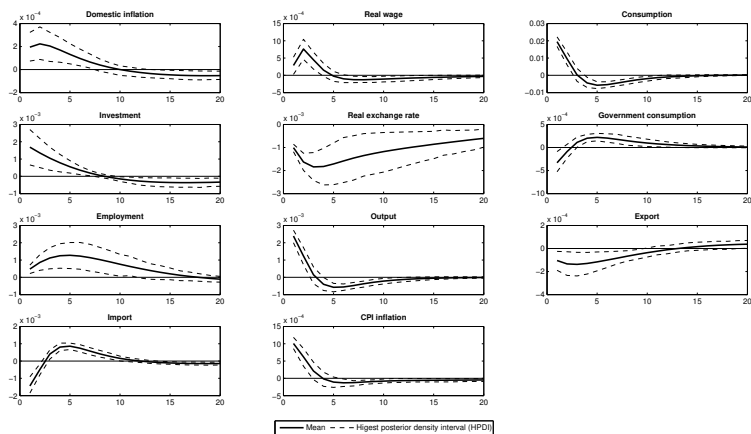Figure F.1: *Impulse responses to a unit-root technology shock*
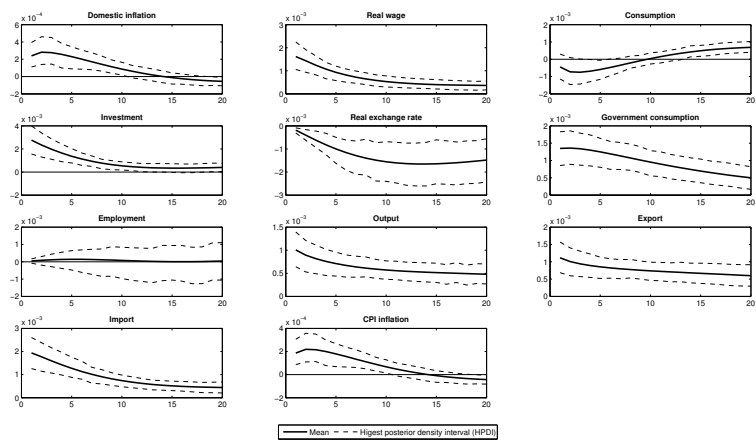
 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.

Figure F.2: *Impulse responses to a stationary technology shock*
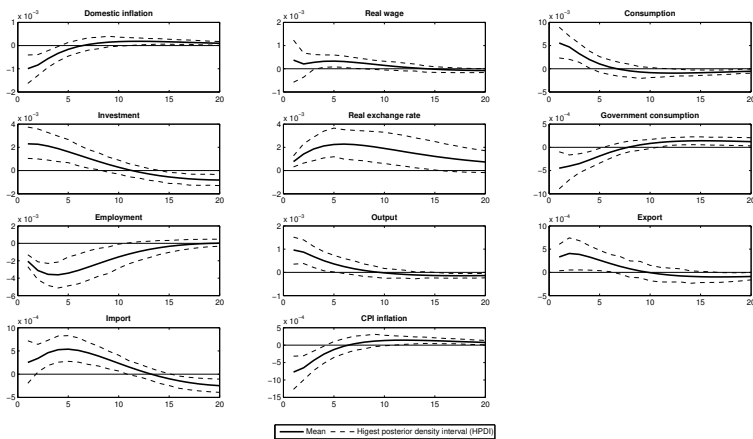
 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.
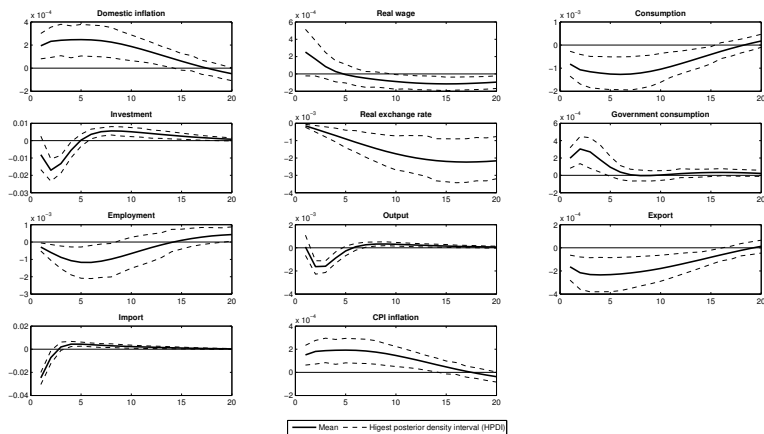
Figure F.3: *Impulse responses to an investment-specific technology shock*
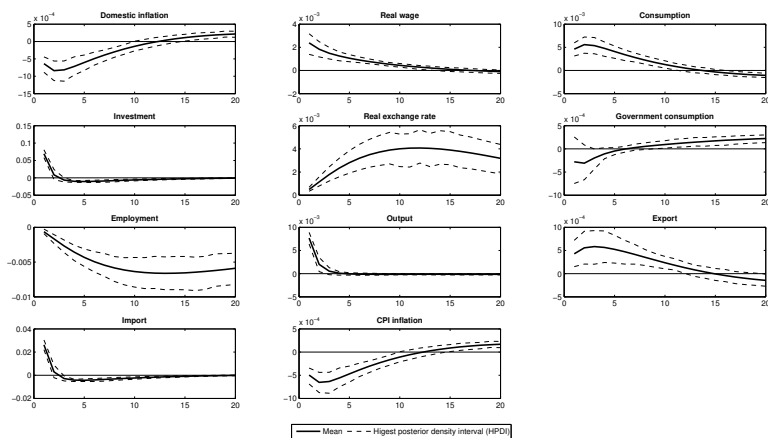
 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.
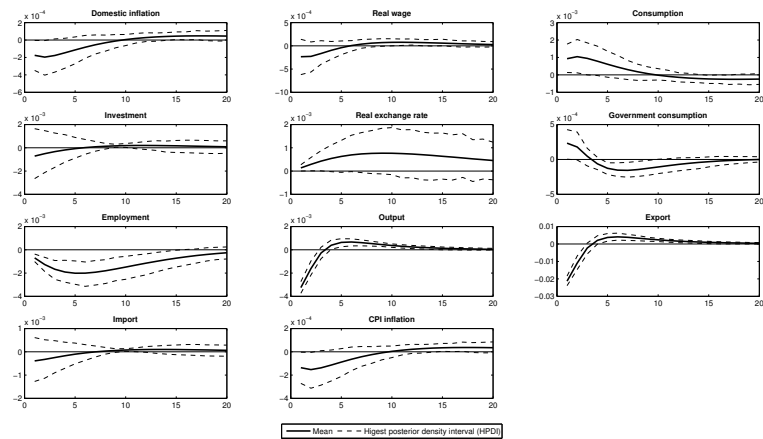
Figure F.4: *Impulse responses to a consumption preference shock*
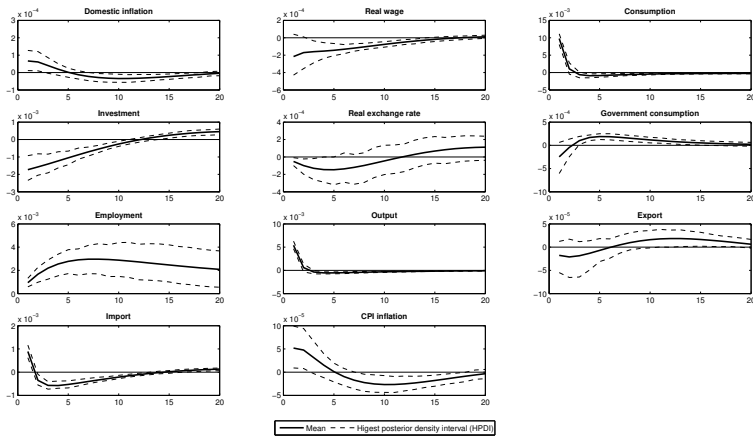
 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.

Figure F.5: *Impulse responses to a labour supply shock*
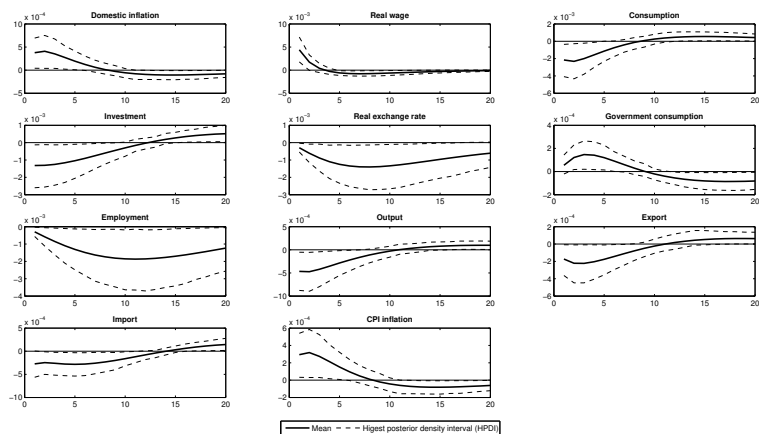
 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.

Figure F.6: *Impulse responses to a domestic mark-up shock*
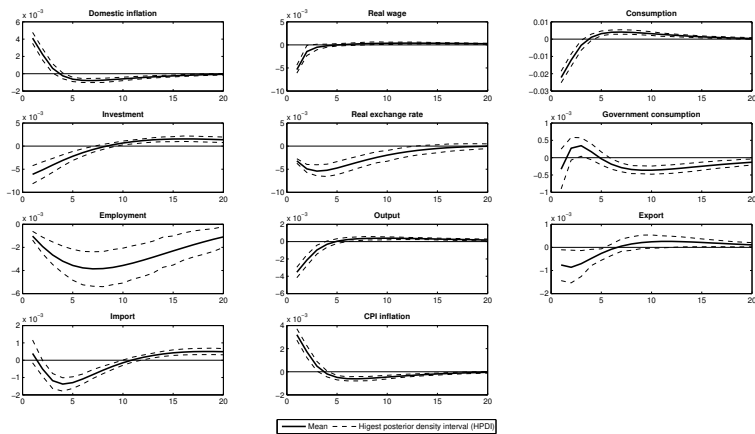

 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed
lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.

Figure F.7: *Impulse responses to an imported consumption mark-up shock*

 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.

Figure F.8: *Impulse responses to an imported investment mark-up shock*

 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.

Figure F.9: *Impulse responses to an export mark-up shock*

 Notes: The solid line shows the average impulse responses results over the MCMC parameter draws; the dashed lines at the 5% and 95% posterior intervals. The impulse horizon is measured in quarters.
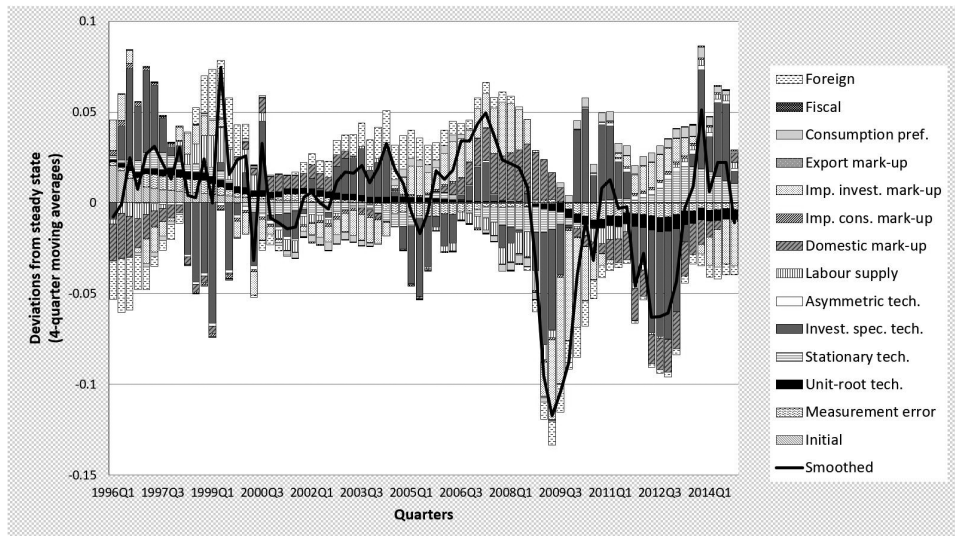
G   HISTORICAL DECOMPOSITIONS

Figure G.1: *Historical decomposition of consumption growth in terms of structural shocks*
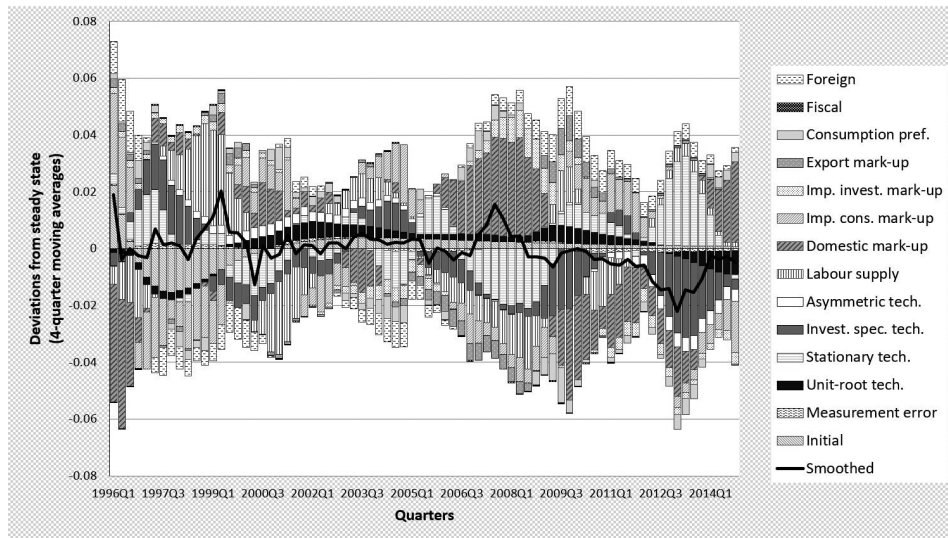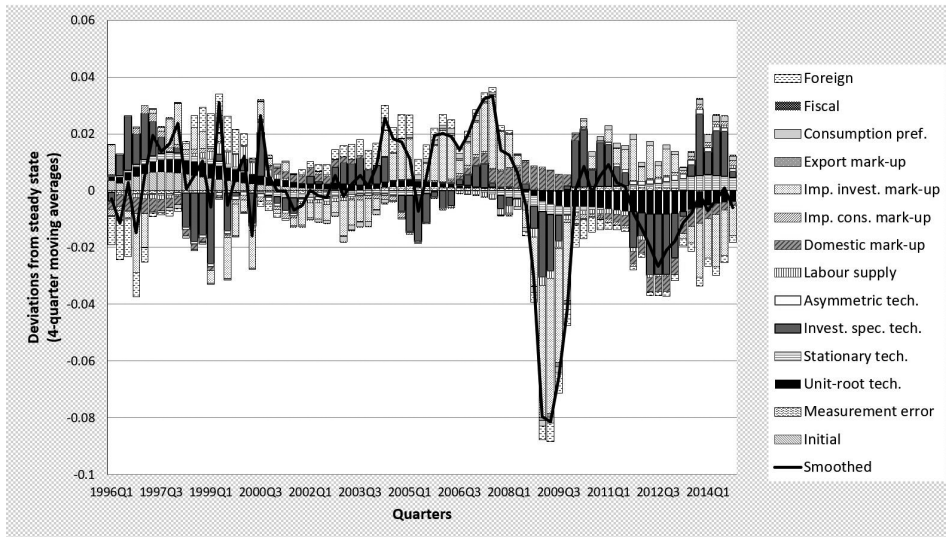

Notes: The smoothed observed time series is plotted excluding its mean.

Figure G.2: *Historical decomposition of investment growth in terms of structural shocks*
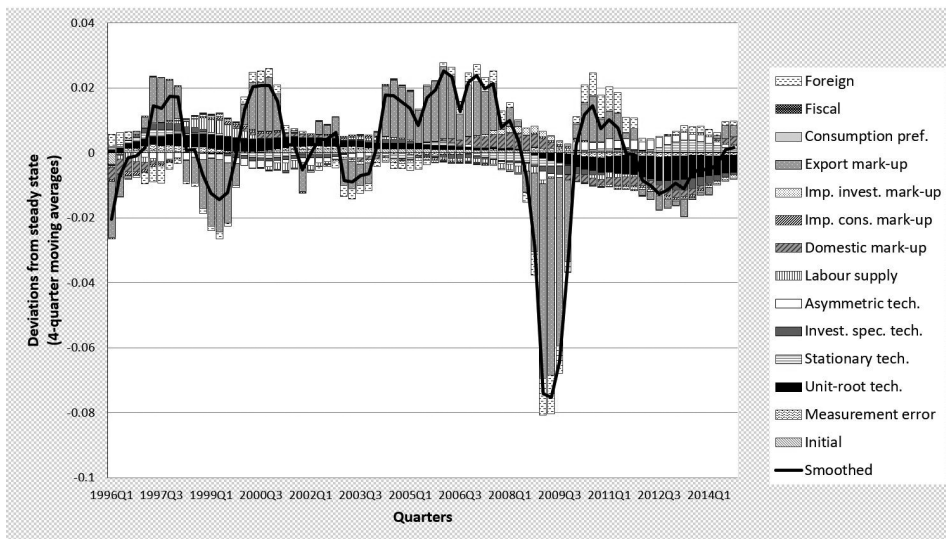

Notes: The smoothed observed time series is plotted excluding its mean.

Figure G.3: *Historical decomposition of import growth in terms of structural shocks*

Notes: The smoothed observed time series is plotted excluding its mean.

Figure G.4: *Historical decomposition of export growth in terms of structural shocks*

Notes: The smoothed observed time series is plotted excluding its mean.