Fiscal Policy Matters

A New DSGE Model for Slovakia

Zuzana MŰČKA and Michal HORVÁTH

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Abstract

The paper sets out a DSGE model designed and calibrated to match key stylized facts about the Slovak economy. The model includes a detailed fiscal policy block that allows a thorough analysis of fiscal policy measures. To evaluate the performance of the model, the response of the economy to a technology shock and to a foreign demand shock is considered under alternative fiscal adjustment scenarios. We find that a well-designed programme involving increases in transfers as well as taxes can stabilize the economy in the short run and improve longer-term growth prospects following a shock with adverse fiscal implications. We study the consequences of fiscal policy shocks in and away from the steady state of the model. The exercise yields implied fiscal multipliers that are relatively large in spite of Slovakia being a small open economy. Raising taxes on employment is particularly bad for the real economy, especially in the long run, whilst cutting government wage bill is the least harmful way of reducing spending.

Keywords: dynamic stochastic general equilibrium model, simulations, fiscal rules, fiscal multipliers, fiscal consolidation.

JEL Classification: E32, C61, C63, D58, E62, H63, H5

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1 Introduction

The consequences of alternative fiscal consolidation strategies have been on top of the policy agenda in Slovakia and elsewhere ever since the attention of policy makers and indeed markets turned towards dealing with the fiscal consequences of the recent severe economic downturn. Although the literature on fiscal multipliers offers some more or less disputed general lessons, the models used in the literature – whether empirical or theoretical – rarely meet the requirements for a meaningful applied policy analysis. Fiscal instruments are usually not considered in a variety that would resemble the real-world conduct of policy, and there are potentially important country-specific aspects ignored in analyses usually tailored to a specific advanced economy. Hence, this paper presents a DSGE model designed and calibrated to fit the Slovak data, with a sufficiently rich fiscal block so that it is equipped to take a realistic account of the policy measures potentially implemented by the Slovak government.

The existing literature on DSGE models in the context of Slovakia is characterized by a rather stylized representation of the fiscal side. This paper, therefore, considers an array of fiscal instruments both on the revenue and the expenditure side, implemented via rules that aim to mimic the real-world decision making of the Slovak authorities. This is an important extension on Slovak models built recently by Zeman and Senaj (2009) and Zeman et al. (2010). The former medium size New Keynesian small open economy model is based on the original Swiss medium-scale DSGE model proposed by Cuche-Curti et al. (2009). The latter uses the two-country monetary union setup of Pytlarczyk (2005) as a benchmark.

The model is unique in three additional ways. First, it considers – in a stylized fashion in the context of a linear economy – the evolution of the risk premia on private and public debt. High private indebtedness is penalized by the risk premium charged by the foreign investor increases which increases with the country’s current net foreign liabilities position. Although standard DSGE models treat government bonds as risk-free securities, several studies (e.g. Erceg and Linde (2011), Corsetti et al. (2012) and Benk and Jakab (2012)) have recently considered the country’s fiscal policy credibility and allow interest rate spreads to depend endogenously usually on past government debt, lagged primary deficit, or their deviations from the desired target levels. We go further and instead of measures of past fiscal stance, we take into account the expectations about evolution of the future debt-to-gdp on a certain time horizon in order to model risk premia on government bonds.

Second, since the conduct of fiscal policy in Slovakia is constrained by a set of domestic and euro area rules, the model has to reflect this. The literature on the design of fiscal policy rules design is rather extensive. It is standard to build in Taylor-like style reaction functions that respond to deviations of public debt or deficit from their target levels or various output gap measures. For example, Kremer (2004) uses a counter-cyclical fiscal policy rule that allows the deficit to deviate from target in proportion to the impact of automatic stabilisers while any additional impact on the deficit, for example on interest expenditure, has to be offset through adjustments of government consumption or taxes. In Sims and Wolff (2013), Forni et al. (2007), Ratto et al. (2008) and Erceg and Linde (2011) rules for tax rates take into consideration the deviation of the public debt-to-gdp or debt target from their equilibrium levels. On the other hand, Stork...
et al. (2009), Canzoneri et al. (2006) and Alitev et al. (2014) use expenditure-based rules arguing that changes in tax rates require a change in legislation which can be very inflexible. However, there is little empirical support for Taylor-type rules for fiscal policy on Slovakia. Therefore, we model fiscal adjustment in a way that reflects the common practice whereby the government reacts to a no-policy-change scenario by setting a headline deficit target (accounting for general equilibrium effects in a rather imperfect manner), which determines the amount of desired fiscal consolidation. This amount is then allocated to different revenue and expenditure items. The fiscal consolidation rule takes into account primarily the debt-to-gdp and the deficit-to-gdp, both in terms of the corresponding gaps (the difference of the current ratio from the current target ratio) and trends (the difference of the current ratio from the previous ratio).

Third, the model aims to account not only for the fact that Slovakia is a small open economy but that its demand and supply structure differs in important ways from those of many advanced economies. Moreover, to emphasize the role of fiscal policy in the production following Forni et al. (2007), Cavallo (2005) and Carvalho and Martins (2011) we let the domestic economy to operate in two sectors – productive private and unproductive public, fully financed by the government. The major driving element of Slovak economy–export–is besides export prices and foreign price level driven essentially by the foreign demand reflecting current and expected euro area output gap. Although Slovakia’s gdp comes mainly from the sector of services, the industrial sector also plays an important role within its economy. Therefore, industrial (private sector) firms are strongly dependent on global price level as they take as given prices of their substantial production inputs - imported raw materials and oil. Through these channels, the country faces foreign demand and price shocks. This dependence of input factor is accentuated by the design of sectoral production technology. Following Cuche-Curti et al. (2009), firms manufacture their heterogeneous goods using a three stage production function gradually combining physical capital, labour, energy and imported raw materials. Production is also affected by technology shocks and infrastructure financed by the government.

The model provides intuitive dynamics following standard shocks. We also find that the nature of adjustment on the fiscal side to deal with the adverse budgetary consequences of structural shocks has important dynamic and distributive implications. We show that – given their powerful impact on the real economy – increasing transfers to consumers can stabilize the economy as well as balance the budget in the short run, whilst relying on labour income tax hikes has negative implications for activity in the short run but is associated with strong and persistent positive mid- and long-term effects on the economy. Hence, from an intertemporal perspective a suitable combination of the two appears desirable. There is, however, another aspect to this adjustment: the choice of fiscal instrument has a significant impact on the welfare of Ricardian versus non-Ricardian agents (see also Kremer (2004), Gali et al. (2002), Gali et al. (2002)).

We then simulate the consequences of innovations in fiscal policy (using different policy instruments) when the model is in its steady state. Also, using a set of realistic initial conditions to account for the current (post-2009-crisis) state of the Slovak economy, we simulate a gradual adjustment driven by fiscal rules that guide the economy to a state in which debt hits a target level of debt. From these two exercises, following Uhlig (2010), we compute implied fiscal multipliers for a wide array of revenue and spending instruments.

\[ \text{In this paper, we do not provide an explicit normative analysis or welfare calculations. This is a significant extension of the analysis requiring higher-order approximations which we plan to do in the future.} \]
We find the multipliers to be relatively large, especially given that the context is a highly open economy but in line with standard multipliers estimates (Blanchard and Perotti (1999), Alesina et al. (2000), Perotti (2004), Burnside et al. (2004)). Cutting the government wage bill is associated with the lowest real income losses. Raising taxes is more harmful for output, in particular when viewed from a long-term perspective. Fiscal adjustment through labour income taxes is costly in the short term and a lot more damaging over a longer horizon.

The rest of the paper is organized as follows. Section 2 sets out the model in more detail. In section 3, we first calibrate the steady state of the model to fit the Slovak data. Then, we examine the performance of the model in the wake of standard structural shocks deemed relevant in the context of Slovakia: a positive technology shock and negative foreign demand shock. In this section, we also compute implied fiscal multipliers from our policy exercises. Finally, section 4 concludes.
2 Model Scheme

The model is a medium-scale DSGE model tailor-made to model developments in the Slovak economy. It highlights some key differences relative to standard practice in DSGE modelling presented by Smets and Wouters (2002), Christiano et al. (2001), Schmitt-Grohe and Uribe (2002) and Gali et al. (2002). In what follows, we explain in more detail and justify a few technical solutions that make the model internally consistent and sketch the baseline model leading equations.

2.1 Technologies and Firms

The domestic economy consists of two sectors - productive private sector and unproductive public sector. The private sector represented by producers and exporters generates in a perfectly competitive environment four types of final good and for each of them a continuum of intermediate goods indexed by $i \in [0, 1]$. The final good is used for consumption and investment by the households, government purchase or exported to foreign economy. There is monopolistic competition in the markets for intermediate goods created by producers.

Within the two-stage private sector production structure, we distinguish between four types of firms:

- Retailers and exporters generate in a perfectly competitive environment four types of homogeneous final goods used directly for consumption and investment by the households, government purchase or exported to foreign economy.
- Producers operating on monopolistically competitive market create differentiated intermediate goods with the specific final purpose (household consumption and investment, government purchase, export).
- Importers transfer and aggregate differentiated imported goods into uniform bundles thereafter employed in production process.

2.1.1 Final Goods Producers

Retailers and exporters aggregate on a zero-profit basis in a perfectly competitive market the intermediate good manufactured by producers into homogeneous bundles to be either purchased by domestic households (for consumption $c$ and investment $i$) and government $g$ or exported abroad (export $f$). The Dixit and Stiglitz (1977) aggregation takes the form of

$$x_t = \left\{ \int_0^1 [x^i_t(i)]^{\theta x} \, di \right\}^{1/\theta x}, \quad x \in \{f, c, i, g\},$$

Therefore the cost minimizing demand of retailer for producers’ specific goods $x^i_t(i)$ given the aggregate price index $P^x_t$ satisfies the following relationship

$$x^i_t(i) = \left[ \frac{P^x_t(i)}{P^x_t} \right]^{-\frac{\theta x}{\theta - 1}} x_t \quad \text{with} \quad P^x_t = \left\{ \int_0^1 \left[ P^x_t(i) \right]^{\frac{\theta x}{\theta - 1}} \, di \right\}^{\frac{\theta - 1}{\theta x}}, \quad \text{for} \quad x \in \{f, c, i, g\}. \quad (1)$$

Similarly, importers aggregate the imported intermediate goods into homogeneous bundles that enter in the domestic production process. Hence,

$$m^i_t(i) = \left[ \frac{P^m_t(i)}{P^m_t} \right]^{-\frac{\theta m}{\theta - 1}} m_t \quad \text{with} \quad P^m_t = \left\{ \int_0^1 \left[ P^m_t(i) \right]^{\frac{\theta m}{\theta - 1}} \, di \right\}^{\frac{\theta - 1}{\theta m}}. \quad (2)$$
The stochastic parameters \((1 - \theta^i)^{-1}, x \in \{m, f, c, i, g\}\) represent the elasticity of substitution among differentiated domestic or imported intermediate products manufactured and utilized either by domestic economy agents (households, government) or abroad (export goods) or in the domestic production process (import). Furthermore, assuming \(\theta^i = \theta^* + \eta^\theta_i\), they determine the price mark-ups in the intermediate-goods markets with the serially uncorrelated zero mean stochastic elements \(\eta^\theta_i\), for all \(x \in \{m, f, c, i, g\}\)\].

The total amount of goods for export \(f_i\) is directly determined by the exogenous foreign aggregate demand function driven by the terms of trade, \(P^d_i / P^d_e = P^e_i\):

\[
f_i = \omega^* \left( P^e_i \right)^{-\sigma^e_i} \Omega^e_i,
\]

with the domestic economy export goods priced in the currency of the foreign economy. \(P^d_e\) is the aggregate price index in the foreign country. \(\Omega^e_i\) represents the foreign aggregate demand for final goods strongly affected by the foreign output gap, \(\omega^*\) is the share of domestic export in the overall import of the foreign economy and \(\sigma^e_i = \sigma^* + \eta^0_i\) the time-dependent foreign elasticity of substitution among the differentiated goods exported to foreign economy with \(\eta^0_i\) i.i.d. normal.

### 2.1.2 Intermediate Goods Producers

In the production process captured by a three-stage combined CES and Cobb–Douglas type production functions, producers gradually combine capital \(k^s_t\) and labour inputs \(h^{p,s}_{t}\), costlessly supplied government investment into private sector infrastructure \(\mathscr{I}^p\), quality technology and productivity shocks, energy \(e^s_t\) and a bundle of imported intermediate goods \(m^s_t\) in order to manufacture differentiated intermediate goods with the specific final purpose \(x\) (household consumption \(c\), and investment \(i\), government purchase \(g\) and export \(f\)).\]

**Technological progress is labour-augmenting.** Furthermore we assume that both the TFP shock \(\eta^{tp,p}_t\) and the technology-specific shock \(\zeta^s_t\) enter stationary production technology.

\[
x_t(i) = \zeta^s_t \left\{ \left[ \alpha^s_t \right]^{\alpha^s_t} \left[ \mathcal{O}^s_t(i) \right]^{\frac{\alpha^s_t}{\alpha^s_t}} \right\}, \quad (4a)
\]

\[
\mathcal{O}^s_t(i) = \eta^{tp,p}_t \left\{ \left[ \alpha^s_t \right]^{\alpha^s_t} \left[ \mathcal{O}^s_t(i) \right]^{\frac{\alpha^s_t}{\alpha^s_t}} \right\} + \left( 1 - \alpha^s_t \right)^{\frac{\alpha^s_t}{\alpha^s_t}} \left[ m^s_t(i) \right]^{\frac{\alpha^s_t}{\alpha^s_t}}, \quad (4b)
\]

\[
\Phi^s_t(i) = \mathcal{S}^t \left[ \mathcal{L}^s_t(i) \right]^{\sigma^s_t} \left[ h^{p,s}_t(i) \right]^{1-\sigma^s_t}, \quad (4c)
\]

---

4In the log-linear version of our model, the serially uncorrelated zero mean price mark-up shocks \(\eta^\theta_i\), \(\eta^\theta_i\) and \(\eta^\theta_i\) can be interpreted as a cost-push shock (see Smets and Wouters 2002 or Justiniano et al. 2008) to price inflation specific to each type of the final usage.

5The assumed composition of the sectoral production function is a substantial extension of the originally assumed form introduced in Cuche-Curti et al. (2009) and adopted by Zeman and Senaj (2009) in the former Slovak DSGE model. In contrast to these models, we assume perfect substitution between physical capital and labour.

6Technically, following Kollmann (2002), we denote \(h^{p,s}_t(i)\) as an index of different types of labour used by the private sector firm \(i\) to produce goods of type \(x\).

7Following Adolfson et al. (2005), Forst et al. (2007), Justiniano et al. (2008), and Pytlicka (2005) for the labour-augmenting type of process we assume that \(log \nu_t = \rho^s log \nu_{t-1} + (1 - \rho^s) log \nu_t + \epsilon^s_t\) with \(\epsilon^s_t = \gamma \nu_{t-1}\) and the white noise innovations \(\epsilon^s_t\). Therefore, any generic variable \(x_t\) is treated in its detrended form \(x_t = X_t / \nu_t\).

8For a purely technical purpose, here we borrow the idea introduced by Andre et al. (2009). The design of the technology-specific productivity shock and the way it enters production process allows us to assume unit real prices for all types of goods in the equilibrium.
...where due to variable capital utilization \( u_i, k_t = u_t k_{t-1}/v_t \) and
\[
\mathcal{J}_t^p = 1 + \frac{2}{\pi} \arctan \frac{\kappa_{t} - \kappa_{f}}{\kappa_{f}}, \quad \text{for} \quad \kappa_{t} = (1 - \delta_p) \frac{\kappa_{t-1}}{v_t} + i s_{t}^{p} \left[ \exp \{ \eta_{t}^{i} \} - \mathcal{J}_{an}^{i} \left( \frac{e_{t}^{p} s_{t}^{p}}{e_{t-1}^{p} s_{t-1}^{p}} \right) \right] \tag{4d}
\]
evaluates extra production generated government infrastructure investment provided to the private sector.\(^9\) Hence, each producer chooses the amounts of inputs (labour, capital, energy and imported intermediate goods) to minimize the final purpose \( x \) specific production cost function 
\[
\mathcal{C}_{t+1}^x(i) \equiv w_{t}^{p} h_{t}^{p}(i) + z_{t} k_{t}^{x}(i) + p_{t}^{i} e_{t}^{x}(i) + p_{t}^{m} m_{t}^{x}(i), \tag{5}
\]
subject to \((4a)-(4c)\). The resulting optimal input–output ratios will be identical across intermediate goods producers and equal to the aggregate input–output ratio. Thus the producers’ marginal costs are independent of the intermediate good produced and are given by
\[
\psi_{t} = [\xi_{t}]^{-1} \left\{ \alpha_{m}^{1} \left[ \xi_{t}^{p} \right]^{1-\sigma_{m}} + (1 - \alpha_{m}^{1}) \left[ p_{t}^{m} \right]^{1-\sigma_{m}} \right\}^{1-\sigma_{m}}, \tag{6}
\]
where \( \xi_{t}^{p} \) and \( \xi_{t}^{q} \) stand for the labour–capital and actual domestic production associated cost aggregates identical across all domestic producers making goods for the given purpose \( x \) and are given as:
\[
\Xi_{t}^{\psi} = [\eta_{t}^{p}]^{-1} \left\{ \alpha_{c}^{1} \left[ \Xi_{t}^{\psi} \right]^{1-\sigma_{c}} + (1 - \alpha_{c}^{1}) \left[ p_{t}^{c} \right]^{1-\sigma_{c}} \right\}^{1-\sigma_{c}},
\]
\[
\Xi_{t}^{\eta} = [\mathcal{J}_{t}^{p}]^{-1} (w_{t}^{p})^{1-\sigma_{t}} (1 - \alpha_{t}^{1})^{1+\sigma_{t}} (z_{t})^{\sigma_{t}} (\sigma_{t} - \sigma_{t}^{i})^{-\sigma_{t}}. \tag{6}
\]

### 2.1.3 Price Setting

Producers have market power and set prices for their outputs. Furthermore, as their production for different final usage is mutually independent, the same holds for the policies they adopt when pricing their intermediate goods for each specific final usage separately. The same holds for importers when pricing the imported intermediate goods over real exchange rate representing their marginal costs.

Hence each firm maximizes its expected real–valued profits using a stochastic discount factor applied by firm’s stakeholders (domestic Ricardians) \( \tilde{\rho}_{t+k} = \tilde{\beta}_{t+k} = \tilde{\beta}_{t+k} \), the time \( t \) discounted marginal rate of intertemporal substitution between consumption of domestic Ricardian households at \( t \) and at \( t+k \):
\[
\pi_{t}^{x} = \left\{ \begin{array}{ll}
(\tilde{\rho}_{t} - \psi_{t}^{x}) \left[ \tilde{\rho}_{t}^{x} / p_{t}^{x} \right]^{-\frac{1}{m_{t}}} x_{t}, & x \in \{ m, c, i, g \}, \\
(\tilde{r}_{t} - \psi_{t}^{f}) \left[ \tilde{r}_{t}^{f} / p_{t}^{f} \right]^{-\frac{1}{1-q_{t}}} f_{t}, & x = f .
\end{array} \right.
\]

\(^9\)From \((4d)\) it follows that only a percentage change of the private sector infrastructure from its equilibrium value affects production. In fact influence of this shock is bounded and its marginal impact declines with shock magnitude.

\(^10\)Recalling Christiano et al. \((2001)\) above, \( \mathcal{J}^{\eta^p} (x) = \mathcal{J}^{\eta^p} (x - 1)^2 \) denotes the detrended government investment adjustment cost function and \( \eta^p \) the exogenous variation shock. Note that \( \mathcal{J} \) is defined so that \( \mathcal{J}(0) = \mathcal{J}^p(1) = 0 \) and \( \mathcal{J}(1) > 0 \).

\(^\dagger\)We ignore fixed production costs as assumed by e.g., Smets and Wouters \((2002)\), Christiano et al. \((2001)\) or Justiniano et al. \((2008)\) and prefer non–zero equilibrium firms’ profits. Furthermore, in order to improve the performance of a supply side of the model, in the future, it may be necessary to incorporate some form of real rigidities into the model. A possible approach presented by Stork et al. \((2009)\), Alitev et al. \((2014)\) or Benk and Jakab \((2012)\) is to replace the linear cost function \((5)\) by the sum of standard symmetric quadratic adjustment costs functions for all input factors as originally introduced by Hamermesh and Pfann \((1996)\).
Pricing is according to Calvo (1983) with the non-optimizers, whose share in the economy is $\chi_t$, following the price-indexation scheme:

$$p_t^i = q_t^i p_{t-1}^i,$$  \quad \text{for} \quad q_t^i = \begin{cases} (\Pi_t^{c})^{1-\chi_t} (\Pi_t^{i})^{\chi_t} (\Pi_t^{g})^{-1}, & x \in \{m, c, i, g\}, \\ (\Pi_t^{c})^{1-\gamma_t} (\Pi_t^{i})^{\gamma_t} (\Pi_t^{g})^{-1}, & x = f. \end{cases}$$  \quad (7)

Profit maximization performed by importers and producers of domestically utilized goods that are allowed to reoptimize their prices at time $t$ results in the following first–order condition:

$$0 = \sum_{k=0}^{\infty} \chi_{k+1} \left( \hat{\rho}_{t+k} \psi_{t-k} \prod_{l=1}^{k} q_{t+l}^{i} - \frac{\psi_{t+1}^{i}}{1 - \theta_{t+k}^{s}} \hat{\lambda}_{t+k}^{s} \prod_{l=1}^{k} q_{t+l}^{i} \right).$$  \quad (8)

Equation above shows that the price set by any optimizing firm at time $t$ is a function of expected future marginal costs. The optimal price will be a mark–up over these weighted marginal costs. If prices are perfectly flexible ($\chi_t = 0$), the mark–up in period $t$ is equal to $\theta_t^i$. With sticky prices the price mark–up becomes endogenous and variable over time. Furthermore, the aggregate real–valued price dynamics exhibits the following dynamic:

$$p_t^i = \left(1 - \chi_t\right) \left[\hat{\rho}_t^i \psi_t^{i-1} + \chi_t q_t^i \hat{p}_{t-1}^i \right] \frac{\eta_t}{\psi_t^{i-1}}.$$

Therefore, to a first–order approximation, the intermediate goods price inflations $\Pi_t^i$ evolve following the following Phillips curves:

$$\hat{\Pi}_t^i = \begin{cases} \beta E_t [\hat{\Pi}_{t+1}^i] + \chi_t (\hat{P}_{t+1} - \beta \hat{\Pi}_{t+1}^i) - \lambda_t [\hat{P}_t^i - \hat{\psi}_t^i - \hat{\theta}_t^i], & x \in \{m, i, g\}, \\ \frac{\beta}{1 + \beta} E_t (\hat{\Pi}_{t+1}^i) + \frac{\gamma_t}{1 + \beta} (\hat{P}_{t+1} - \beta \hat{\Pi}_{t+1}^i) - \lambda_t [\hat{P}_t^i + \hat{\gamma}_t - \hat{\psi}_t^i + \hat{\lambda}_t^i], & x = f. \end{cases}$$

for $\lambda_t = (1 - \chi_t)(1 - \beta \chi_t)/\chi_t$. Notice that $r_t = s_t P_t^i / P_t^c$ denotes the real exchange rate between the domestic and foreign economy with the nominal exchange rate $s_t$ representing the amount of domestic currency necessary to buy one unit of the foreign currency. The rate of change of prices charged for exported goods in foreign currency unit increases with the real marginal cost and depends on the strength of domestic currency in real terms (an increase in $r_t$ is a real depreciation).

The aggregate real profits of all the producers and importers of the intermediate goods are given as the weighted average of the respective real domestically valued profits of those who optimize their price and the corresponding indexation rules following:

$$\pi_t^i = \left(1 - \chi_t\right) \left[\hat{\rho}_t^i - \psi_t^i \right] \frac{1}{\psi_t^{i-1}} + \chi_t (\hat{P}_t^i - q_t^i \hat{p}_{t-1}^i) \left(\hat{P}_t^i - q_t^i \hat{p}_{t-1}^i \right) \frac{1}{\psi_t^{i-1}} \chi_t.$$

In contrast to Smets and Wouters (2002) and Pytlarczyk (2005) who use partial price indexation to past inflation and Erceg et al. (2000) with indexation to the average steady-state inflation rate we prefer the weighted average of these two approaches in a similar fashion as Justiniano et al. (2008). As a consequence, the resulting inflation process is not purely forward–looking (as in case of Calvo (1983)) but weights both the past and expected future inflation evolution. Furthermore, our price–indexation scheme is consistent with steady–state constant price requirement even in case of non–zero steady state inflation.

In case of exporters due to setting the price in the currency of the trading partner and comparing the export prices $p_t^e = P_t^e / P_t^c$ with those on the foreign market, they employ the foreign inflation $\Pi_t^e$ instead of the domestic one $\Pi_t^c$ and multiply the second term in the price–setting optimality conditions by the factor $r_t$. In case of importers we are allowed to suppress the firm–specific index $i$ and denote the optimal price as $\hat{p}_t^i$ since all firms adjusting prices choose the same optimum.

In order to evaluate the profit of exporters express prices in domestic currency, i.e. use $r_t p_t^i$ and $r_t \hat{p}_t^i$ in (11). Similarly, in case of importers substitute the real marginal costs $\psi_t^i$ by $n_t$.

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2.1.4 Public Sector

Following Cavallo (2005), Forni et al. (2007) and Carvalho and Martins (2011) we introduce public sector firms operating in a perfectly competitive environment. They combine household labour input $h^g_t$ with public sector infrastructure to produce homogeneous output consumed by households. Two other processes enter public goods production process: the unit root productivity shock $\eta_t^{fp,g}$ and the non-stationary technology-specific $\zeta^c_t$. Therefore, public goods are produced using the following Cobb-Douglass type technology:

$$c^g_t = \zeta^c_t \eta_t^{fp,g} \left[ \mathcal{J}^g_t \right]^{1-\sigma_g} \left[ h^g_t \right]^{\sigma_g}.$$  \hspace{1cm} (12)

The public sector infrastructure $\kappa^g_t$ is built through public investment by government as follows:

$$\mathcal{I}^g_t = 1 + \frac{2}{\pi} \arctan \frac{\kappa^g_t - \kappa^g_{t-1}}{\kappa^g_{t-1}} + is^g_t \left[ \exp \left\{ \eta_t^{is} \right\} - \mathcal{J}^i_{t-1} \right].$$ \hspace{1cm} (13)

Thus $\mathcal{J}^g_t$ evaluates extra production generated by infrastructure supplied above its equilibrium limit by government investment provided to the public sector. In contrast to private sector, public sector firms do not optimize their production factor quantities as both the public sector labour input and infrastructure are determined by fiscal rules. As suggested by Sims and Wolff (2013) public goods produced by public sector firms are consumed by different types of households (see below) in quantities given by the government:

$$c^g_t = \lambda c^g_t n + (1-\lambda)c^g_r.$$  

2.2 Households and Labour

There is a continuum of infinite lived households of measure one indicated by index $j \in [0,1]$ maximizing their intertemporal utility function subject to a lifetime budget constrain. Following Mankiw (2000) we assume that households are of two types – Ricardians (savers) with share of $1-\lambda$, and Non–Ricardians (spenders, rule–of–thumb households) with share of $\lambda$. The former type of households at each period make decisions on consumption, investment, labour supply, physical capital rental and financial asset holdings in such a way as to maximize their life-time utility. A typical ability of Ricardians is to smooth their consumption, i.e. distribute the current income shock over the whole future time horizon. However, a significant share of households simply consume all their income (see Mankiw (2000), for example).

Furthermore, following Rabanal and Lopez-Salido (2006) and Schmitt-Grohe and Uribe (2002) households preferences are given by a utility function suggested by Greenwood et al. (1988)—hereafter referred to as GHH—which is non–separable in consumption and labour.

---

16 Inclusion of government expenditures in the production function within DSGE models is not common. A possible way how to incorporate directly government who has incorporated both productive government expenditures (on capital ans labour) in the private sector production function was presented by Pappa (2009) and later on extended by Carvalho and Martins (2011). Their approach is perfectly suitable to analyse effects and transmission mechanisms of fiscal consolidations.

17 Above, a time–to–build dimension is present in the infrastructure building process and $\mathcal{J}^{is}(x) \equiv \frac{\eta^{is}}{2} (x-1)^2$ denotes the detrended government investment adjustment cost function with $\eta^{is}$, the exogenous variation shock.

18 Jaimovich (2008) pointed out in models with endogenous labour supply, the presence of income effect on the demand for leisure is a necessary condition for the existence of indeterminacy. Hence, we prefer the GHH utility function introduced by Greenwood et al. (1988) (who examined business cycle dynamics in a small open economy).
to Cavallo (2005) and Carvalho and Martins (2011) and Sims and Wolff (2013) the utility function is extended to include public goods which are available for all households free of charge.

We assume habit persistence in consumption as in Abel (1990) and Fuhrer (2000). Therefore, household $j$ of type $\tau \in \{r, n\}$ utility depends positively on private goods consumption level $c^{p, \tau}_t$ measured relatively to lagged aggregate real private goods consumption index $c^{p}_{t-1}$, which is common for all households and modulated by habit persistence factor $\kappa^c \in (0, 1)$. Since besides the private goods households consume also public goods $c^{g, \tau}_t$ at the level prescribed by government, they evaluate their access to public goods relatively to past level of aggregate public goods consumption under the presence of habit formation represented by habit persistence factor $\kappa^g \in (0, 1)$.

Hence, at time $t$ household $j$ of type $\tau \in \{r, n\}$ (Ricardian, Non–Ricardian) maximizes a detrended form of the intertemporal utility function

$$
\max E T \sum_{k=0}^{\infty} \beta^k U(c^{p, \tau}_{t+k}(j), h_{t+k}(j)),
$$

subject to their budget constraint and in case of Ricardian household also subject to physical capital accumulation law. Above, $\beta \in (0, 1)$ is the time–discount factor and $\alpha^g$ determines the nature of the relationship between public goods consumption and private consumption. Moreover the household faces a demand shifter – serially correlated preference shock $\epsilon^l_t$ that affects the intratemporal trade–off between their consumption and labour $h_t$. Households supply differentiated labour services to domestic firms so they have market power in setting their wages.

2.2.1 Non–Ricardians

Following Campbell and Mankiw (1989) we assume that in each period Non–Ricardian agents consume their current disposable income (i.e. the after–tax real income adjusted by the real valued lump–sum transfers)\footnote{There are various alternative setting of the Non–Ricardian households, e.g. they are allowed to hold money to smooth their consumption over time (see Coenen et al. (2008)), but in this case Ricardians and non-Ricardians have similar consumption behaviour – hence it is difficult to have a non negative response of private consumption to a government expenditure shock (Forni et al. (2007)).} They face the budget constraint

$$
(1 - \pi^r_t) w^p_t(j) h^r_t(j) + \tau^r_t j(1 + \pi^r_t) c^{p, r}_t(j).
$$

There’s no intertemporal optimization present.

2.2.2 Ricardian Households

At time $t$ any Ricardian household $j$ maximizes an detrended form of the intertemporal utility function (14) subject to household budget constraint and physical capital accumulation law.

Furthermore, as shown in Aimovich and Rebelo (2009), non–separable preferences can be viewed as a special case of an intertemporal utility function $U_t = (1 - \sigma)^{-1}(c_{t} - \alpha h^r_{t-1}(\sigma^{-1} - 1)$ with $\bar{\xi} = c_{t}^{-1}/ \sigma - 1$ when $\gamma = 0$. Then evidently a permanent rise in real wage induces level shift in labour supply. On the other hand, as long as $\gamma \in (0, 1)$ hours worked converge to the steady state despite permanently increased real wage. (see Greenwood et al. (1988)). Another polar case known as King–Plosser–Rebelo preferences, is obtained when $\gamma = 1$ (see Aimovich and Rebelo (2009), King et al. (1988) and Aimovich (2008)).
Household Budget Constraint: The j-th Ricardian household faces the following budget constraint:

\[
\begin{align*}
\text{deb}_t(j) - s_t f \text{deb}_{t-1}(j) & + (1 - \tau^u_t)(1 - \lambda w_t(h_t(j) - tr^j_t + (1 - \tau^u_t) \left[ \frac{\zeta_t}{V_t} \Psi_t(j) u_t(j) + \text{div}_t \right]) \\
& \geq \frac{\text{deb}_t}{R^b_t} - s_t f \text{deb}_t(j) + (1 + \tau^u_t) \left[ (1 - \lambda) c^p_t(j) + p_j^t i_t(j) + \frac{\nu t}{V_t} \Psi_t(j) u_t(j) \right].
\end{align*}
\]

(16)

The real (detrended) financial wealth inherited from the previous period is represented by a portfolio of one-year net domestic bonds and foreign liabilities \((\text{deb}_{t-1} - s_t f \text{deb}_{t-1})/\Pi_t V_t\). The after-tax labour based real-valued income from renting labour service to both the public and the private sector \((1 - \tau^w_t) w_t(h_t(j))\) is adjusted by the real net transfers \(tr^j_t\) identical across all Ricardian households. Next, \((1 - \tau^u_t) \zeta_t u_t(j)/V_t\) is the after-tax income from renting physical capital stock installed with the effective rate of utilization \(u_t(j)\) and the rate \(\zeta_t\) illustrates the rental rate of capital charged by Ricardian households to the producers. The variable capital utilization reduces the impact of changes in output on the rental rate of capital and therefore smooths the response of marginal cost to fluctuations in output. The term \((1 - \tau^w_t)\text{div}_t\) are net real dividends distributed from the profits \(\pi_t\) of producers to any Ricardian households reduced by the factor income of Ricardians \(i^*_t\). We assume that Ricardians perceive them as given. Notice that the tax rate \(\tau^u_t\) is imposed by the government on investment.

Ricardian households invest into securities with discount returns \(R^b_t\) and \(R^u_t\) respectively. Furthermore, they make a purchase decision about their private consumption goods \(c^p_t\) and investment goods \(i_t\). The household’s decision is affected by physical capital adjustment costs induced by variations in the degree of capital utilization \(\Psi = \psi(u_t)\) per unit of physical capital as discussed by Christiano et al. [2001] and Collard and Dellas [2004].

Capital Accumulation Law: As in Christiano et al. [2001] the Ricardian household \(j\) owns and accumulates the overall detrended physical capital stock according to the following equation:

\[
\text{K}_t(j) = (1 - \delta) \frac{\text{K}_{t-1}(j)}{V_t} + i_t(j) \left[ \exp \{\eta_t^j\} - J^l(v^i_t^j i_t(j) - \frac{\nu t}{V_t} \Psi_t(j) u_t(j) \right].
\]

(17)

Various models e.g. Forni et al. [2007], Stork et al. [2009], Kim [2000], Alitev et al. [2014] or Benk and Jakab [2012] introduce an additional type of symmetric quadratic adjustment costs incurred if the aggregate nominal wage deviates from the steady state path (along which gross aggregate wage inflation \(\Pi^w\) is assumed equal to gross price inflation \(\Pi^p\)) and is expressed in terms of the equilibrium wage rate \(w_t\). Hence for any household \(j\) (regardless Ricardian or Non-Ricardian) they can be expressed like \(\frac{\nu t}{2} \frac{\Pi^w_t}{\Pi^p_t} (w_t(j)/w_{t-1}(j) - \Pi^w_t)^2\). Also, the design of cost to capital utilization rate function should satisfy the following requirements: increasing the rate of capital utilization implies additional costs (penalization) and so it enters as an additional expenditure term in the constraint; marginal penalization raises with capital utilization rate and this penalization is not applied when capital is fully utilized. Hence this penalization function possesses the subsequent form of an increasing convex function \(\psi(u_t) = \rho^u_1 \{ \exp[\rho^u_2 (u_t - 1)] - 1 \}\). Then, \(\psi'(1) = 0, \psi'(1) = \rho^u_1 \rho^u_2 \rho^u_2\) and \(\psi''(1)/\psi'(1) = \rho^u_2\). In the log-linear approximation of the model solution this \(\rho^u_2\) is the only parameter that matters for the dynamics.

The capital stock accumulation technology is a special version of intertemporal adjustment costs, suggested by Kim [2003] in more general form \(\text{K}_t = \left( (1 - \delta) \left( \frac{s_t}{\delta} \right) + \delta \left( \frac{i_t}{\delta} \left( 1 - S(h_t(h_t - 1)) \right) \right) \right)^{\frac{1}{1 - \delta}}\) with \(\sigma_k \rightarrow \infty\). Referring to Andrele et al. [2009], a similar result can be obtained by setting \(\sigma_k = 1\).
where \( \mathcal{S}^i = \mathcal{S}^i(i_t(j), i_{t-1}(j)) \) denotes the detrended investment adjustment costs taking the subsequent form\(^{22}\)

\[
\mathcal{S}^i \left( \xi^i_t h_t(j), \xi^i_{t-1}(j) \right) \equiv \phi_i \left[ \xi^i_t h_t(j) \xi^i_{t-1}(j) - 1 \right]^2.
\]

Next, following Justiniano et al. (2008) the efficiency with which the final investment goods can be transformed into physical capital and thus into tomorrow’s capital input is affected by the exogenous variation investment shock \( \eta^r \) which is an i.i.d. random variable following a stochastic process \( \eta^r_t \sim \mathcal{N}(0, \sigma^2) \). The adjustment cost depends on deviations in investment flow and reflects the time–to–build dimension to the capital accumulation procedure.

### 2.2.3 Labour Market

**Labour Supply and Labour Demand** We assume the labour force of all households to be uniformly distributed among the differentiated firms in both sectors and employers not distinguishing between them. Private and public sectors are not perfectly substitutable in the labour market and household utility function, i.e. hours are not costlessly interchangeable across these two sectors\(^{23}\). Hence any household divides their labour services with finite elasticity of substitution \( \sigma_h \) between the firms in both sectors according to the following labour supply composite:

\[
h_t = \left\{ (\alpha_h) \frac{1}{\sigma_h} \left[ h^p_t \right]^{1-1/\sigma_h} + (1 - \alpha_h) \frac{1}{\sigma_h} \left[ h^g_t \right]^{1-1/\sigma_h} \right\} \frac{\sigma_h}{(\sigma_h-1)}.
\]

Following Cavallo (2005), Forni et al. (2007) and Carvalho and Martins (2011) we describe the public sector labour market as a perfectly competitive and the demand for labour service supplied by any household is determined by government following fiscal rules. Hence, the detrended public sector wage bill (measured relatively to do gdp) follows the AR(1)– type process

\[
w^p_t h^p_t = (1 - p^w_t) \left( h^g_t \right) \left( h^p_{t-1} w^g_{t-1} \right) ^{\rho w g} \left[ w^g_t h^g_t \right] ^{1-\rho w g} \exp \{ \eta^{wh}_t \},
\]

with the white noise process \( \{ \eta^{wh}_t \}_{t \geq 0} \) and consolidation driven public wage bill adjustment \( p^w_t \) (see Section 2.4.1). Households set their private sector real wages to maximize their instantaneous objective function subject to the intertemporal budget constraint and the demand for labour of type \( j \) satisfying

\[
h^p_t(j) = \left[ w^p_t(j) / w^p_t \right]^{-\theta} h^p_t.
\]

with the public sector labour demand prescribed by the fiscal rules, the aggregate private sector labour supply is given as

\[
(1 - \alpha_h) h^p_t = \alpha_h \left[ w^p_t / w^g_t \right] ^{-\sigma_h} h^p_t.
\]

**Wage Setting.** Households have market power in the labour market. The underlying gross real wage index arising from household gross labour income \( w_t h_t \) maximization problem is as follows

\[
w_t = \left\{ \alpha_h \left[ w^p_t \right] ^{1-\sigma_h} + (1 - \alpha_h) \left[ w^g_t \right] ^{1-\sigma_h} \right\} ^{\frac{1}{\sigma_h}}.
\]
Based on observations we assume that the aggregate gross real–valued wage rate in the public sector $w_{t}^{p}$ partially reflects the lagged private sector nominal wage inflation $\Pi_{t-1}^{p}$ and the equilibrium consumption price inflation $\Pi^{c}$ while taking into account possible fiscal consolidation–related shocks as follows\footnote{We introduce the shock $\varepsilon^{w,g}$ in the public wage indexation scheme since we want government to be able to adjust public wages in a discretionary manner.}

$$w_{t}^{p} = q_{t}^{w,g} w_{t-1}^{g}, \quad q_{t}^{w,g} \equiv (\Pi^{c})^{1-\gamma_{e}} (\Pi_{t-1}^{p,w})^{\gamma_{e}} (\Pi^{c})^{-1} + \varepsilon_{t}^{w,g}, \quad \varepsilon_{t}^{w,g} \sim N(0, \sigma_{w,g}^{2}). \quad (24)$$

Note that there is no wage optimization present in the public sector and each household works for same amount of hours $h_{t}^{k}$ receiving the same real gross wage $w_{t}^{k}$ regardless of whether it is Ricardian or not.

As regards private sector wages, wage setting `a la Calvo is applied on Ricardian household labour–induced income with a share $\chi_{w}$ of wage non–optimizers considering the following real gross wage indexation rule:

$$w_{t+1}^{p} = q_{t+1}^{w,p} w_{t}^{p}, \quad q_{t+1}^{w,p} = (\Pi^{c})^{1-\gamma_{e}} (\Pi_{t}^{g})^{\gamma_{e}} (\Pi^{c})^{\gamma_{m}} / \Pi_{t+1}^{c} \quad (25)$$

$$\Pi_{t}^{c} = \frac{1 + \tau_{t}^{w}}{1 + \tau_{t-1}^{w}}, \quad \Pi_{t}^{g} = \frac{1 - \tau_{t}^{w}}{1 - \tau_{t-1}^{w}}, \quad 0 \leq \gamma_{e}, \gamma_{m}, \gamma_{w}, \leq 1.$$\footnote{Any representative Ricardian household solves the intertemporal problem of setting optimally private sector wage for its labour $j$ that would maximizes the expected discounted stream of their utility taking into account the labour demand constraint \footnote{by assumption, Non–Ricardians do not have an intertemporal optimizing behaviour, following Erceg et al. \cite{2005} we assume that the non-Ricardian wage rate simply equals the average of the Ricardians. Then as in the equilibrium all households face the same private sector labour demand both the steady state hours worked and wage rate will be equal for every agent in the economy. Various studies \cite{2005} use labour unions to aggregate labour force and negotiate their private sector wages for all agents by maximizing the weighted average of the expected discounted stream of Ricardian and Non–Ricardian utilities and consider current and future adjustment costs misalignments of wage growth from equilibrium \cite{2007} and \cite{2009}.}}

Note that the wage indexation may partially reflect past changes in consumption and labour tax rates. We assume that the Non–Ricardians’ private–sector gross wage rate simply follow the wage indexation rule:

$$\Pi_{t}^{g} = \left(1 - \chi_{w}\right) (\Pi_{t}^{w,p})^{1-\theta_{t}} + \chi_{w} (\Pi_{t}^{w,p})^{1-\theta_{t}} \Pi_{t}^{w,p} / \Pi_{t-1}^{c} \quad (26)$$

with the optimal real–valued gross wage $\tilde{w}_{t}^{p}$ and constant real gross wages in equilibrium regardless of the indexation rule used. Then, the real–valued private sector gross wage inflation $\pi_{t}^{w,p} = \tilde{w}_{t}^{p} / w_{t-1}^{p}$ evolves following the Phillips curve below

$$\tilde{w}_{t}^{w,p} = \beta \Pi_{t}^{c} [\tilde{w}_{t+1}^{w,p} + \gamma_{w} q_{t+1}^{w,p} - \beta \tilde{w}_{t+1}^{w,p}] - \lambda_{w} \tilde{w}_{t}^{p} + \lambda_{w} \tilde{w}_{t+1}^{p} + \frac{\lambda_{w} \lambda_{m}}{1 - \vartheta} \tilde{h}_{t}, \quad \Pi_{t}^{w,p} = \frac{\Pi_{t}^{p,w}}{\Pi_{t}^{c}} = \frac{w_{t}^{p}}{w_{t-1}^{p}} \quad (27)$$

$$\lambda_{w} = \frac{\left(1 - \chi_{w}\right)(1 - \beta \chi_{w})}{\chi_{w}(1 + \varepsilon_{w})}, \quad \varepsilon_{w} = -\frac{\sqrt{\Pi_{h} \sigma_{h} - \mathcal{H} \Pi_{h}^{2}}}{\sigma_{h}(1 + \mathcal{H})}, \quad \mathcal{H} = \left(1 - \alpha_{h}\right) \frac{\delta}{\delta_{h}} \left[\frac{\Pi_{h} \sigma_{h}}{\Pi_{h}^{2}} \right]^{\alpha_{h}-1}$$
Notice that \( \mu^p \) symbolizes the after-tax market private sector mark-up over the marginal rate of substitution in the private sector:

\[
\hat{\mu}^p = [\hat{w}^p \tau^w - \hat{w}^p \tau^w \hat{v}^p] - \left\{ \hat{\epsilon}_l^p + \hat{\psi} \left[ \frac{\epsilon_w}{\sigma_{u}} \right] \hat{w}_t^g + \frac{\epsilon_w}{\sigma_{u}} \hat{w}_t^g \hat{v}^p + \tau^c \hat{v}^c \right\} .
\] (28)

\( \hat{\psi} \) represents the cost-push shock (see Smets and Wouters (2002)) to the private sector wage inflation observed at time \( t \).

There are for key observation that can be made in relation with the derived wage inflation evolution regardless wage indexation strategy chosen: first of all, due to utility function chosen there is no consumption effect in the wage inflation as marginal rate of substitution \( \psi^p = \psi^p \left[ \frac{h_t}{\hat{v}^p} \right] \) is independent of private goods consumption, it is driven by changes in overall household labour supply. Secondly, the impact of the private sector market mark-up on private sector wage inflation evolution is relatively smaller than in one sectoral labour market and decreases with the higher proportion of public sector. Next, variations in public sector labour supply (e.g. due to fiscal consolidation) affect private sector wage evolution. Finally, the degree in which optimizing households project changes in consumption and labour tax rates in the desired gross wage changes with 0 \( \leq \gamma_c, \gamma_t \leq 1 \). Hence with positive \( \gamma_c \) and \( \gamma_t \) consumption and labour taxes represent additional burden for firms that will raise their marginal costs.

### 2.3 Monetary Policy and Interest Rates

Due to monetary union with the foreign (world) economy, the domestic country does not govern its own monetary policy, and so it takes as given the baseline risk–free interest rate.

In order to be able to simulate policy-relevant scenarios reflecting the domestic fiscal policy sustainability we introduce a risk premium applied on domestic liabilities charged by the domestic investor above the baseline ECB gross interest rate\(^{26}\) It captures the flow of current and future expected nominal public debt-to-gdp ratios, so that the overall return \( R_t^b \) is

\[
R_t^b = R_t \exp \left\{ \text{prem}_t^b + \xi_t^b \right\} ,
\]

\[
\text{prem}_t^b = \alpha^b + \rho^0 \left( 1 + \frac{\rho}{\text{debt}} \right) , \quad \text{P}_t = \delta_b \left[ \frac{\delta_t - \delta_t^0}{\gamma_t} \right] + (1 - \delta_b) \epsilon_t \rho_{t+1} ,
\] (29)

with the known value of risk premium \( \rho^0 \) is associated with a certain known debt-to-gdp ratio \( \text{debt} \), and \( \delta_b \in (0, 1] \) associated with forward-lookingness of investor concerning about the future debt and fiscal policy credibility (lower \( \delta_b \) corresponds to longer time horizon considered)\(^{27}\). Furthermore, \( \xi_t^b \) is the white noise process illustrating the unpredictable financial shock to domestic securities risk premium.

\(^{26}\) In standard DSGE models government bond securities are risk-free, agents believe that the government will repay its nominal obligations, so that market risk premium paid above interest rate is zero. In reality, investors usually penalise the country’s excessive indebtedness by demanding a higher interest rate premium. Several studies e.g. Erceg and Lindé (2011), Corsetti et al. (2012), or Benk and Jakab (2012) consider the consequences of fiscal policy when spreads depend endogenously on government debt.

\(^{27}\) Benk and Jakab (2012) presented quite a similar approach to model the return on domestic bonds. In order to evaluate the credibility of domestic fiscal policy and hence define the risk premium instead of the debt-to-gdp expectations they rather evaluate the current debt position relative to its equilibrium value. However, risk premium on debt in the standard DSGE models is far too small and stable relative to empirical measures obtained from the data. As Swanson and Rudebusch (2009) noted, introducing Epstein–Zin preferences, a model can help to produce large and variable risk premia.
Next, in order to close the model, thereby imposing a unique stationary equilibrium, the interest rate on foreign liabilities must be endogenised. The nominal interest rate on foreign liabilities \( R^f \) carries a risk premium charged by the foreign investor above the foreign gross interest rate \( R^f \) which is decreasing in the level of the country’s current net foreign asset position [see Kollmann (2002)]. Thus in order to stabilize the model high private indebtedness is penalized by augmenting interest rates on additional borrowings:

\[
R^f_t = R^f_t \exp \{ \text{prem}_t + \text{trans}_t + \xi_t^a \} , \quad \text{where} \quad \text{prem}_t = \frac{\Pi^f_t}{\delta^*} f \text{debt}_t .
\]  

(30)

The parameter \( t \) evaluates the degree of capital mobility, \( \text{trans}_t \), illustrates the transition costs imposed by foreign economy in order to rebalance returns of securities in the equilibrium, \( \Pi^f_t \) is the foreign economy inflation and \( \delta^* \) is the steady state domestic exports measured w.r.t. the foreign gdp. The gross return on foreign liabilities is also affected by the white–noise process \( \xi^a_t \). The assumption of imperfect capital mobility \( t > 0 \) guarantees the existence of a stationary equilibrium. Higher equilibrium level of exports, capital mobility or appreciation of the real exchange rate resulting from increasing foreign inflation lead to decrease in the risk premium.

### 2.4 Fiscal Authority

The government levies and collects various taxes imposed on producers, importers and households to finance their expenditures – a fraction of them is put back to the economy in the form of infrastructure or contributes to utility of households directly and the rest is pure waste. Tax changes are costly as the household adaptation process takes a while and the fiscal authority must reflect a “time–to–build” aspect. Therefore, following Mertens and Ravn (2011), we assume a standard quadratic–form tax rate adjustment costs. Hence the detrended real–valued primary budget balance is \( pb_t = \text{rev}_t - \text{exp}_t \) with

\[
\text{exp}_t = p^p_t \left( \text{gov}^p_i + \text{trans}_i + \text{trans}_i^\ast \right) + w^p_t \kappa^p_t + \left( (1 - \lambda) \Pi^p_t - \lambda \text{tr}_t^p \right)
\]

\[
\text{rev}_t = \sum_{\alpha \in \{ c,k,w \}} \left[ \tau^\alpha - S^\alpha_t \left( \frac{\tau^\alpha}{V_{t-1}} \eta^\alpha_t \right) \right] \Phi^\alpha_t , \quad S^\alpha_t \left( \frac{\tau^\alpha}{V_{t-1}} \eta^\alpha_t \right) = \frac{\Phi^\alpha_t}{2} \left[ \frac{\tau^\alpha}{V_{t-1}} \eta^\alpha_t - 1 \right]^2 ,
\]

\[
\Phi^c_t = c^c_t + p^c_t \phi^c_t + \psi(u_t) \frac{k^c_t - 1}{V_t} , \quad \Phi^k_t = \text{div}_t + \frac{k^c_t - 1}{V_t} u_t , \quad \Phi^w_t = w_t h_t ,
\]

Taking into account the interest payments with the gross discount return \( R^f_t \) associated with the debt service, the authority issues new real–valued detrended public debt:

\[
\frac{\text{debt}_t}{R^f_t} = \frac{\text{debt}_{t-1}}{V_t \Pi^f_t} - p^\text{f}_t .
\]  

(31)

#### 2.4.1 Fiscal Rules

We postulate specific reaction functions for each type of government expenditures and taxes. Each item \( x_i \) of the detrended government budget has been assigned its pre-consolidation

A similar approach is used by Cuche-Curti et al. (2009), Benigno (2001), Stork et al. (2009) and Zeman and Senaj (2009). Furthermore, Benk and Jakab (2012) present an alternative approach to describe the dynamics of the foreign debt interest rate charged above the steady state real interest rate. Agents consider the deviation of the foreign debt and domestic debt positions from their steady states and the financial premium shock [see Schmitt-Grohe and Uribe (2002)]. On the other hand, Andrei et al. (2009) uses the concept of perfectly competitive forex dealers in order to determine the pricing formula for the country’s foreign debt. Escud (2014) suggested to consider also country’s international reserves ratio.
value $\xi_t$ ($\tau_t$) following the corresponding AR(1)-type process:

$$\tau_t = x_{\tau_{t-1}} t^{1-\rho_\tau} \exp\{\xi_{\tau_t}\}, \quad \xi_t = x_{\xi_{t-1}} t^{1-\rho_\xi} \exp\{\xi_{\xi_t}\}. \quad (32)$$

Nominally valued pre–consolidation budget expenditure items $\tau_t$ (public sector labour demand $\bar{R}_t$, transfers $\bar{P}_t$, infrastructure supplied for both sectors ($\bar{T}_t^f$ and $\bar{T}_t^c$), and government waste consumption $\bar{P}_t^w$) are detrended and measured relatively to current domestic nominal output. Furthermore, the pre–consolidation prescriptions of tax $\tau_t$ (consumption tax $\bar{\tau}_t^c$, capital tax $\bar{\tau}_t^k$, and personal income tax $\bar{\tau}_t^p$) revenues consider also the corresponding detrended tax base $\Phi_t^D$ expressed relatively to domestic output. These pre–consolidation variables generate the corresponding detrended primary balance $\bar{p}b_t$ gradually accumulated into the detrended public debt $^{29}$

$$\bar{debt}_t = \bar{R}_t^p \left( \frac{\bar{debt}_{t-1}}{\bar{I}_t^F, \bar{V}_t} - \bar{p}b_t \right). \quad (33)$$

Next we establish the correction functional $C_t$ evaluating the level of necessary consolidation (as a change in detrended primary budget balance $\bar{p}b_t$ calculated using pre–consolidation detrended values of all budget items) necessary to achieve gradually the desired debt–to–gdp $\bar{debt}_t$ and primary balance–tang–gdp $\bar{p}b_t$ levels using debt–to–gdp and primary balance–to–gdp gaps (deviations of the debt-to-gdp and balance-to-gdp from the corresponding target) and trends (changes in debt-to-gdp and balance-to-gdp ratios from the last period values) $^{30}$

$$C_t = a_{\Omega} \text{sgn}(\Omega_t) \left\{ \text{sgn}(\Omega_t) \Omega_t + a_{\delta} \delta - a_{\delta} \text{sgn}(\delta_t) \left[ \text{sgn}(\delta_t) \delta_t + a_{\Delta} \Delta \delta \right] \right\} + \varepsilon_t, \quad (34)$$

Thus, the initial public debt and primary balance are adjusted to their post–consolidation counterparts $^{31}$

$$p_b_t = \bar{p}b_t + C_t, \quad \text{and} \quad debt_t = \bar{debt}_t - R_t^p C_t$$

providing that all budget items are modified as follows:

$$x_t = (1 - p_t) x_t, \quad \bar{p}_t = \bar{p}_t - \bar{p}b_t, \quad \bar{\tau}_t = (1 + p_t^\tau) \bar{\tau}_t, \quad \bar{p}_t^\tau = \bar{p}_t^\tau - \bar{p}_t^\tau, \quad \bar{\tau}_t = \bar{\tau}_t - \bar{\tau}_t$$

The parameter $D_t$ is the given (possibly time–dependent) percentage adjustment on the revenues side, $D_t^c$ ($D_t^f$) denotes the prescribed percentage change in the budget expenditure (revenue) item $x_t$ ($\tau_t$) that has to be made in order to achieve the consolidation effort determined by (34). Moreover, $p_t^\tau$ ($p_t^\tau$) represents the percentage correction in the initial setting of the item $x_t$ ($\tau_t$) determined by the consolidation process. Therefore, providing that budget items follows rules prescribed by (35), they act as debt stabilizers.

---

$^{29}$Here we refer $R_t^p$ to $R_t^p$ as the risk premium on public debt takes into consideration the debt evolution. Therefore variations in the risk premium due to changes in debt evolution represent another aspect that is taken into account in the fiscal consolidation process.

$^{30}$Notice the presence of i.i.d. fiscal shock process $\varepsilon_t^C \sim N(0, \sigma_\varepsilon^C)$ that allows the government to design its own policy, and directly affect primary balance regardless of the given consolidation procedure.

$^{31}$Providing that the correction takes place observe that $\Delta \bar{debt}_t - \bar{debt}^{\text{tar}}_t < \frac{\Delta \bar{debt}_t - \bar{debt}^{\text{tar}}_t}{\bar{debt}^{\text{tar}}_t}$ and the debt convergence to its target (and the speed of convergence) is satisfied by the proper choice of $a_{\Omega} < R_t^p$. 

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2.4.2 Domestic Product

Employing the traditional DSGE approach we determine the domestic output gap as the log difference of the actual sticky–price output from its potential counterpart. Hence it is essential to use a proper technique to characterize potential output.

According to Vetlov et al. (2011) there are three standard measures of potential output: the trend level of output (the sequence of permanent stochastic technology shocks characterizing the stochastic balanced–growth model path) with the output gap measuring the business cycle component of the model; the efficient level of output (prevailing if labour and goods markets are perfectly competitive and prices and wages are flexible) with the output gap evaluating the significance of nominal rigidities; and the natural level of output (imperfect competition on labour and goods markets but with flexible prices and wages) with the output gap evaluating the significance of nominal rigidities.

Kiley (2013) extends the list of output gap measures by another two approaches: first, the deviation of output from its long-run stochastic trend (the Beveridge–Nelson method); and the deviation of output from the level consistent with current technologies and normal utilization of capital and labour input (the production function approach).

The Beveridge–Nelson Gap is defined as the deviation of the actual output from its long—run stochastic trend, as the forecast of gdp growth in excess of its steady–state level going forward:

\[ \tilde{y}_{t} \equiv E_t \left[ \sum_{\tau = 0}^{\infty} \mathbb{E}_{\tau}^{y_{\text{gdp}}} - \sum_{\tau = -\infty}^{\infty} \mathbb{E}_{\tau}^{y_{\text{gdp}}} \right] \]

\[ \exp \mathbb{E}_{t}^{y_{\text{gdp}}} = \left( \frac{m_t}{m_{t-1}} \right)^{-r} \left( \frac{c_{t-1}}{c_t} \right)^{-\rho} \prod_{x \in \{c,i,g,f\}} \left( \frac{x_{t-1}}{x_t} \right)^{\rho^x} \]

On the other hand, in the Production Function approach (or CBO approach) for each type of product the gap is defined as the deviation of output from the level that would occur if inputs of labour, energy and imports, and capital utilization rate coincide with their steady state values. Then the production function gap is computed as the share–weighted aggregate of goods–specific gaps. Therefore, we define

\[ \tilde{y}_{t}^{\text{prod}} = \sum_{x \in \{c,i,g\}} \tilde{y}_{t}^{x_{\text{prod}}} \]

2.5 Closing the model

**Resource Constraints:** Market clearing for the private sector labour, rental capital, oil and intermediate goods imports requires

\[ h_t^p = \sum_{x \in \{f,c,i,g\}} h_{t,x}^p, \quad m_t = \sum_{x \in \{f,c,i,g\}} m_{t,x}, \quad k_t = \sum_{x \in \{f,c,i,g\}} k_{t,x}, \quad e_t = \sum_{x \in \{f,c,i,g\}} e_{t,x}. \]

Furthermore, domestic households consume all public and private consumption goods produced in the domestic economy and are the exclusive uniformly distributed suppliers of labour services in both sectors:

\[ c_t^p = (1 - \lambda) c_t^{p,r} + \lambda c_t^{p,n}, \quad c_t^f = (1 - \lambda) c_t^{f,r} + \lambda c_t^{f,n}. \]

Concerning the labour market, within the public sector all households supply the same labour and receive the same wage,

\[ h_t^{f,n} (j^f) = h_t^{p,n} = h_t^c = h_t^{g,r} = h_t^{g,f} (j^f), \quad j^p \in [0, \lambda], \quad j^f \in (\lambda, 1]. \]
Next, since Non–Ricardians facing the same labour demand as Ricardians set their private sector wage equal to Ricardians’ aggregate private sector wage, it holds that

$$h_t^{p,n} (f^a) = h_t^{p,a} = h_t^{p,r} = h_t^p, \quad f^a \in [0, \lambda].$$

Finally, aggregate demand is given by the following resource constraint:

$$y_t = c_t^p + p_t^i h_t + p_t^g g_t + \Psi_t,$$  
(37)

where \(\Psi_t\) stands for (detrended) adjustment costs in real terms,

$$\Psi_t = \psi(u_t) \frac{k_t^{-1}}{v_t} + \sum_{\alpha \in \{c,k,w\}} S_t^\alpha \left( \frac{\eta_t^\alpha}{\eta_t^{-1} - \eta_t^\alpha} \right) \Phi_t^\alpha,$$

and \(k_t = \int_0^1 k_i (d_i) di\) represents the aggregate demand for capital.

**Price and Wage Dispersions:** Referring to [Adjemian et al. (2007), Sims and Wolff (2013), Beignon and Woodford (2005) and Jakab and Vilagi (2008)](https://doi.org/10.1016/j.jeconom.2008.08.015) using (1)–(2) for each type of goods \(x \in \{c, i, g, f, m\}\) we introduce the idea of price dispersions evaluating inefficiency of an asymmetric distribution of the intermediate goods supply ([Benk and Jakab (2012)](https://doi.org/10.1016/j.econlet.2012.06.016)). This concept reflects the overall demand for the individual intermediate goods measured with respect to the aggregate demand in the following way:

$$\nabla_t^x = \int_0^1 p_t^i (i) \frac{p_t^i}{p_t^i} \frac{1}{1-\tilde{\eta}_t} di \approx \left( 1 - \chi_x \right) \left[ \frac{\tilde{p}_t^i}{p_t^i} \right]^{-\frac{1}{1-\tilde{\eta}_t}} + \chi_x \left[ q_t^x \frac{p_t^{i-1}}{p_t^i} \right]^{-\frac{1}{1-\tilde{\eta}_t}} \left\{ (1 + \Delta \theta_t^x) \nabla_{t-1}^x - \Delta \theta_t^x \right\},$$

with \(\Delta \theta_t^x = (1 - \theta_t^x)^{-1} - (1 - \theta_{t-1}^x)^{-1}\) the trend in the time–dependent elasticity of substitution among intermediate goods for \(x \in \{c, i, g, f, m\}\). For each type of domestically produced goods \(x_i\), the output of the procedure (4a)–(4c) satisfies the following goods market clearing condition, where \(\Omega_t^x\) is given by (4b)–(4c):

$$\tilde{x}_t \equiv \int_0^1 x_t (i) di = \tilde{\xi}_t \left\{ (\alpha_m^x)^{\frac{1}{\alpha_m}} [\Omega_t^x]^{-\frac{1}{\alpha_m}} + (1 - \alpha_m^x)^{\frac{1}{\alpha_m}} [m_t]^{-\frac{1}{\alpha_m}} \right\} = \nabla_t^x \tilde{x}_t, \quad x \in \{c, i, g, f\}.$$

Moreover, from (2) it follows that the total inflow of imported goods satisfies \(\tilde{m}_t = \nabla_t^m m_t\).

Next, the wage setting mechanism implies that neither hours worked nor wage vary across the Non–Ricardian households and all households supply the identical public sector labour input as they receive the public sector wage. Therefore, recalling (21) we borrow the idea of above introduced price dispersions and introduce its private sector real wage counterpart by the following prescription:

$$\nabla_t^w = \int_0^1 w_t^p (j) \frac{w_t^p}{w_t^p} \frac{1}{1-\tilde{\eta}_t} dj \approx \left( 1 - \chi_w \right) \left[ \frac{\tilde{w}_t^p}{w_t^p} \right]^{-\frac{1}{1-\tilde{\eta}_t}} + \chi_w \left[ q_t^w \frac{w_t^{p-1}}{w_t^p} \right]^{-\frac{1}{1-\tilde{\eta}_t}} \left\{ (1 + \Delta \theta_t) \nabla_{t-1}^w - \Delta \theta_t \right\},$$

32 Notice that \(\tilde{V}_t = \chi_x \left( \tilde{V}_{t-1} + \Delta \theta_t^x \right)\). Therefore, in case of steady-state initial conditions and missing cost–push shocks, price/wage dispersions do not affect the dynamics of the log–linearized model.

33 From the optimality conditions for the problem (3) it follows that marginal rate of substitution between various production inputs is identical for all private sector firms producing goods of the same type \(x \in \{c, i, g, f\}\).

34 To obtain the last equality sign reuse the concept of price dispersions and apply (1)–(2).
with $\Delta \vartheta_t = \vartheta_t - \vartheta_{t-1}$ the trend in the time–dependent elasticity of substitution between various Ricardian suppliers of labour input to private sector firms. Private sector wage dispersion directly contributes to the variation in the Ricardians’ marginal utility of consumption (and hence the aggregate conditional welfare).35

**Further Market Clearing Conditions:** The overall resource constraint implies that in equilibrium the current account balance finances the net purchasing of foreign liabilities the cost of increasing the utilization rate of capital and factor income of Ricardians, so that its surplus reduces the accumulated foreign debt. Therefore, the balance of payments satisfies

$$s_t f_{\text{deb}t} - \Psi(u_t) \kappa_{t-1} s_t = f_{\text{deb}t-1} s_t - c_{a_t}, \quad c_{a_t} = r_t (p^e_t f_t - \nabla m_t) - p^e_t e_t - \iota^*_t.$$  

Since persistent and frequent deviations from the uncovered interest parity condition are well known in order to be able to simulate policy–relevant scenarios we allow for an exogenous zero mean portfolio shock $\bar{\xi}_t$ (McCallum and Nelson (1999) and Cuche-Curti et al. (2009)) to the foreign currency, so that

$$R^b_t = R^e_t \exp\left\{\xi_t^{\text{up}}\right\} E_t \left[\frac{s_{t+1}}{s_t}\right].$$ (39)

The non–stationary labour–augmenting process growth rate $\nu_t$ drives the key variables of the economy and so that the domestic gdp nominal rate of growth equals $\Pi^c_t \nu_t$, which determines the economy’s balanced growth path. Furthermore, we assume the non–zero steady state both foreign and public debt–to–gdp ratios, which are stabilized at their respective target values, hence the corresponding positive equilibrium primary balance–to–gdp and current account balance–to–gdp satisfy at any time $t$ the following:

$$pb = \frac{1 - \beta}{\Pi^c \nu} f_{\text{deb}t}^{\text{tar}}, \quad \text{and} \quad ca = s - \frac{1 - \beta}{\Pi^c \nu} f_{\text{deb}t}^{\text{tar}}.$$ (40)

The steady state characterized by stabilized fiscal policy is also characterised by no additional fiscal consolidation hence by inactive correction functional $C = 0$ (see (34)) and fiscal variables adjusted only by the nominal gdp steady state growth rate $\Pi^c \nu$ (as all $p^x, p^\tau$ are zero in the equilibrium).36

**World and Exogenous Environment:** Since the Slovak economy is a small open, raw materials–dependent, oil–dependent, and export–oriented economy, the transmission of world economy shocks (world demand, oil price, baseline interest rate etc.) into the key domestic macroeconomic variables is of the crucial importance for economic policy. Hence in order to describe the behaviour of the foreign economy – we incorporate stylized models of the foreign economy (an average of Euro–Zone and the rest of the world trade partners) into our model (see Stork et al. (2009) and Alitev et al. (2014)).37 The foreign economy model captures the behaviour of

35The deviation in the marginal utility of consumption $\Lambda_t$ is set above its dispersions–ignoring counterpart $\tilde{\Lambda}_t$ by considering the deviations in wage dispersions, i.e. $\Lambda_t = \tilde{\Lambda}_t + \tilde{\alpha}_w \nabla w$ where $\tilde{\alpha}_w = \frac{\tilde{\gamma} h}{\nabla h}$.

36In this model, all fiscal variables are specified in levels $x_t$ instead of the output shares $x_t / y_t$. Since the steady-state de-trended output is normalized to one, these two specifications coincide in the steady–state.

37The foreign economy is assumed to be the weighted composite of the Slovak economy trade partners, both the euro–area members with the weight $\omega$ and the rest of the world countries. So we model the evolution of key foreign economy variables – output gap, inflation, and nominal interest rate – as a weighted average of the corresponding variables of trade partners.
three foreign agents: households maximizing a simple utility subject to budget constraint, monopolistically competitive firms maximizing a profit and set output prices following the Calvo price setting mechanism, and a monetary authority which determines a short-term interest rate following the Taylor rule. For euro area and non-euro area economies denoted $\kappa \in \{ \text{eu}, \text{neu} \}$ respectively, we have

\[
\hat{y}_t^\kappa = \alpha_{y}^{\kappa} \hat{y}_{t-1}^\kappa + (1 - \alpha_{y}^{\kappa}) E_t \hat{y}_{t+1}^\kappa - \alpha_{\pi}^{\kappa} E_t i_t - \hat{\Pi}_{t+1}^\kappa + \xi_{t}^{\kappa,y}, \tag{41a}
\]

\[
\hat{\Pi}_{t}^\kappa = \alpha_{\pi}^{\kappa} \hat{\Pi}_{t-1}^\kappa + (1 - \alpha_{\pi}^{\kappa}) E_t \hat{\Pi}_{t+1}^\kappa + \alpha_{y}^{\kappa} \hat{y}_{t}^\kappa + \xi_{t}^{\kappa,\pi}, \tag{41b}
\]

\[
\hat{i}_{t}^\kappa = \alpha_{\pi}^{\kappa} \hat{\Pi}_{t}^\kappa + \alpha_{y}^{\kappa} \hat{y}_{t}^\kappa + \alpha_{i}^{\kappa} i_{t-1} + \xi_{t}^{i,j}. \tag{41c}
\]

Then the modified UIP condition is used to model the evolution of the nominal EUR–USD exchange rate $s_t$ affected by the white–noise shock process $\xi_{s,t}^x$, so that the resulting nominal exchange rate $s_t$ evolves also according to \(^{38}\)

\[
\hat{s}_t = \frac{(1 - \vartheta) s_t^x}{\vartheta + (1 - \vartheta) s_t^x} \hat{s}_t^x; \quad \text{where} \quad \hat{s}_t^x = \alpha_{y}^x \left[ E_t \hat{s}_{t+1}^x + \hat{s}_{t-1}^x \right] - \alpha_{\pi}^x \left[ \Delta i_{t}^\text{eu} - \Delta i_{t}^\text{neu} \right] + \xi_{s,t}^x. \tag{42}
\]

Reverting to Benk and Jakab (2012) and Cuche-Curti et al. (2009) export goods producers reflect in addition to the level of current foreign demand also its past and expected value. Moreover, we extend this view and let the foreign demand $\Omega^n_t$ to be affected by the foreign output gap as well, and so its deviation evolves as

\[
\hat{\Omega}^n_t = \alpha_{\Omega}^n \left[ (1 - \alpha_{\Omega}^n) \left( \hat{\Omega}^n_{t-1} + (1 - \alpha_{\Omega}^n) \hat{\Omega}^n_{t+1} \right) + \alpha_{\Omega}^n \hat{\gamma}^n_t \hat{y}^n_t \right] + \xi_{\Omega}^n. \tag{43}
\]

\(^{38}\)The nominal exchange rate $s_t$ is modelled as an weighted average of exchange rates with the trade partners. Thus, only the the share of $1 - \vartheta$ is formed by the volatile EUR–USD exchange rate as the remaining $\vartheta$ part is fixed due to monetary union sp the domestic economy faces smaller transmission of nominal exchange rate shocks.
In order to solve the already stationarized non-linear model presented in this paper (and summarized in the Appendix A), we first determine its deterministic steady state and derive its (log-)linear approximation to describe its behaviour in the neighbourhood of that steady state. Then, we perform various fiscal consolidation exercises. For the purposes of our numerical analysis, we calibrate the model in the following way.

### 3.1 Model Calibration

To calibrate the model, i.e. to match a number of key target variables characterizing the Slovak economy (listed in Appendix C.1 and Appendix C.2), a large set of parameters in terms of key economy ratios (public and foreign debt, gdp composites shares, fiscal variables), labour market (employment and interaction between public and private sector) and production (input shares), characteristics of households and foreign environment (interest rates, inflation and exchange rate) enters the calibration exercise. The model calibration procedure, its inputs and resulting outcomes are clarified from the technical point of view in the Appendix B.

More specifically, we assume that in the steady state public debt and foreign debt attain 40 and 22.5 percent of GDP respectively. The character of a small extremely open transition economy and its dependence on import of raw materials and oil is reflected in substantial 93 percent export-to-GDP ratio. The consumption-to-GDP ratio is also lower than the figure for EU-15 countries at 54 percent, and so is the ratio of government purchases to GDP at 19 percent. The effective tax rates imply revenues at 40 percent of GDP. Note that the capital tax rate has been set so that the primary balance is consistent with the set steady-state debt-to-GDP ratio. Since both ratios are currently away from these steady state values, it is implicitly assumed that capital taxes would bear the brunt of the adjustment to the steady state. The effective rates of labour income and consumption taxes are calibrated to match current values observed in the economy. The steady state domestic inflation is set to be 2 percent per year and the labour–augmenting growth rate (equivalence of the real gdp growth rate) to 3 percent per year. The risk premium on Slovak bonds is 3 percent.

As regards production, imported raw materials and oil cannot be substituted easily \((\sigma_c^m = \sigma_i^m = .25, \sigma_g^m = .15 )\) whereas government goods do not use it at all. Next, oil represent approximately 10 percent of non-import inputs for all types of goods. In the private sector physical capital inputs are preferred to labour service usage \((\sigma^m = .65\) identically for all types of goods) and the opposite holds in the public sector \((\sigma^{pK} = .5)\). Furthermore, private capital and both the public and private infrastructure are built subject to depreciation rate \(\delta_k = \delta^p_K = \delta^g_k = .015\).

Based on EU–SILC data the share of Non–Ricardian households (who use approx. three times more public goods than the Ricardians) is estimated at 40 percent and households are quite persistent \((\kappa_c = \kappa_g = .7)\) in their preferences for consuming both private and public of goods. A proper calibration of respective shares of Ricardians and Non–Ricardians is crucial, as it fundamentally affects consumption dynamic following shocks. The literature provides a wide variety of estimates and calibrations ranging from 25 percent \(\text{(Coenen and Straub (2005))}\) to 34–57 percent \(\text{(Forni et al. (2007))}\) for the Euro–area. Furthermore, Gali et al. (2002) estimates 50 percent shares of Non-Ricardians in United States. In this study we use the methodology proposed by Stork et al. (2009), thus we employ EU–SILC database to deduce the share of Non–Ricardians. First of all, we consider as Non–Ricardians those, who are long–term unemployed and non-working pensioners. Next, based on expert judgement, approximately 20 percent of employees, 10 percent of self-employed, 50 percent of working pensioner, 70 percent of those unemployed for less than a year, and half of others are assumed to be Non–Ricardians. Therefore, we set \(\lambda = 40\%\).
time discount factor of $\beta = .9966$ is consistent with a 6.5 percent nominal interest rate on public bonds. The inverse of the elasticity of the capital utilization cost function ($\rho_1^\Psi = .2$), inverse of the elasticity of substitution in consumption ($\sigma = 1$) and Frisch elasticity of labour supply ($\nu_h = 3.8$) are set consistently with standard literature. In the equilibrium, employment is concentrated mainly in the private sector (80 percent) and public/private sector transition is not perfectly elastic ($\sigma_h = 1.5$). Wages are optimized once a year on average ($\chi_w = .75$) and labour supply elasticity is $\vartheta_w = 4$.

The foreign economy is a weighted average of the EU economy (70 percent) growing 1% per year and Slovak Non–EU trade partners with 4 percent real growth rate. In the steady state it is described by 2 percent inflation and 3.2 percent interest rate. The Slovak economy is approximately 1/1000 of the foreign economy, foreign demand for our export goods is very elastic ($\sigma^* = 25$) and for the small open economy within the Euro–Zone capital is highly mobile.

All parameters and the non–linear model are summarized in the Appendix.

3.2 Model Dynamics

In order to examine the performance of the model, we study the response of the key macroeconomic variables to standard shocks: a positive technology shock (Figures 3.1–3.4) and a negative foreign demand shock (Figures 3.5–3.9) of half of their respective standard deviations. The consequences of these shocks for fiscal sustainability are dealt with either through changes in the labour income tax rate or adjustment in the lump-sum transfer given to consumers. The fiscal policy maker is assumed to follow the rules described earlier. Furthermore, for the sake of comparison, we also show how the economy responds to these shocks should fiscal policy aim to keep the primary balance unchanged in every period, and adjust either transfers or labour tax rate to achieve this goal. This is shown in the figures with dashed lines.

Figure 3.1: Response to a positive technology shock I.

3.2.1 Positive Technology Shock

Let us first consider the performance of the economy following a positive persistent technology shock (Figures 3.1–3.4). Following the positive technology shock, marginal costs decline, and so prices fall temporarily. This stimulates domestic and foreign demand for goods (see Figure 3.1). From the fiscal point of view, the productivity shock actually worsens the outlook: the labour market implications of the productivity shock – a simultaneous increase in real wages

40Within this article, each figure depicts the deviation of the concrete variable from its equilibrium value measured in percentage points of its steady state. Furthermore, remark that output equals one in the steady state.
and a drop in employment – result in lower (expected) government revenue. To restore fiscal sustainability, the government has to take action. The choice of the fiscal instrument to carry out fiscal consolidation has a considerable impact on the economy both over time and in the cross-section.

Restoring fiscal sustainability requires either an income tax increase or an increase in transfers to the consumers. The latter, in particular, might come as a surprise. The reason for this is the large consumption effect associated with transfers. This profound demand effect boosts employment and investment as well, and the overall fiscal impact of increasing transfers is positive: consumption tax revenues and labour income tax revenues both increase significantly.

When income taxes go up to deal with the budget shortfall, we get the expected negative response in employment and consumption. On the other hand, our fiscal rules imply that output would stay higher over a prolonged period of time if taxes are used as the means of fiscal adjustment. There is, thus a clear intertemporal trade-off here if the objective is to achieve output growth.

There is also another trade-off in place: the consumption response of Ricardian versus non-Ricardian consumers is affected by the choice of the consolidation instrument.

Overall, it appears a suitable combination of the two instruments could do reasonable job at stabilizing output as well as consumption both over time and in the cross section.
3.2.2 Negative Foreign Demand Shock

Now we assume that the foreign economies face a negative persistent temporary unanticipated shock directly affecting their output and therefore the overall demand for goods. The foreign monetary authority expecting drop in inflation reduces its interest rate and hence partially offsets negative evolution of foreign output (Figure 3.5). The negative trends in the foreign economy are immediately transmitted to Slovak economy, as foreign market with decreasing output require less production inputs hence weaken demand for the country’s export goods (Figures 3.6-3.7).

Fall in the production of export goods has a negative impact on the trade balance and hence worsens the country’s current account and foreign debt position. Increasing risk premium also plays its role in foreign debt deterioration (Figure 3.6). Furthermore, exporters adjust their usage of production factors to this drop in the foreign demand. Since smaller amounts of imports,
energies and household services (capital, labour) are needed, households provide less capital and price it below its long term value. In the environment of weak private sector employment household face net labour income reduction and so their consumption shrinks even though this decrease is partially offset by using the accumulated savings (see Figure 3.8). Marginal costs fall due to cheaper production inputs, and form a significant negative pressure on domestic prices which makes consumption and investment less expensive. Therefore declining prices of domestic goods partly help households to offset losses in labour income. Exporters also reduce their price in order to be more competitive with their goods. Decreasing production output and demand for its inputs imply deterioration in all tax bases (Figure 3.9). Therefore the subsequent shortfall in tax revenues induces a fall in primary budget balance and leads to a rise in public debt.

The government responds to this situation by either a transfers cut or a labour tax rate hike. Unlike in the previous case of a positive productivity shock, both measures are now pointing in the direction one would consider intuitive. This suggests that our policy rules imply different policy prescriptions for the same instruments depending on the exogenous environment.

Provided that the labour tax rate is increased, marginal costs increase and consequently, prices do not fall by as much. Households suffering lower net labour income and falling payoffs from capital renting do not invest and spend their savings on consumption instead (Figures 3.7–3.8). In spite of the tax increase, aggregate revenues do not increase in the short term, the tax base shrinks due to a fall in employment amplified by wage negotiated by employees reflecting the labour tax increase. Furthermore, in addition to the initial insufficient foreign demand for export goods, its production drops even more sharply due to costly inputs and hence high export prices. Therefore, the current account balance gets worse and the foreign debt position rapidly deteriorates (Figure 3.6). The drop in production and usage of production inputs has long-lasting effects on the economy.

If the government decides to lower transfers, no wage pressure occurs and so the substantial decline in production marginal costs inducing price fall (Figure 3.6) makes goods more accessible for households facing lower non-labour income. This supports production and hence, after an initial drop in labour inputs, firms start to require more labour, capital, import and energy. In order to build up capital stock, households invest and prefer savings to consumption (see Figures 3.7–3.8). Therefore in spite of an initial fall in government revenues they soon rise with low transfers helping to stabilize and even increase primary balance and so reducing public debt. Furthermore, low marginal costs enable exporters to keep price below its long-term value and hence contribute to better current account balance and foreign debt decline (Figure 3.6). Thus, as
before, the effects of the transfers cut on the performance of the economy facing a sudden drop in foreign economy output gap are much better than the consequences of labour tax increase.

3.3 Fiscal Consolidation Scenarios

We also study the effects of various fiscal policies the government might implement to stabilize the debt and deficit that are currently considerably above their safe levels. We set the initial conditions of our economy so that they reflect the current state of the world from the perspective of Slovakia. More specifically, we assume that the public debt attains 57 percent of GDP and the government runs a primary deficit of 1.9 percent of GDP with poor domestic and EU economy performance (production in both is 1.75 percent below its long-term trend). At the same time, both economies face zero inflation and low interest rates (2.7 percent p.a. nominal rate for Slovak government bonds).

When modelling fiscal consolidation from an initial state away from the steady state, we do not rely on simple linear approximations around the deterministic steady state characterized above. Instead, we gradually shift the steady state of the economy in line with the debt adjustment trajectory implied by our fiscal rules, and calculate approximations around the nodes of this gradually shifting sequence of steady-states.\footnote{The steady state is shifted in intervals corresponding to four percentage-point decreases in the public debt-to-GDP ratio. Experiments with different frequencies of adjustment revealed there is little gain in accuracy (but significant cost in computing time) from shifting to a higher frequency. At the same time, there are significant...}
In what follows, we describe the response of economy assuming that the fiscal authority aims to reduce public debt to a target level of 40 percent of GDP within 20 years. Again, the choice of the fiscal variable to consolidate public debt has a significant influence on key macro variables and these effects differ among various fiscal instruments. Although any of them can reliably consolidate public finance and in the long term and bring the debt to safe level, they have rather different implications for the real economy. In what we present in our figures, the government chooses to adjust either transfers, or labour income tax. Furthermore, when government is to determine the amount of consolidation needed in the current time period, it takes into consideration both the debt and deficit gaps (the difference between the actual debt (deficit) and its target value).

Transfers Reduction. The economy starts off with low marginal costs, as the performance falls well short of the potential level. When adjustment is conducted through transfers, marginal costs are not affected directly, and so final goods prices fall even more and make final goods differences compared with using a simple log-linear approximation around the deterministic steady state of the model. For presentation purposes, we smooth out the obtained series.
Fiscal consolidation scenarios under realistic initial conditions performed providing that government adjusts either transfers (dark line) or labour tax (blue line). Dashed lines represent debt and deficit targets.

more attractive. Non-Ricardians, followed by Ricardians (owing to strong habit persistence) suffering lower income due to transfers reduce their consumptions immediately. Next, Ricardians now not buying consumption goods invest and save more. The initial decline in marginal costs supports also lower export prices (permanently lower than in case of adjustment in labour tax rate) which helps exports. Increasing domestic and foreign demand for the export and investment goods requires higher production inputs which acts to quickly raise and then stabilize employment and capital stock. Moreover, as the effect of appreciation in export exceeds imports growth, the trade balance, the current account balance (for a short time negative due to lags in production demands for imported goods) and foreign debt are in a better shape. Hence, despite the initial fall in domestic production and temporary public debt increase, economic activity is positively affected at a later stage.

Labour Tax Rate Increase. On the other hand, in the case when the fiscal authority decides to raise the labour tax rate, it generates output loss over the medium- to long-term horizon. Initially, the higher labour tax (and hence real wage reflecting tax changes) causes marginal costs increase partially offsetting the initial low level of prices. This intensifies the contraction in firms’ production inputs demand - capital, labour, imports and energy. The increasing export
price contributes to shrinking of export and so substantially worsens the country’s current account position. This leads to a steep growth of the foreign debt. Household, initially untouched by higher labour taxes (as they project it into their wage requirements), now face decreasing employment; drop in capital rental & dividend income. Non-Ricardians consume less and Ricardians’ investment activity diminishes as firm’s demand for capital wanes.

**Fiscal implications** From the fiscal policy point of view, if the government decides to consolidate the debt by cuts in transfers, as a result of a large drop in consumption, both the consumption tax base and revenues drop. This more than offsets the increase in labour tax revenue only over the long term. A similar pattern in the short run can be observed for the capital tax base and revenues. Indeed, the stimulus of initial higher households’ investment activity and the associated increase in the capital stock in the environment of increasing labour tax rate disappears soon. So if government adjusts transfers to lower the debt in the mid- and long-term both the capital tax base and revenues are higher than in case of a labour tax rate hike. On the other hand, even though the labour tax revenues are higher if government chooses a labour tax hike, the opposite is true for the labour tax base due to the permanent contraction of employment.

### 3.4 Fiscal Multipliers

We can use the above exercise to compute implied fiscal multipliers. We contrast the results with implied multipliers from a benchmark simulation in which the government unexpectedly adjusts different fiscal instruments with the economy initially in its deterministic-steady state. The comparison should give us a flavour of the nonlinearities in the economy and their implications for the effectiveness of fiscal policy strategies in stimulating the real economy in various stages of the economic cycle.

The behaviour of government has an essential impact on whole economy. Therefore, we evaluate the fiscal multipliers for two types of reaction functions: realistic policy rules introduced in Section 2.4.1 and standard Taylor-like rules. We model the realistic policy rules in rather parsimoniously fashion by simplifying the correction functional to be responsive to deviations in debt only. Similarly, in case of Taylor-like rules we let fiscal instruments react to past deviation of the public debt-to-GDP from its equilibrium value.

### 3.4.1 Steady-state fiscal multipliers

Table 3.1 summarizes implied fiscal multipliers at various horizons for all fiscal instruments from our benchmark simulation. Following Uhlig (2010), we calculate the implied net present...
Table 3.1: Standard implied fiscal multipliers

<table>
<thead>
<tr>
<th>Activity</th>
<th>Realistic Rules</th>
<th>Taylor Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>transfers</td>
<td>0.57</td>
<td>0.91</td>
</tr>
<tr>
<td>public wage bill</td>
<td>0.26</td>
<td>0.35</td>
</tr>
<tr>
<td>public infrastructure</td>
<td>0.90</td>
<td>0.85</td>
</tr>
<tr>
<td>private infrastructure</td>
<td>0.90</td>
<td>0.85</td>
</tr>
<tr>
<td>government waste</td>
<td>0.90</td>
<td>0.86</td>
</tr>
<tr>
<td>consumption tax</td>
<td>-0.63</td>
<td>-1.51</td>
</tr>
<tr>
<td>capital tax</td>
<td>-0.79</td>
<td>-1.88</td>
</tr>
<tr>
<td>labour tax</td>
<td>-0.52</td>
<td>-1.65</td>
</tr>
</tbody>
</table>

Table 3.2: Implied fiscal multipliers in a recession

<table>
<thead>
<tr>
<th>Activity</th>
<th>Realistic Rules</th>
<th>Taylor Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>4</td>
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<tr>
<td>transfers</td>
<td>0.54</td>
<td>0.14</td>
</tr>
<tr>
<td>public wage bill</td>
<td>0.17</td>
<td>-0.87</td>
</tr>
<tr>
<td>public infrastructure</td>
<td>0.79</td>
<td>-0.02</td>
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<tr>
<td>private infrastructure</td>
<td>0.83</td>
<td>-0.05</td>
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<tr>
<td>government waste</td>
<td>0.86</td>
<td>-0.09</td>
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<tr>
<td>consumption tax</td>
<td>-0.68</td>
<td>-1.29</td>
</tr>
<tr>
<td>capital tax</td>
<td>-0.57</td>
<td>-1.32</td>
</tr>
<tr>
<td>labour tax</td>
<td>-1.84</td>
<td>-3.88</td>
</tr>
</tbody>
</table>

We see that in both cases the obtained values rather reasonable, in consistence with standard literature and regardless the choice of the fiscal rule, the key implications remain the same.

In general, tax changes have large long-run consequences. Evidently, the labour tax raise turns out to be the most harmful in the long-term, although it seems to be least damaging revenue instrument in the short-run. Furthermore, capital tax is more detrimental than consumption tax in the long term.

On the other hand, cutting the wage bill appears to be the least harmful method of fiscal consolidation, while reduction in capital expenditures is calculated to be fairly costly in terms of real economy performance in the long run.

The implied multipliers obtained using the rules providing a realistic description of the conduct of fiscal policy are not too different from the multipliers one would obtain using a conventional fiscal policy Taylor rule calibrated to produce fiscal adjustment of a similar magnitude.

The obtained results are summarised in Table 3.1 and illustrated on Figure D.1 in Appendix D.1.

31
3.4.2 Fiscal multipliers in a recession

In the alternative simulation starting off from the steady state, the implied multipliers show somewhat different patterns. Cuts in government expenditures have small long-run impacts and are also less harmful in the long-run than tax hikes. Reduction of the public wage bill turns out to have even positive consequences on the economy. On the other hand, the detrimental effect of labour income tax hikes is even more pronounced in a high-debt, low-growth context.

The obtained results are summarized in Table 3.2 and illustrated on Figure D.2 in Appendix D.2.
4 Concluding remarks

We have set out a medium-scale DSGE model designed and calibrated to capture developments in the Slovak economy. The response of the economy to a technology shock and to a foreign demand shock was studied under alternative fiscal policy scenarios. This revealed interesting policy trade-offs in the choice of the means of fiscal adjustment. We also analysed various strategies used to lower the public debt permanently from an elevated level, and computed the corresponding implied fiscal multipliers. Generally, we have found these multipliers to be relatively large given the openness of the Slovak economy. Cuts in government wage bill are least harmful for the real economy especially if the economy is in a recession. Among tax measures, labour income tax increases are the most harmful for growth in the long term in general.

There is an interesting further research agenda emerging from this work. First, the model needs to be estimated in order to obtain an even better account of developments in Slovakia. Those parameters whose value is not pinned down by steady-state ratios or whose calibration is surrounded by larger-than-usual uncertainty, whilst having a significant impact on aggregate dynamics, deserve a particular attention in this regard. For this reason, our conclusions concerning multiplier effects might slightly change in the future. Second, an empirical exercise will allow us to determine the key driving forces of business cycle dynamics in Slovakia. Second, there are several avenues for further extensions. Demographic developments are an important aspect of the Slovak economy over the medium-to long-term not captured in this framework. Explicit modelling of labour force participation and unemployment seem to be extensions worthwhile to consider too. Finally, accounting for the presence of non-tradable goods and services could better capture the causes and consequences of the real exchange rate dynamic, including foreign direct investment decisions, which is very important in the context of Slovakia’s highly open economy.
5 Bibliography


Appendix A  Model Summary

Private Sector Production

\[ m_t^e = (1 - \alpha_m^e) \left[ \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right] \left( \frac{\sigma_t^h}{\bar{\sigma_t^h}} \right) x_t \]

\[ e_t^e = \alpha_m^e(1 - \sigma_e^e) \left[ \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right] \left[ \frac{\eta_t^{ip,p} \frac{\xi_t}{\bar{\xi_t}} \sigma_t^h}{\eta_t^{ip,p} \frac{\xi_t}{\bar{\xi_t}} \sigma_t^h} \right] \left( \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right) x_t \]

\[ h_t^{p,e} = \alpha_h^e(1 - \sigma_h^e) \left[ \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right] \left[ \frac{\eta_t^{ip,p} \frac{\xi_t}{\bar{\xi_t}} \sigma_t^h}{\eta_t^{ip,p} \frac{\xi_t}{\bar{\xi_t}} \sigma_t^h} \right] \left( \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right) x_t \]

\[ k_t^{e} = \alpha_h^e(1 - \sigma_h^e) \left[ \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right] \left[ \frac{\eta_t^{ip,p} \frac{\xi_t}{\bar{\xi_t}} \sigma_t^h}{\eta_t^{ip,p} \frac{\xi_t}{\bar{\xi_t}} \sigma_t^h} \right] \left( \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right) x_t \]

\[ \psi_t^e = \left( \frac{\xi_t}{\bar{\xi_t}} \right) \left( \frac{\bar{\xi_t}}{\xi_t} \right) \psi_t \]

Price Settings

\[ \Pi_t^e = \frac{1}{1 + \beta v_z x_t} \beta v_z E_t \xi_{t+1} + \gamma_t \xi_t + (1 - \lambda_t)(1 - \beta v_z x_t) \xi_t^{-1} (\psi_t^e - \bar{\psi_t}^e) \]

Public Goods

\[ \Pi_t^e = (1 - \beta v_z x_t) \left[ \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right] \left( \frac{\psi_t - \psi_t^b}{\bar{\psi_t} - \psi_t^b} \right) x_t \in \{ c, i, g, f \} \]

Profits

\[ \pi_t = (1 - \lambda_t) \left[ \psi_t^e - \psi_t^b \right] \left( \psi_t - \psi_t^b \right) + \lambda_t \left[ \psi_t - \psi_t^b \right] \left( \psi_t - \psi_t^b \right) \left( \psi_t - \psi_t^b \right) \left( \psi_t - \psi_t^b \right) x_t \in \{ c, i, g \} \]

Households

\[ \lambda_t = (1 + \tau_t^e)^{-1} \lambda_t^e \]

\[ \omega_t = \left( \frac{c_t^{e,p}}{c_t} \right)^{\lambda_t^e} + \left( 1 - \lambda_t^e \right) \frac{\xi_t}{\bar{\xi_t}} c_t^{e,*} \exp \left( \frac{\xi_t}{\bar{\xi_t}} \right) x_t \]

\[ \rho_t^e \exp (\rho_t^e (u_t - 1)) \left( \frac{1 + \tau_t^e}{1 + \tau_t^e} \right) \]
### Aggregates and Definitions

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
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<tbody>
<tr>
<td>Eq. 29</td>
<td>( div = \pi^* + \pi^* + \rho^* + \rho^* - \tau^* )</td>
</tr>
<tr>
<td>Eq. 30</td>
<td>( \theta^* = \theta^* + \eta^* )</td>
</tr>
<tr>
<td>Eq. 31</td>
<td>( k_t = \sum_{s \in \mathcal{X}(x,y,t)} k_t^s )</td>
</tr>
<tr>
<td>Eq. 32</td>
<td>( e_t = \sum_{s \in \mathcal{X}(x,y,t)} e_t^s )</td>
</tr>
<tr>
<td>Eq. 33</td>
<td>( \rho^<em>_n = (1 - \lambda) \rho^</em>_p + \lambda \rho^*_n )</td>
</tr>
<tr>
<td>Eq. 34</td>
<td>( h^<em>_p = (1 - \lambda) h^</em>_p + \lambda h^*_n )</td>
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<tr>
<td>Eq. 35</td>
<td>( tr_t = \lambda tr^<em>_p + (1 - \lambda) tr^</em>_n )</td>
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### Labour Market

<table>
<thead>
<tr>
<th>Equation</th>
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<tbody>
<tr>
<td>Eq. 36</td>
<td>( w_t b_t = w^<em>_t h^</em>_b + w^<em>_t h^</em>_p )</td>
</tr>
<tr>
<td>Eq. 37</td>
<td>( \delta_t^w = \beta E_t \left[ \delta_{t+1}^{w, p} \right] + \eta^w \left[ \delta_{t+1}^{w, p} - \delta_t \right] + \lambda w_t \delta_t^p + \lambda w_t \delta_t^b )</td>
</tr>
<tr>
<td>Eq. 38</td>
<td>( \lambda_t = \frac{1}{t^{\frac{1}{1+\eta^w}}} \left[ \frac{1}{(1+\eta^w)} \right] \left[ \frac{1}{(1+\eta^w)} \right] )</td>
</tr>
<tr>
<td>Eq. 39</td>
<td>( \delta_t^p = \frac{w_t^p - \sigma^{\delta^p}}{\sigma^{\delta^p}} )</td>
</tr>
<tr>
<td>Eq. 40</td>
<td>( \delta_t^{w, p} = \left( \Pi_t^{w, p} \right)^{1-\gamma_{w, p}} \left( \Pi_t^{w, p} \right)^{\gamma_{w, p}} \left( \Pi_t^{w, p} \right)^{\gamma_{w, p}} \left( \Pi_t^{w, p} \right)^{\gamma_{w, p}} )</td>
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<tr>
<td>Eq. 41</td>
<td>( \Pi_t^{w, p} = \frac{1 + \tau^p}{1 - \tau^p} )</td>
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### Market Clearing Conditions and Fiscal Variables

<table>
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<th>Equation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Eq. 42</td>
<td>( s_t \frac{d{debt}_t}{R^*} - \psi(u_t \delta_t^{w, b}) = s_t \frac{d{debt}<em>t}{\Pi_t^{w, b}} - c</em>{a_t} )</td>
</tr>
<tr>
<td>Eq. 43</td>
<td>( \delta_t = \beta E_t \left[ \delta_{t+1} \right] \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
</tr>
<tr>
<td>Eq. 44</td>
<td>( \kappa_t = \left[ \Pi_t^{w, b} \right] \gamma_{w, b} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
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<tr>
<td>Eq. 45</td>
<td>( \kappa_t = \left( 1 - \delta_t \right) \left[ \Pi_t^{w, b} \right] \gamma_{w, b} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
</tr>
<tr>
<td>Eq. 46</td>
<td>( \frac{d{debt}_t}{R^*} = \frac{d{debt}_t}{\Pi_t^{w, b}} - \psi_t )</td>
</tr>
<tr>
<td>Eq. 47</td>
<td>( \psi_t = \left[ \Pi_t^{w, b} \right] \gamma_{w, b} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
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### Interest Rates, Asset Prices and Bond Yields

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<tr>
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<tbody>
<tr>
<td>Eq. 49</td>
<td>( \lambda_t = \beta E_t \left[ \lambda_{t+1} \right] \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
</tr>
<tr>
<td>Eq. 50</td>
<td>( R^*_p = R_t \exp \left[ \left( \psi_t + \delta_t \right) \right] \exp \left[ \xi_t \right] )</td>
</tr>
<tr>
<td>Eq. 51</td>
<td>( \psi_t = \left[ \Pi_t^{w, b} \right] \gamma_{w, b} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
</tr>
<tr>
<td>Eq. 52</td>
<td>( R^*<em>p = R_t \exp \left( x^{\psi_t} \right) \left[ \Pi_t^{w, b} \right] \gamma</em>{w, b} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
</tr>
<tr>
<td>Eq. 53</td>
<td>( \psi_t = \frac{1}{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} )</td>
</tr>
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### Output Gap

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Eq. 54</td>
<td>( y_t = c_t^f + p_t h_t + p_t g_t + \psi_t )</td>
</tr>
<tr>
<td>Eq. 55</td>
<td>( \psi_t = \psi(u_t \delta_t^{w, b}) )</td>
</tr>
<tr>
<td>Eq. 56</td>
<td>( \alpha_{dep} = \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \left[ \left( \frac{m_t}{m_{t+1}} \right)^{\alpha \psi_t} \right] \left[ \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \right] \left[ \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \right] \left[ \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \right] )</td>
</tr>
<tr>
<td>Eq. 57</td>
<td>( \alpha_{bom} = \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \left[ \left( \frac{m_t}{m_{t+1}} \right)^{\alpha \psi_t} \right] \left[ \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \right] \left[ \left( \frac{m_{t+1}}{m_t} \right)^{\alpha \psi_t} \right] )</td>
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### Fiscal Rules

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</thead>
<tbody>
<tr>
<td>Eq. 58</td>
<td>( \alpha_t = \psi_t \left[ \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \right] \left[ \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \right] \left[ \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \left( \Pi_t^{w, b} \right)^{\gamma_{w, b}} \right] )</td>
</tr>
<tr>
<td>Eq. 59</td>
<td>( \Omega_t = \frac{\Delta{debt}_t}{y_t} - \psi_t )</td>
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<tr>
<td>Eq. 60</td>
<td>( \Delta_t = \frac{\psi_t}{y_t} - \psi_t )</td>
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<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Eq. 61</td>
<td>( tr_t = (1 - p_t)tr_{t-1} )</td>
</tr>
<tr>
<td>Eq. 62</td>
<td>( h_t^e = (1 - p_t)h_t^e )</td>
</tr>
<tr>
<td>Eq. 63</td>
<td>( g_{\nu t}^w = (1 - p_t)g_{\nu t}^w )</td>
</tr>
<tr>
<td>Eq. 64</td>
<td>( i_t^p = (1 - p_t)i_t^p )</td>
</tr>
<tr>
<td>Eq. 65</td>
<td>( i_t^e = (1 - p_t)i_t^e )</td>
</tr>
<tr>
<td>Eq. 66</td>
<td>( t^e_t = (1 + p_t)\hat{t}_t^e )</td>
</tr>
<tr>
<td>Eq. 67</td>
<td>( t^f_t = (1 + p_t)\hat{t}_t^f )</td>
</tr>
<tr>
<td>Eq. 68</td>
<td>( t^w_t = (1 + p_t)\hat{t}_t^w )</td>
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**World**

<table>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq. 69</td>
<td>( \hat{\rho}<em>t^{nu} = \alpha</em>{\rho_t}\hat{\rho}<em>{t-1}^{nu} + \alpha</em>{\nu_t}\eta_t^{nu} + \alpha_{t_t}^\nu + \epsilon_t^{\nu,u} )</td>
</tr>
<tr>
<td>Eq. 70</td>
<td>( \hat{\Pi}<em>t^{nu} = \alpha</em>{\Pi_t^{nu}}\Pi_{t-1}^{nu} + (1 - \alpha_{\Pi_t^{nu}})\hat{\Pi}<em>t^{nu} + \alpha</em>{\nu_t}p_t^{nu} + \epsilon_t^{\nu,u} )</td>
</tr>
<tr>
<td>Eq. 71</td>
<td>( \hat{y}<em>t^{nu} = \alpha</em>{y_t}y_{t-1}^{nu} + (1 - \alpha_{y_t})\hat{y}<em>t^{nu} + \alpha</em>{\nu_t}p_t^{nu} + \epsilon_t^{nu,y} )</td>
</tr>
<tr>
<td>Eq. 72</td>
<td>( \hat{\eta}<em>t^{nu} = \alpha</em>{\eta_t}\hat{\eta}<em>{t-1}^{nu} + \alpha</em>{\nu_t}p_t^{nu} + \epsilon_t^{\nu,i} )</td>
</tr>
<tr>
<td>Eq. 73</td>
<td>( \hat{\Pi}<em>t^{nu} = \alpha</em>{\Pi_t^{nu}}\Pi_{t-1}^{nu} + (1 - \alpha_{\Pi_t^{nu}})\hat{\Pi}<em>t^{nu} + \alpha</em>{\nu_t}p_t^{nu} + \epsilon_t^{\nu,u} )</td>
</tr>
<tr>
<td>Eq. 74</td>
<td>( \hat{y}<em>t^{nu} = \alpha</em>{y_t}y_{t-1}^{nu} + (1 - \alpha_{y_t})\hat{y}<em>t^{nu} + \alpha</em>{\nu_t}p_t^{nu} + \epsilon_t^{nu,y} )</td>
</tr>
<tr>
<td>Eq. 75</td>
<td>( \hat{\Pi}<em>t^{nu} = \Pi</em>{t-1}^{nu} + (1 - \alpha_{\Pi_t^{nu}})\hat{\Pi}_t^{nu} )</td>
</tr>
<tr>
<td>Eq. 76</td>
<td>( \hat{y}<em>t^{nu} = y</em>{t-1}^{nu} + (1 - \alpha_{y_t})\hat{y}_t^{nu} )</td>
</tr>
<tr>
<td>Eq. 77</td>
<td>( \hat{\delta}<em>t^{\nu} = \alpha</em>{\delta_t}^{\nu}\hat{\delta}_{t-1}^{\nu} + \epsilon_t^{\nu} )</td>
</tr>
<tr>
<td>Eq. 78</td>
<td>( \hat{\zeta}<em>t^{\nu} = \alpha</em>{\zeta_t}^{\nu}\hat{\zeta}_{t-1}^{\nu} + \epsilon_t^{\nu} )</td>
</tr>
<tr>
<td>Eq. 79</td>
<td>( \hat{p}<em>t^{nu} = \alpha</em>{p_t}^\nu p_{t-1}^{nu} + \epsilon_t^{nu} )</td>
</tr>
<tr>
<td>Eq. 80</td>
<td>( \hat{\eta}<em>t^{nu} = \alpha</em>{\eta_t}^{nu}\hat{\eta}_{t-1}^{nu} + \epsilon_t^{nu} )</td>
</tr>
<tr>
<td>Eq. 81</td>
<td>( \hat{\zeta}<em>t^{\nu} = \alpha</em>{\zeta_t}^{\nu}\hat{\zeta}_{t-1}^{\nu} + \epsilon_t^{nu} )</td>
</tr>
<tr>
<td>Eq. 82</td>
<td>( \hat{\nu}<em>t^{nu} = \alpha</em>{\nu_t}^{nu}\hat{\nu}_{t-1}^{nu} + \epsilon_t^{nu} )</td>
</tr>
<tr>
<td>Eq. 83</td>
<td>( \hat{\delta}<em>t^{\nu} = \alpha</em>{\delta_t}^{\nu}\hat{\delta}_{t-1}^{\nu} + \epsilon_t^{nu} )</td>
</tr>
</tbody>
</table>
Appendix B  Model Calibration

Appendix B.1  Preliminary Assumptions

Inputs: Values of the following variables and parameters are taken as given and determine the steady state of the whole non-linear model:

- Production: $\alpha_{it}, \alpha_{it}', \alpha_{it}^0, \alpha_{it}^0, \alpha_t, \alpha_t', \alpha_{it}', \sigma_{it}, \sigma_{it}', \sigma_{it}^0, \sigma_{it}^0', \sigma_t, \sigma_t'$
- External Environment: $\sigma', \sigma'', \psi, \delta, \Pi^{ca}, R, \Pi^{prem}, \Pi^{0}, \omega$
- Monetary Policy: $t, \delta^{**}, deb^{0}, prem^{0}_{b}, R_b$
- Prices & Wages: $\beta_0, \beta_0, \beta, \Pi', \chi_0, \theta_0, \theta_0, \theta_f, \theta_f$
- Households: $\kappa', \kappa''$, $\sigma, \lambda, p_2^y$, $\alpha_0, \theta_0, \zeta_h$
- Fiscal Policy: debt, $f_{debt}, c, g, f, q^g, tr, wh, is_g, is_p, \tau_c, \tau_m$

Structural Assumptions

- Stationarized model, i.e. no growth in the steady state.
- Full utilization of capital in the equilibrium, i.e. $u = 1$. Therefore $\psi(u) = 0$.
- Unit price of goods in the equilibrium (evaluated in the domestic currency), i.e. $p_e = p_i = p_g = r_p = p_m = p_e$. Therefore, marginal costs coincide with elasticity of substitution, $\psi_e = \theta_q$, and we need to find out the steady state values of the technology–specific processes $\zeta_t$ under which such equality would hold.

Model Particularities:

- Utility Function: in case of a different choice if the utility function (e.g. consumption–labour separable) change marginal utility of consumption relationship (B.59) in Block (B.6).
- Production Function: Blocks (B.3) and (B.5) are designed for our specific three stage CES & Cobb–Douglas type production function. Thus, if other type of production function is needed, change these blocks and the associated input parameters.

Appendix B.2  Fiscal and Monetary Policy

Inputs:

- given: $\psi, \Pi', R_b, R, deb^{0}, t, \Pi^{prem}, \Pi^{0}, \omega, \delta, f_{debt}, \text{debt}$
- derived in previous blocks: none

List of Relationships:

\[ \beta = \frac{\psi \Pi'}{R_b}, \quad R_a = R_b \]  \hspace{1cm} (B.1)

\[ s = \sigma + (1 - \sigma) s_x, \quad \Pi^{*} = \sigma \Pi^{ca} + (1 - \sigma) \Pi^{neu} \]  \hspace{1cm} (B.2)

\[ prem^{b} = \log(R_b) - \log(R) \]  \hspace{1cm} (B.3)

\[ prem^{d} = \psi \Pi' \frac{f_{debt}}{1 - \beta} \]  \hspace{1cm} (B.6)

\[ foreign \ debt \ & \ current \ account \]  \hspace{1cm} (B.7)

Euler Equation & UIP

\[ \beta = \frac{\psi \Pi'}{R_b}, \quad R_a = R_b \]  \hspace{1cm} (B.1)

FX and Foreign inflation

\[ s = \sigma + (1 - \sigma) s_x, \quad \Pi^{*} = \sigma \Pi^{ca} + (1 - \sigma) \Pi^{neu} \]  \hspace{1cm} (B.2)

Domestic debt risk premium

\[ prem^{b} = \log(R_b) - \log(R) \]  \hspace{1cm} (B.3)

Domestic debt risk premium functional

\[ prem^{d} = \psi \Pi' \frac{f_{debt}}{1 - \beta} \]  \hspace{1cm} (B.6)

Domestic debt & primary balance

\[ debt = \frac{bb \Pi' \psi}{1 - \beta} \]  \hspace{1cm} (B.5)

Foreign debt星空 addiction

\[ foreign \ debt \ & \ current \ account \]  \hspace{1cm} (B.7)

Procedure:

From (B.1)–(B.4) we deduce the discount factor $\beta$ interest rates on foreign debt $R_a$, domestic debt risk premium and the associated debt premium functional steady state. As $debt$ is given, we use (B.5) to derive steady state primary balance and for a given value of current account (B.8) is employed in order to get equilibrium $ca$. Finally, employing (B.2) both the nominal FX and foreign inflation are determined thus foreign debt premium prem$^d$ and transition costs come from (B.6)–(B.7).

Outputs: $\beta, R_a, s, \Pi^{*}, \text{prem}^{d}, \psi, bb, \text{prem}^{d}, \text{ca, trans}$.
Appendix B.3 Core

Inputs:

- given: \( \alpha_m, \alpha_m^i, \alpha_m^b, \alpha_c, \alpha_v, \alpha_m^\sigma, \sigma_m^v, \sigma_v, \Gamma, \theta_i, \theta_g, \theta_f, \delta_c, c, r, f, tr, wh_g, is_g, is_p, r^c, r^w \)
- derived in previous blocks: \( bb, \beta \) (both from Block B.2)

List of Relationships:

- Physical Capital Bill
  \[
  zk = \sigma_k \alpha_k \sum_{x \in \{c,i,g,f\}} \frac{\theta_0^{1-\sigma_m} - \sigma_i^m x}{\phi_x} \tag{B.9}
  \]
- Private Sector Wage Bill
  \[
  wh_p = (1 - \alpha_k) \sum_{x \in \{c,i,g,f\}} \frac{\theta_0^{1-\sigma_m} - \sigma_i^m x}{\phi_x} \tag{B.10}
  \]
- Household Budget Constraint
  \[
  wh_p + zk + \pi = 1 \tag{B.11}
  \]
- GDP Identity
  \[
  c + i + g + tb = 1 \tag{B.12}
  \]
- Tax Bases
  \[
  \Phi^i = c + i \quad \Phi^t = zk + \pi + (ca - tb) \quad \Phi^w = wh_p + wh_g \tag{B.13}
  \]
- Primary Balance
  \[
  bb = rev - exp \tag{B.14}
  \]
- Marginal Costs:
  \[
  \Xi_\phi = \left( \frac{wh_p}{\alpha_i^m} \right)^{1-\sigma_m} \left( \frac{c}{\alpha_i} \right) \frac{1}{1 + \sigma_m} \quad \Xi_\omega = \left[ \alpha_m \Xi_\phi^{1-\sigma_m} + (1 - \alpha_m) \right]^{1/\pi} \tag{B.21}
  \]

Procedure:

1. \( \text{[B.9] & [B.10]} \Rightarrow zk = \frac{\sigma_k}{\phi_x} wh_p \tag{B.22} \)
2. \( \text{[B.11] & [B.13]} \Rightarrow \pi = 1 - \frac{wh_p}{\alpha_k} \quad \Phi^i = 1 - wh_p + ca - tb \tag{B.23} \)
3. \( \text{[B.12]} \Rightarrow \Phi^t = ca - wh_p + c + g + i \tag{B.24} \)
4. \( \text{[B.14] & [B.15]} \Rightarrow 1 - t^k = \frac{ca - bb - tr - (1 - t^r)(wh_p + wh_g) + (1 + t^r)(c + i)}{ca - wh_p + c + g + i} \tag{B.25} \)
5. \( \text{[B.15] & [B.22]} \Rightarrow 1 - t^k = \frac{1 - \alpha_k}{\alpha_m^i} \frac{1}{\beta_m} k \left( 1 - \frac{1 - \delta_i}{r} \right) \tag{B.26} \)
6. \( \text{[B.26] & [B.16]} \Rightarrow 1 - t^k = \frac{1 - \alpha_k}{\alpha_m^i} \frac{1}{\beta_m} \frac{1 - \frac{1}{\beta_i} k}{1 - (1 - \delta_i)} \tag{B.27} \)
7. \( \text{[B.28]} \Rightarrow i = \frac{i}{wh_p} \tag{B.28} \)
8. \( \text{[B.19] & [B.20]} \Rightarrow tb = f + \pi - m - e - \sum_{x \in \{c,i,g,f\}} \pi_x \tag{B.29} \)
9. \( \text{[B.12] & [B.20] & [B.29]} \Rightarrow \frac{wh_p}{\alpha_i^m} + m + e = \sum_{x \in \{c,i,g,f\}} \theta_x \tag{B.30} \)
10. \( \text{[B.31]} \Rightarrow \frac{wh_p}{\alpha_i^m} = \sum_{x \in \{c,i,g,f\}} \theta_x \left[ 1 - \frac{\theta_0^{1-\sigma_m}}{\phi_x} \right] \left[ (1 - \alpha_m^i) + \alpha_m^i (1 - \alpha_m) \Xi_\phi^{1-\sigma_m} \right] \tag{B.31} \)
Then, as \( \phi \) is from (43) known, using (B.10) we determine \( w_{ph} \), from (22) \( z \) and from (28) \( i \). Therefore, employing (B.16) we get \( k, z = k^*/k \) and so using (B.21) we obtain \( w_{ph}, \Xi_{\Omega}, \Phi_{m} \) and \( \Phi_{f} \), which are directly used to determine \( m \) and \( e \) using (B.17)–(B.18). On the other side, under the knowledge of \( i \), (B.12) provides us \( t_{b} \) so that using (B.19) we get \( \theta_{m} \).

Then, we employ (23) to calculate \( \pi \) and (24) to obtain \( \pi_{x} \). Finally applying (B.13)–(B.14) we find all \( \Phi^{+} \) and from (B.15) we get \( t^{*} \).

**Outputs:** \( \Xi_{\Omega}, w_{ph}, z, k, i, \theta, \phi, \psi, \phi_{f}, p_{e}, t_{b}, \theta_{m}, \pi_{x}, \pi_{f}, \pi_{m}, \pi, \Phi^{+}, \Phi^{'}, \Phi^{''}, t^{*} \).

**Appendix B.4 Labour Market**

**Inputs:**
- given: \( w_{ph}, \phi_{m}, \beta_{m}, t_{v}^{*}, \zeta_{m}, \theta, \sigma_{pg}, \epsilon_{v} \)
- derived in previous blocks: \( w_{ph}, h, r_{ph} \) (all from Block B.3)

**List of Relationships:**

\[
\begin{align*}
\text{Aggregate Wage} & \quad w = \left[ \theta_{m} w_{ph}^{1-\sigma_{m}} + (1 - \theta_{m}) w_{ph}^{1-\sigma_{m}} \right]^{1/\sigma_{m}} \tag{B.34} \\
\text{Aggregate Labour} & \quad h = \left[ \theta_{m} h_{ph}^{1-\sigma_{m}} + (1 - \theta_{m}) h_{ph}^{1-\sigma_{m}} \right]^{1/\sigma_{m}} \tag{B.35} \\
\text{Public–Private Employment Relationship} & \quad h_{ph} = \beta_{m} h_{ph} \tag{B.36} \\
\text{Public Wage Bill} & \quad w_{ph} = h_{ph} \tag{B.37} \\
\text{Private Wage Bill} & \quad w_{ph} = w_{ph} \tag{B.38} \\
\text{Aggregate Wage Bill} & \quad w_{ph} = r_{ph} h_{ph} + h_{ph} \tag{B.39} \\
\text{Private Sector Labour Supply} & \quad (1 - \tau^{*}) w_{ph} = \frac{\theta_{m}}{\theta_{m} - 1} \zeta_{m}(1 + \tau^{*}) \left[ \theta_{m} h_{ph}^{1-\sigma_{m}} \right]^{\sigma_{m}} \tag{B.40} \\
\text{Public goods production} & \quad c_{v} = \zeta_{m} h_{ph}^{\sigma_{m}} \tag{B.41} \\
\text{Marginal private sector labour costs} & \quad \mu = \frac{w_{0}}{\theta_{m}} \tag{B.42}
\end{align*}
\]

**Procedure:** Suppose we know private sector wage \( w_{ph} \), and both public and private wage bills, \( w_{ph} \) and \( h_{ph} \). Furthermore, \( \sigma_{m} \) and \( \beta_{m} \) are prescribed. Then, (B.38) implies \( h_{ph} = w_{ph}/w_{ph} \) and using (B.36) we get private wage \( w_{ph} = w_{ph}/(\alpha_{h} h_{ph}) \). Next, due to (B.39) the aggregate wage bill \( w_{ph} \) is known. Hence, multiplying (B.34) by (B.35) and using (B.39) we solve the resulting equation for \( \theta_{m} \). Then, from (B.34)–(B.35) we deduce directly both \( w, h \) so that (B.40) gives us the value of \( v_{0} \). Finally given \( \epsilon_{v} \) from (B.41) we obtain \( \zeta_{m}^{v} \) and marginal costs \( \mu \).

**Outputs:** \( w, w_{ph}, \phi_{m}, h_{ph}, w_{ph}, \psi_{m}, \zeta_{m}^{v}, \mu \).

**Appendix B.5 Production**

**Inputs:**
- given: \( \theta_{m}, \theta_{k}, \phi_{f}, \theta_{m}, \alpha_{m}, \alpha_{m}, \alpha_{m}, \sigma_{m}, \sigma_{m}, \alpha_{m}, \sigma_{m}, \alpha_{m}, \sigma_{m}, \alpha_{m}, \sigma_{m} \)
- derived in previous blocks: \( \phi_{m}, \phi_{m}, \phi_{f}, \Xi_{\Omega}, \Xi_{\phi}, w_{ph}, z, \pi_{m} \) (all from Block B.3)

**List of Relationships:**

\[
\begin{align*}
\text{Overall marginal costs} & \quad \psi_{k} = \theta_{k} \tag{B.43} \\
\text{Technology–specific process sstte} & \quad \zeta_{k} = \frac{\theta_{k}}{\theta_{k}} \tag{B.44} \\
\text{Technology–specific demand for import} & \quad m_{k} = (1 - \alpha^{k}) \beta_{k} \tag{B.45} \\
\text{Technology–specific demand for energy} & \quad e_{k} = \alpha^{k} (1 - \alpha^{k}) \Xi_{\Omega}^{1-\sigma_{k}} \tag{B.46}
\end{align*}
\]
Technology–specific demand for labour

\[ h^l_p = \psi_p^{-1}(1 - \alpha) \alpha_n \alpha_e \alpha_i \phi \rho \sigma \theta_s x \xi \]  

(B.47)

Technology–specific demand for capital

\[ k_x = c^{-1} \theta \phi \rho \sigma \theta_s x \xi \]  

(B.48)

Aggregate demand for import

\[ m = m_c + m_i + m_g + m_f \]  

(B.49)

Aggregate demand for energy

\[ e = e_c + e_i + e_g + e_f \]  

(B.50)

Profits of importers

\[ \pi_m = (1 - \theta_m)m \]  

(B.51)

Procedure: From (B.43) we obtain technology–specific overall marginal costs and use them to evaluate the steady state values of the technology–specific processes \( \zeta \) defined by (B.44). Next, employing (B.45)–(B.48) we derive technology–specific optimal demands for all production inputs (energy, imports, capital, labour). Then, we aggregate state values of the technology–specific processes \( \zeta \).

From (B.52) we derive Tobin’s q \( \psi \). As both \( \psi \) and \( \sigma \) are known, using (B.53) and (B.56) we find \( \rho_f \psi \) and capital adjustment cost with its derivative. Finally the overall capital stock comes from (B.55). Given the value of transfers using (B.57) we derive transfers for Non–Ricardians \( \tau_n \), and then from (B.58) we get the Ricardian transfers.

\[ \tau = \lambda \tau_n - (1 - \lambda) \tau_r \]  

(B.58)

Marginal utility of consumption

\[ \Lambda = \left[ \frac{c (1 - \frac{1}{\theta_s}) + \alpha_c x (1 - \frac{1}{\theta_s}) - \frac{1}{1 + \nu^h} h^{1 + \nu^h}}{1 + \tau^c} \right]^{-1} \]  

(B.59)

Appendix B.6 Households

Inputs:

- given: \( \tau^c, \delta_k, \nu, \rho_f^{\psi}, c, \tau^c, \lambda, \alpha_c, \kappa^{c}, \kappa^{e}, \zeta_{th}, \sigma, \tau_r \)
- derived in previous blocks: \( \tau^c, z, i \) (all from Block (B.3)), \( \psi, c^e, \nu_f \) (all from Block (B.4)), \( \beta \) (Block B.2)

List of Relationships:

- FOC Investment \( \psi = 1 + \tau^c \)  
  (B.52)
- FOC Capital utilization rate \( \psi f = \psi(u) \)  
  (B.53)
- Capital Accumulation Law \( i = \int (1 - \frac{1}{\nu}) \)  
  (B.54)
- Active Capital \( k = \frac{k}{\nu} \)  
  (B.55)
- Capital Adjustment Costs \( \psi(u) = 0, \psi' = \frac{1 - \tau^c}{1 + \tau^c} \)  
  (B.56)
- Transfers for Non–Ricardians \( \tau_n + (1 - \tau^c) \psi = (1 + \tau^c) c \)  
  (B.57)
- Transfers for Ricardians \( \tau_r = \lambda \tau_n - (1 - \lambda) \tau_r \)  
  (B.58)
- Marginal utility of consumption \( \Lambda = \frac{c (1 - \frac{1}{\tau^c}) + \alpha_c x (1 - \frac{1}{\theta_s}) - \frac{1}{1 + \nu^h} h^{1 + \nu^h}}{1 + \tau} \)  
  (B.59)

Procedure: From (B.52) we derive Tobin’s q \( \psi \). As both \( \psi \) and \( \sigma \) are known, using (B.53) and (B.56) we find \( \rho_f^{\psi} \) and capital adjustment cost with its derivative. Finally the overall capital stock comes from (B.55). Given the value of transfers using (B.57) we derive transfers for Non–Ricardians \( \tau_n \), and then from (B.58) we get the Ricardian transfers. Finally, by (B.59) we derive the equilibrium marginal utility of consumption.

Outputs: \( \psi, \psi_f, \psi_f(1), \psi_f(1), \Omega, k, \tau_n, \tau_r, \Lambda \)

Appendix B.7 External Environment

List of Relationships:

- Foreign Demand \( f = \rho_f^{\psi} \phi \psi \Omega \)  
  (B.60)
- Foreign interest rate \( R^* = \phi R + (1 - \phi) \)  
  (B.61)
- Nominal FX \( s = \phi + (1 - \phi) s_t \)  
  (B.62)
### Appendix C Model Steady State

#### Appendix C.1 Key Steady-state Ratios

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>c/y</td>
<td>Aggregate (private goods) consumption of households to gdp</td>
<td>0.5400</td>
</tr>
<tr>
<td>i/y</td>
<td>Aggregate production of investment goods</td>
<td>0.2223</td>
</tr>
<tr>
<td>k/y</td>
<td>Aggregate demand for physical capital inputs to gdp</td>
<td>9.9144</td>
</tr>
<tr>
<td>g/y</td>
<td>Aggregate government consumption to gdp</td>
<td>0.1900</td>
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<tr>
<td>f/y</td>
<td>Aggregate export to gdp</td>
<td>0.9300</td>
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<tr>
<td>mthm/y</td>
<td>Aggregate import to gdp</td>
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</tr>
<tr>
<td>e/y</td>
<td>Aggregate demand for energy/oil to gdp</td>
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<tr>
<td>tb/y</td>
<td>Trade balance to gdp</td>
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<td>ca/y</td>
<td>Current account to gdp</td>
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<tr>
<td>fdebt/y</td>
<td>Foreign debt to gdp</td>
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<tr>
<td>debt/y</td>
<td>Public debt to gdp</td>
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<td>bb/y</td>
<td>Primary balance to gdp</td>
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<td>tr/y</td>
<td>Transfers to households to gdp</td>
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<td>wspw/y</td>
<td>Public sector wage bill to gdp</td>
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<td>Public goods to gdp</td>
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<td>Government investment to public sector infrastructure to gdp</td>
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<td>bspt/y</td>
<td>Government investment to private sector infrastructure to gdp</td>
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<td>govw</td>
<td>Government waste consumption to gdp</td>
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</tr>
<tr>
<td>Τc</td>
<td>Effective consumption tax rate</td>
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<tr>
<td>τw</td>
<td>Effective labour tax rate</td>
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<td>Effective capital tax rate</td>
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</tr>
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<td>Consumption tax revenues to gdp</td>
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<td>τsrfr/y</td>
<td>Capital tax revenues to gdp</td>
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<td>τwfr/y</td>
<td>Labour tax revenues to gdp</td>
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<td>p0</td>
<td>Gross return on domestic bonds (annualized)</td>
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<td>Domestic equilibrium CPI inflation (annualized)</td>
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<tr>
<td>wh/y</td>
<td>Aggregate wage bill (whole economy) to gdp</td>
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#### Appendix C.2 Model Parameters

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### Appendix C.3 Calibration Inputs

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Implied fiscal multipliers for budget expenditure and revenue items estimated under the equilibrium initial conditions and realistic (upper row) or Taylor-like (lower row) fiscal rules.
Appendix D.2  Multipliers in recession

Figure D.2: Fiscal multipliers in recession

Implied fiscal multipliers for budget expenditure and revenue items estimated under the assumption of recession and realistic (upper row) or Taylor-like (lower row) fiscal rules.