

# **Fiscal Policy Matters**

A New DSGE Model for Slovakia

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# **Fiscal Policy Matters** A New DSGE Model for Slovakia<sup>1</sup> Zuzana MÚČKA<sup>2</sup>

## Abstract

The paper sets out a multiple-trend DSGE model designed, calibrated and estimated 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 and evaluate country's fiscal policy credibility using interest rate spreads.

The estimated model is firstly employed to identify the structural economic shocks that drive the economy and determine the sources of the forecast uncertainty. The empirical analysis emphasizes the importance of the foreign shocks on domestic GDP, trade and employment growth and high influence of productivity shocks on inflation and labour market dynamics.

Next, using the model we study the response of the economy to a technology shock and to a foreign demand shock under alternative fiscal adjustment scenarios. We find that a well-designed programme involving increases in transfers as well as tax cuts can stabilize the economy in the short run and improve longer-term growth prospects following a shock with adverse fiscal implications. We analyse the consequences of fiscal policy shocks in and away from the steady state of the model. The exercise yields implied fiscal multipliers that are in line with standard literature. Raising capital and labour tax especially is particularly bad for the real economy, mainly in the long run. On the other hand, cutting subsidies and unproductive government consumption are the least harmful way of reducing spending, while reduction in the public wage bill and public investment has negative implications on household consumption and wealth.

**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.

## **Model Specifics**

The model is unique in four additional ways. First, it considers – in a stylized fashion in the context of a linear economy – the evolution of the risk premium on private and public debt.

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. We introduce a set of realistic fiscal rules that reflect the common practice whereby the government reacts to a no-policy-change scenario by setting a headline deficit target, 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.

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. We emphasize that the model design enables us to capture typical signs of converging small open economies – observed wedge between the value added and the real growth rate of trade (volume of exports and imports), increasing trade openness and real exchange rate appreciation. Realistic forecasting and policy analysis require model to treat properly long-run trends of key variables, capture the medium-run behaviour of the economy and track the interactions between the trends and the business cycle. Therefore, following Andrle et al. (2009) the model is enriched by various trend processes that introduce the wedge between real growth rates of trade and domestic economy, sectoral relative prices, trade openness, gradual convergence towards more developed countries and a mechanism allowing the long-run economy appreciation. Moreover, to emphasize the role of fiscal policy in the production following Forni et al. (2007) and Cavallo (2005) we let the domestic economy to operate in two sectors – productive private and unproductive public, fully financed by the government. We employ a standard approach on non-tradable and tradable goods when describing the private sector production technology.

Fourth, we allow *productive* government spending to interact with households consumption and following Leeper et al. (2015) and Papageorgiou (2014) extend their utility function to in-





clude public goods supplied to all households free of charge.

## **Empirical Analysis Results**

The model has been estimated using Bayesian inference methods (see Forni et al. (2007)). Following Andrle et al. (2009) due to in general different growth rates of model real variables and assumed impact of openness and quality technologies observed in the date we do not use standard Hodrick-Prescott filtering technique. We prefer to express the corresponding variables in the estimation procedure in growth rates rather than levels. We computed relative contributions of individual shocks to the total variance to determine the main sources of future uncertainties for the key model variables. Furthermore, we use the estimated model to build a simple Kalman filter that enabled us to detect the evolution of model shocks and determine their contribution to observed values of model variables.

Our finding about the sources of potential uncertainty based on 2009-2015 data are summarised as follows. Not surprisingly, due to high proportion of exports on GDP and increasing trade openness uncertainty in the real GDP growth and output gap (measured as the difference between the GDP and its stochastic long-run trend path) forecast is mostly a result of the uncertainty about the evolution of the foreign economy, mainly from the foreign demand volatility, variable price competitiveness of exporters and oil price fluctuations. Shocks in domestic productivity are the major domestic source of the GDP growth and output gap uncertainty. Private consumption growth forecast uncertainty is driven mainly by changes in the supply of public good, shocks in productivity and habit formation and variations in the transfer. Uncertainty about the growth of export and import is forced mainly by the fluctuations in foreign demand, trade openness, export price competitiveness and by changes in the quality or composition of export goods. Despite the initial large impact of the technology shock on the employment forecast uncertainty, long-run dynamics of the labour market is influenced especially by shifts in household preferences and foreign demand. However, shifts in household preferences are the largest contributor to the uncertainty in the real wage growth.

Furthermore, we employed the Kalman filter to determine and analyse the contribution of individual structural shocks to most important model variables between 2009 and 2015. We highlight several observations. Fall of the GDP growth was mainly due to losses in foreign demand and fall in the long-term growth. During the post-crisis period, gradually increasing foreign demand, export and domestic technologies are the main driving forces in the output recovery and recently slightly higher domestic demand help to improve the output growth. Private consumption has lost much of its pre-crisis level, mainly due to negative shocks in domestic and foreign demand and low performing productivity. Next, negative signals from the foreign economy and its slack recovery deepen the consumption fall in the post-crisis period. However, recently foreign environment, mainly decreasing rates, low oil price and inflation up to some stage compensate this negative trend in consumption fall. We have observed that decline of export and import during the crisis came from a significant fall in foreign demand and price competitiveness. Nevertheless these two forces and the export-specific process helped to recovery the trade in the post-crisis period. Recently foreign demand have weaken while trade openness improved. Labour market dynamics has been driven by changes in the foreign demand (with positive impact on the post-crisis recovery), domestic technologies and lately with some positive sway of shifts in household preferences.

## **Model Dynamics Results**

The estimated 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 Gali et al. (2002)).

We then used the estimated model to 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. As Leeper et al. (2015) remarks implied fiscal multipliers may be considerably higher and more persistent in the environment of passive monetary and active fiscal policy than in case of active monetary and passive fiscal policy.

We find these multipliers to be in general in line with standard multipliers estimates. Concretely, we confirm that raising taxes is more harmful for the growth in the short and long term than expenditure cuts. Among tax measures, direct taxes have larger impact on the economy than the consumption tax. Fiscal adjustment through labour income taxes is costly in the short term and a lot more damaging over a longer horizon especially for the economy in a recession.

We show that cuts in public investment are the most harmful in the long-run for the real economy in a high-debt, low-growth context when fiscal consolidation is needed. Most negative short-run externalities are associated with reduction in the public wage bill. Deleteriousness of using certain expenditure instruments for fiscal consolidation arises from a substantial role of public goods (produced using public capital and public sector labour force) in the economy and its complementarity or substitutional impact on consumption of Ricardians and Non-Ricardians. Furthermore, we observe that public goods existence leaves room for interesting private-public sector interactions, namely private investment crowding-out (due to higher public investment spending) or labour markets dynamics in terms of the private-public sector competition (resulting from the public wage bill adjustment).

The rest of the paper is organized as follows. Since the aim was to build a compact story-telling tool that would be useful for fiscal policy analysis and simulations, policy evaluation and forecasting. section 2 highlights some key differences relative to standard practice in DSGE modelling. Here we explain and justify a few several stylized facts and features that we want this fiscal model to capture. Section 3 is devoted to present in detail the model structure and explain its specifics. In section 4, we first stationarize the model and calibrate its steady state to fit the Slovak data. Then, we estimate the linearised model. For the purpose of simulation and forecasting we compute and analyse the forecast error variance decompositions for key model variables using the 2009-2015 data. Next, employing the Kalman filter we obtain the evolution of the model shocks and finally we determine the drivers of the economy in the recent period. The aim of Section 5 is to examine the performance of the estimated model in the wake of standard structural shocks deemed relevant in the context of Slovakia: a positive technology shock and negative foreign demand shock. Furthermore we simulate various scenarios of the fiscal consolidation in a low-productivity, high-debt environment. In this section, we also compute implied fiscal multipliers from our policy exercises and discuss the impact of the fiscal rule design on multipliers and the fiscal policy ability to achieve its target in a given horizon. Finally, section 6 concludes.





# 2 Motivation and Modelling Background

We present a medium-scale a small open emerging economy DSGE model tailor-made to describe developments in the Slovak economy still residing in its post-transition phase and gradually approaching more developed European economies. The aim was to build a compact story-telling tool that would be useful for fiscal policy analysis and simulations, policy evaluation and forecasting. 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) and in many technical aspects refers to the design of the model of the Czech National Bank presented in the paper of Andrle et al. (2009).

In what follows, we explain in more detail and justify a few several stylized facts and features that we want this fiscal model to capture.





## 2.1 **Production and Trends**

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 see Cuche-Curti et al. (2009) and Pytlarczyk (2005) we employ a standard approach on non-tradable and tradable goods when describing the private sector production technology. Firms manufacture their heterogeneous intermediate goods using a two stage production function gradually combining physical capital, labour, energy and combine this tradable semi-product with imported intermediate goods. Nevertheless, the export-specific technology process results in more expensive and less efficient imports in the production and yet make domestic intermediate goods more attractive. Production is also affected by technology shocks and subsidies financed by the government.

Furthermore, to emphasize the role of fiscal policy in the production we let the domestic economy to operate in two sectors – productive private and unproductive public, fully financed by the government.

In the subsequent text, referring to Andrle et al. (2009) we explain in more detail and justify a



Source: *NBS*, *author's calculations* 



few stylized facts and non-standard features that we want this fiscal model to capture when describing its production side: trends in sectoral relative prices and gradual convergence towards developed economies, increasing trade openness and large import intensity of exports.







## **Trends and Shares**

Realistic policy simulations and forecasting require model to treat properly long-run trends of key variables, describe the medium-run behaviour of the economy and capture its business cycle. Therefore a proper definition of the balance growth path is necessary. Slovakia as a typical emerging economy faces more often large structural shocks during its gradual convergence than its more developed counterparts (see Figure 2.1) and trend-cycle interactions observed in the data cannot be omitted. Therefore Andrle et al. (2009) suggests not to blindly rely on filtering techniques (e.g. using standard Hodrick-Prescott filter) that would removes trend-cycle interactions and modify the business cycle dynamics of the data leads to inconsistency in data dynamics and hence invalidates the assessment of policy simulations and forecasting. Instead of it we rather prefer the *endogenous* filtration of the observed data. Long-run trends in sectoral relative prices and the evolution of expenditure shares determine the definition of the model balanced growth path. Concerning the medium-term nominal expenditure shares we assume their constancy in the steady state as they gradually approach the targeted ratios of key endogenous variables in the developed small open economies. However, this specification still allows the model to include the long–run trends in sectoral relative prices.



#### Source: EUROSTAT, author's calculations

Thus we define a balanced growth path of the multi-sectoral model of the economy such that the nominal quantities of Slovak macroeconomic variables are cointegrated, which is perfectly consistent with our observation of data (Figure 2.2 shows that nominal expenditure shares are apparently more stable than the real shares). On the other side, under the constancy of nominal





expenditure shares different growth rates of real quantities go hand in hand with different trends in relative prices (Figure 2.2).

## **Trade Openness**

The issue of overall increasing trade openness is a common experience in former-communist small open Central European economies (Figure 2.3). In last two decades they have undergone a transformation process, many structural reforms, huge inflow of foreign direct investment, integrated into Euro-Area (and, in case of Slovakia, became a member of the Euro Area) and started to catch up with more developed Western economies – hence, a substantial real appreciation is a fundamental symptom of the gradual convergence (see Figure 2.1). The excessive imports are tightly connected with the country's trade openness since they are driven by heavily import-intensive exports and in past it used to be also associated with massive capital inflows to the production process.

Employing a standard approach, a disproportionate long-run growth trade volumes with respect to output growth leads to an inconsistency with the balanced growth path. Simultaneously, we are unable to explain the evolution of foreign demand, export, import, and their prices using the standard framework of the balanced growth path with both the nominal expenditure shares and volumes constant since it would lead to serious bias in filtering, estimation, policy simulations or forecasting (see Figure 2.2). Hence, with our definition of the balanced growth path we keep nominal shares constant and allow for excessive real growth of trade volumes (export, import and foreign demand) relative to domestic output in the long run. As we offset by the evolution of export prices in the opposite direction the permanent effects of this trade-specific technology thus allow for consumption-based real exchange rate appreciation in the long run.





As Andrle et al. (2009) suggests the world import growth rate is on average higher than the growth rate and so there is an observed wedge between the real (measured in volumes) growth rate of trade and value added. The trend in trade significantly exceeds the trend in value added because it is not just value added that is traded. He approximates the trade growth rate by a quadruple of the year-on-year GDP growth rate.

Evidently the assumption of constant steady-state nominal expenditure shares is contradictory to trend observed in data (see Figures 2.3, and 2.1). Since this is a single-country small open economy model, be cannot solve this problem by adding another endogenous trend. Therefore following Andrle et al. (2009), we introduce an exogenous openness technology to explain the trend in the nominal expenditure share of trade in value added and employ it when han-



Source: NBS, author's calculations



dling the observed data. Furthermore, since Slovakia has during last two decades experienced a transformation process and faced many structural reforms it has become not only considerably more open economy but it significantly changed the composition and quality of its export product. Hence, replicating the approach of Andrle et al. (2009) we launch the quality stochastic process that enables us to describe the periods of growing exports despite raising relative export prices and modest foreign demand (measured by foreign imports) and so or captures increasing quality of exported goods.



Source: Eurostat, author's calculations

## 2.2 Debt Premium and the Absence of Monetary Policy

Slovakia is a member of monetary union from January 2009 - therefore, it does not govern its own monetary policy and so it takes as given the baseline risk-free ECB interest rate. Therefore to account for the country's fiscal policy credibility and public debt long-term sustainability we give up the usual idea of risk-free government bonds and allow for the risk premium on domestic bonds. Several studies (e.g. Erceg and Linde (2011) 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, introduce the design of the risk premium that reflects the forward-looking investors expectations about evolution of the future debt-to-GDP on a certain time horizon. Recent recession and financial and debt crisis particularly show us the usefulness of this concept. Even Bi and Leeper (2013) relax from the originally assumed government ability to repay its debt fully and depending on effective fiscal limit allow partial default which is in turn directly reflected by the interest charged by the government borrowers – households.

Concerning interest rate on foreign liabilities we penalise excessive private indebtedness by the risk premium. Additionally, the spread between foreign and domestic liabilities is augmented by the country-specific risk premium<sup>1</sup> charged by the foreign investors. 2.6).

Similarly from January 2009 the nominal exchange rate between Slovakia and the rest of Euro-Area is fixed. Since we assume that from 2009 domestic and foreign inflation targets coincide, there is no room for the long-run trend in the real exchange rate appreciation. On the other hand side, in case of the independent monetary policy (pre-2009 era) the nominal exchange rate appreciates in the long run as we observe from the data (see Figure 2.6). Inflation target

<sup>&</sup>lt;sup>1</sup>Consistency of the country-specific risk premium with the rest of the model is achieved by employing the uncovered interest parity condition to determine its steady-state value.







Source: NBS, author's calculations

determines the common equilibrium long-run trend growth rate of all nominal prices of goods and factor inputs in model economy. We assume that after 2009 due to common monetary policy domestic and foreign inflation coincide. Hence, the steady–state inflation rate is taken from the long-term inflation target and set to be 2% annually.

## 2.3 Fiscal Policy and Rules

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. Models with very parsimonious fiscal sector usually assume balanced budget rule and zero debt in the steady state. Nowadays this approach is not very helpful indeed, especially if the model is focused on simulations of various fiscal policies and the fiscal consolidation is due to high debt needed (see Figure 2.7).

We want our model to be realistic so we assume a positive debt/GDP ratio in the steady state. After all, this assumption implies budget balance surplus which is far from observed data (see Figure 2.7). Therefore, to bring the model to the data we violate the Euler condition and modify the uncovered interest parity to have in the steady-state positive simultaneously both the government budget deficit and public debt – consistently with our observations – while having current account surplus and positive external debt<sup>2</sup>.

Within this model government levies taxes on household consumption, labour income and capital. On the other side, government supplies transfers for households, finances public sector wage bill, purchases goods and services and invests to build gradually public infrastructure.

## **Fiscal Rules**

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 Forni et al. (2007) and Erceg and Linde (2011) rules for tax rates take into

<sup>&</sup>lt;sup>2</sup>Technically, we introduce a stationary and persistent wedge into interest rate charged on domestic debt. This is highly desirable since the equilibrium rate determined by the Euler equation under non-zero inflation target and long-run aggregate growth is significantly higher than the data-based calibration of nominal rate and the time-discount parameter.



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Source: NBS, author's calculations

consideration the deviation of the public debt-to-GDP or debt target from their equilibrium levels.

Moreover, Forni et al. (2007) reflect that government usually does not uses cuts in expenditures to consolidate. On the other hand, Stork et al. (2009) and Canzoneri et al. (2006) 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 in 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).

## Impact of Government Spending on Households and Firms

Referring to Forni et al. (2007) Cavallo (2005) and Papageorgiou (2014) we introduce the unproductive public sector which is fully financed by the fiscal authority. Using public sector labour force, public investment and social transfers in kind they produce public goods.

We allow government spending on public goods production to interact with households consumption and following Leeper et al. (2015) and Papageorgiou (2014) extend their utility function to include public goods supplied to all households free of charge. However, as Leeper et al. (2015) remarks since Ricardians and Non-Ricardians have different propensity to consume public goods, the overall picture after increasing government spending on public goods becomes core complex: while Non-Ricardians with a lack of resources gain from their substitutional nature and increase their wealth, complementarity essence in case of Ricardians comes out of reduced private investment in the long-run. Apart from this specific feature, in consistence with our observation of data the utility function of households has a standard consumptionlabour separable form.





## 3 Model Scheme

The model is a medium-scale DSGE model tailor-made to model developments in the Slovak economy. 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.

## 3.1 Production and Technologies

The domestic economy is formed by the productive private and unproductive public sector. We employ a standard approach on non-tradable and tradable goods when describing the private sector. Tradable intermediate goods made from domestic inputs is combined with imported intermediate goods to produce final goods. The model design enables us to capture typical signs of converging small open economies – observed wedge between the value added and the real growth rate of trade (volume of exports and imports), increasing trade openness and real exchange rate appreciation. Furthermore, to describe better the price-setting mechanism in the economy and to explain cross-country and cross-sector inflation differentials we allow for monopolistic competition in production of semi-final intermediate goods, exports and imports. Aggregated profits are then rebated to firm owners - domestic households. Hence, within the two–stage private sector production structure, we distinguish between these types of firms:

- Intermediate Goods Firms
  - Producers operating on monopolistically competitive market create differentiated intermediate goods from capital, labour and energy inputs, and combine them to homogeneous packages to be used in the production of final goods.
  - Importers transfer and aggregate differentiated imported goods into uniform bundles thereafter employed in production process.
- Final Goods Firms (Retailers) create goods that is sold to domestic or foreign agents. It is produced combining packages supplied by domestic producers with imported goods:
  - Final goods bought by domestic subjects is manufactured in a perfectly competitive environment and it either consumed by households and government, or invested.
  - Exported to foreign economy are produced in a monopolistically competitive environment in order to emphasize its complex price-setting and the import intensity.

At this stage the model is enriched by features that introduce the wedge between real growth rates of trade and domestic economy.

## 3.1.1 Intermediate Firms

## Producers

There is a continuum of domestic intermediate goods producers indexed by  $i \in [0,1]$  who produce differentiated goods using the same two–stage combined CES and Cobb-Douglass technology. Each firm *i* gradually merges the capital stock  $K_t^p(i)$ , labour force  $H_t^p(i)$  hired from domestic households and energy  $E_t(i)$  to produce their specific intermediate goods  $x_t(i)$ 

$$X_t(i) = a_t \left\{ \alpha_e^{1/\sigma_e} [E_t(i)]^{1-1/\sigma_e} + (1-\alpha_e)^{1/\sigma_e} [X_t^{KH}(i)]^{1-1/\sigma_e} \right\}^{\frac{\sigma_e}{\sigma_e-1}},$$
(1)

$$X_t^{KH}(i) = \phi_t^{sub,p} [K_t^p(i)]^{\sigma_k} [A_t H_t^p(i)]^{1-\sigma_k}, \qquad (2)$$

where  $a_t$  and  $A_t$  are the stationary total factor productivity shock and the non-stationary labouraugmenting stochastic process, respectively. Furthermore, the production technology is enriched by the term  $\phi_t^{sub,p}$  depicting the impact of government subsidies<sup>3</sup> Sub<sub>t</sub><sup>p</sup> supplied costlessly to private sector firms.

<sup>&</sup>lt;sup>3</sup>Since our observations on direct role of public subsidies in the production sector are scarce we prefer this *shock-like* functional form,  $\phi_t^{sub,p} = \alpha_{\phi^{sub,p}} [1 + \frac{2}{\pi} \arctan \widehat{Sub}_t^p]$ . However, Papageorgiou (2014) and Leeper et al. (2015) model the public capital entry to the production function in the way that makes it to be effective in the model steady state.





Hence, each producer chooses the amount of inputs (capital, labour and energy) to minimize the cost of production  $R_t^k K_t^p(i) + W_t^p H_t^p(i) + P_t^E E_t(i)$  subject to (1)–(2). The resulting optimal input-output ratios will be identical across intermediate goods firms. Thus the firms' marginal (and also average) costs are independent of the intermediate good produced and are given by

$$Q_{t}^{X}(i) = Q_{t}^{X} = a_{t}^{-1} \left\{ \alpha_{e} [P_{t}^{E}]^{1-\sigma_{e}} + (1-\alpha_{e}) [Q_{t}^{KH}]^{1-\sigma_{e}} \right\}^{\frac{1}{1-\sigma_{e}}}, \qquad Q_{t}^{KH} = \frac{1}{\phi_{t}^{sub,p}} \frac{[R_{t}^{K}]^{\sigma_{k}} [W_{t}^{p}]^{1-\sigma_{k}}}{\sigma_{k}^{\sigma_{k}} (1-\sigma_{k})^{1-\sigma_{k}}}.$$
 (3)

Next, employing the CES aggregation individual varieties are costlessly transformed into homogeneous composite bundle. This bundle  $X_t$  is then sold for further production of consumption, government, investment and export final goods. The aggregation takes the form of

$$X_{t} = \left\{ \int_{0}^{1} \left[ X_{t}(i) \right]^{\theta_{t}^{x}} di \right\}^{1/\theta_{t}^{x}}, \quad \text{and} \quad X_{t} = X_{t}^{c} + X_{t}^{i} + X_{t}^{g} + X_{t}^{f}.$$

Therefore the cost minimizing demand of retailer for producers' specific goods  $X_t(i)$  given the aggregate price index  $P_t^x$  satisfies the following relationship

$$X_{t}(i) = \left[\frac{P_{t}^{X}(i)}{P_{t}^{X}}\right]^{-\frac{1}{1-\theta_{t}^{X}}} X_{t} \quad \text{with} \qquad P_{t}^{X} = \left\{\int_{0}^{1} \left[P_{t}^{X}(i)\right]^{\frac{\theta_{t}^{X}}{\theta_{t}^{X}-1}} di\right\}^{\frac{\theta_{t}^{X}-1}{\theta_{t}^{X}}}.$$
(4)

The stochastic parameter  $(1 - \theta_t^x)^{-1}$  represent the elasticity of substitution among differentiated intermediate products and  $\theta_t^X = \theta^X + \eta_t^{\theta_X}$  contains zero mean stochastic elements  $\eta_t^{\theta_X}$ . The monopolistic competition in the intermediate goods market gives rise to a Phillips Curve with Calvo-style with indexation to the sectoral average price level. The desired markup remains constant but due to price rigidities the actual markup fluctuates.<sup>4</sup>

#### Importers

We form the world as the continuum of countries. Following Andrle et al. (2009) importers create on zero-profit basis their specific packages  $M_t(i)$  of diverse imported goods from homogeneous bundles of exported goods from foreign economies. Since importers share identical production technology and common technology parameters and trends

$$M_t(i) = \eta_t^M \left\{ \int_0^1 \left[ \omega_t^*(\widetilde{z}) \right]^{\frac{\theta_t^m - 1}{\theta_t^m}} d\widetilde{z} \right\}^{\frac{\theta_t^m}{\theta_t^m - 1}},\tag{5}$$

where  $\theta_t^m$  is the time-varying elasticity of substitution between each pair of bundles from different countries and  $\omega_t^*(\tilde{z})$  is the package of the exports from the  $\tilde{z}$ -foreign economy. Above  $\eta_t^M$  denotes a common stationary stochastic shock. These importer-specific composites are bundled into homogeneous package and employed in the production by domestic final goods retailers and exporters. Thus we define sector-wide imported intermediate goods production as

$$M_t = \int_0^1 M_t(i) di = M_t^c + M_t^i + M_t^f.$$
 (6)

Consequently exporters compete only within the country while aggregate bundles compete among countries. The cost-minimisation problem of importers implies the subsequent relationship between their marginal (and average) costs  $Q_t^M$  and country effective exchange rate i.e. the price of foreign economy goods evaluated in domestic currency

$$Q_t^M = \overline{P}_t^* / \eta_t^M = S_t P_t^* / \eta_t^M.$$
<sup>(7)</sup>

<sup>&</sup>lt;sup>4</sup>In the log–linear version of our model, the serially uncorrelated zero mean price mark–up shocks  $\eta_t^{\theta_x}$  can be interpreted as a cost-push shock to production price inflation.





#### 3.1.2 Final Good Firms

Retailers create goods that is sold to either domestic or foreign subjects.

#### Exporters

Exporters operate in the monopolistically competitive environment and employ the identical production technology. They combine the bundle of domestic intermediate goods with the bundle of imported intermediate goods in order to produce their goods,

$$\int_{0}^{1} F_{t}(i) di = \eta_{t}^{F} \left[ \alpha_{f}^{1/\sigma_{f}} \left( M_{t}^{f} \right)^{1-1/\sigma_{f}} + (1-\alpha_{f})^{1/\sigma_{f}} \left( X_{t}^{f} a_{t}^{X} \right)^{1-1/\sigma_{f}} \right]^{\frac{\sigma_{f}}{\sigma_{f}-1}},$$
(8)

where  $\eta_t^F$  is a common technology stochastic process. The corresponding nominal marginal costs are identical across firms and satisfy the subsequent relationship:

$$Q_t^F = \left(\eta_t^F\right)^{-1} \left[\alpha_f \left(P_t^M\right)^{1-\sigma_F} + \left(1-\alpha_f\right) \left(P_t^X/a_t^X\right)^{1-\sigma_f}\right]^{\frac{1}{1-\sigma_f}}.$$
(9)

Following Andrle et al. (2009) here we introduce another export-specific technology shock  $a_t^X$  that results in more expensive and less efficient imports in the production. It drives the wedge between the trade growth rate and the value added and its variation has a strong and permanent impact on the sources of the real exchange rate appreciation in the long run.

The total amount of goods for export  $F_t$  is directly determined by the exogenous foreign aggregate demand function driven by the terms of trade,  $P_t^F/P_t^*$ :

$$F_t = \left(P_t^F / P_t^*\right)^{-\sigma_t^*} \Omega_t^*.$$
(10)

Above,  $\sigma_t^* = \sigma^* + \eta_t^{\sigma^*}$  the time–dependent foreign elasticity of substitution among the differentiated goods exported to foreign economy with  $\eta_t^{\sigma^*}$  i.i.d. normal and  $P_t^F$  and  $P_t^*$  symbolise the export price index and foreign economy aggregate price index, respectively both expressed in *foreign* currency. Next,  $\Omega_t^*$  represents the foreign aggregate demand for final goods. Within this model, it is understood as the total volume of world trade as expressed by imports of Slovakia main trading partners. As foreign demand and export grow with the same pace, terms of trade remain stationary.

#### **Domestic Final Goods**

Perfectly competitive combine the bundle of domestic intermediate goods with the bundle of imported intermediate goods in order to produce a certain type final goods  $Z_t$  utilized by domestic households and government: consumption goods  $C_t$ , investment goods  $I_t$  and government purchase goods  $G_t$ :

$$Z_{t} = \begin{cases} \eta_{t}^{Z} \left[ \alpha_{z}^{1/\sigma_{z}} \left( M_{t}^{z}/a_{t}^{X} \right)^{1-1/\sigma_{z}} + (1-\alpha_{z})^{1/\sigma_{z}} \left( X_{t}^{Z} \right)^{1-1/\sigma_{z}} \right]^{\frac{\sigma_{z}}{\sigma_{z}-1}}, & Z \in \{C, I\}, \\ \eta_{t}^{G} X_{t}^{G}, & Z = G. \end{cases}$$
(11)

Above,  $\eta_t^Z$  is a sector–specific common technology stochastic shock and  $a_t^X$  is an export-specific technology shock. Furthermore, in consistence with our observation of national accounts we assume that production of government purchase goods does not require imports. The nominal price of domestically utilized final goods of type *Z* charged to domestic households or government equals

$$P_{t}^{Z} = \begin{cases} \left(\eta_{t}^{Z}\right)^{-1} \left[\alpha_{z} \left(P_{t}^{M} a_{t}^{X}\right)^{1-\sigma_{z}} + (1-\alpha_{z}) \left(P_{t}^{X}\right)^{1-\sigma_{z}}\right]^{\frac{1}{1-\sigma_{z}}}, & Z \in \{C, I\}, \\ P_{t}^{X} / \eta_{t}^{G}, & Z = G. \end{cases}$$
(12)

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The impact of the export-specific technology shock  $a_t^X$  on the attractiveness and preference of domestic inputs is evident – increase in  $a_t^X$  implies higher effectiveness and productivity of domestic intermediate good bundle in the production process.

Finally, we assume that demand for investment goods is determined by Ricardian households (private investment) and government (public investment) and investment goods producers do not distinguish between them. Therefore,

$$I_t = I_t^h + I_t^g \,. \tag{13}$$

## 3.1.3 Price Setting

Intermediate goods firms, exporters and importers 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. Notice that exporters are assumed to price their product in the currency of the customer. Hence each firm maximizes its expected profits using a stochastic discount factor applied by firm's stakeholders (domestic Ricardians)  $\tilde{\rho}_{t|t+k} = \beta \rho_{t|t+k} = \beta \frac{\lambda_{t+k}}{\lambda_t}$ :

$$\Psi_t^Z = \begin{cases} \left( \widetilde{P}_t^Z - Q_t^Z \right) \left[ \widetilde{P}_t^Z / P_t^Z \right]^{-\frac{1}{1 - \theta_t^Z}} Z_t , & Z \in \{M, X\} , \\ \left( S_t \widetilde{P}_t^F - Q_t^F \right) \left[ \widetilde{P}_t^F / P_t^F \right]^{-\frac{1}{1 - \theta_t^F}} F_t , & Z = F . \end{cases}$$

Above, identical sectoral marginal costs allow us to suppress the firm–specific index *i* and denote the nominally valued optimal price as  $\tilde{P}_t^Z$ ,  $Z \in \{X, M, F\}$ . Pricing is according to Calvo (1983) with the share of  $\chi_z$  of the non-optimizers who stick to the price chosen in the previous period. Profit maximization results in the following first–order condition:

$$0 = \sum_{k=0}^{\infty} \chi_z^k \mathbb{E}_t \left\{ \widetilde{\rho}_{t+k|t} Z_{t+k} \left[ \frac{\widetilde{P}_t^Z}{P_{t+k}^Z} \right]^{-\frac{1}{1-\theta_{t+k}^Z}} \left[ \frac{Q_{t+k|t}^Z}{1-\theta_{t+k}^Z} - \frac{\theta_{t+k}^Z}{1-\theta_{t+k}^Z} \widetilde{P}_t^Z \right] \right\}.$$
 (14)

The aggregate price dynamics exhibits the following dynamic:

$$P_t^Z = \left\{ (1 - \chi_Z) \left[ \widetilde{P}_t^Z \right]^{\frac{\theta_t^Z}{\theta_t^Z - 1}} + \chi_Z \left[ P_{t-1}^Z \right]^{\frac{\theta_t^Z}{\theta_t^Z - 1}} \right\}^{\frac{\theta_t^Z}{\theta_t^Z - 1}}, \qquad Z \in \{X, M, F\}.$$

$$(15)$$

To a first-order approximation, the inflation  $\Pi_t^Z$  evolve as subsequently:

$$\widehat{\Pi}_{t}^{Z} = \frac{\beta}{1+\beta} \mathbb{E}_{t} \widehat{\Pi}_{t+1}^{Z} + \frac{1}{1+\beta} \widehat{\Pi}_{t-1}^{Z} - \lambda_{Z} [\widehat{P}_{t}^{Z} - \widehat{Q}_{t}^{Z}] + \eta_{t}^{\theta^{Z}}, \qquad \lambda_{Z} = \frac{(1-\chi_{Z})(1-\beta\chi_{Z})}{\chi_{Z}(1+\beta)}.$$
(16)

The Phillips curves of consumption, investment and government purchase price inflation are the weighted averages of imported and domestic inflation adjusted by change in  $a_t^X$ ,

$$\widehat{\Pi}_{t}^{C} = -\Delta \widehat{\eta}_{t}^{C} + \alpha_{c} (\widehat{\Pi}_{t}^{M} + \Delta \widehat{a}_{t}^{X}) + (1 - \alpha_{c}) \widehat{\Pi}_{t}^{X}, \qquad \widehat{\Pi}_{t}^{G} = -\Delta \widehat{\eta}_{t}^{G} + \widehat{\Pi}_{t}^{X}, 
\widehat{\Pi}_{t}^{I} = -\Delta \widehat{\eta}_{t}^{I} + \alpha_{i} (\widehat{\Pi}_{t}^{M} + \Delta \widehat{a}_{t}^{X}) + (1 - \alpha_{i}) \widehat{\Pi}_{t}^{X}.$$
(17)

The aggregate profits of all the producers, exporters and importers are given as the weighted average of the respective profits of optimizers and non-optimizers<sup>5</sup>,

$$\Psi_{t}^{Z} = \left\{ (1 - \chi_{Z}) \left[ \widetilde{P}_{t}^{Z} - Q_{t}^{Z} \right] \left( \widetilde{P}_{t}^{Z} / P_{t}^{Z} \right)^{-\frac{1}{1 - \theta_{t}^{Z}}} + \chi_{Z} \left[ P_{t-1}^{Z} - Q_{t}^{Z} \right] \left( P_{t-1}^{Z} / P_{t}^{Z} \right)^{-\frac{1}{1 - \theta_{t}^{Z}}} \right\} Z_{t},$$
(18)

with  $Z \in \{X, M, F\}$ . Then the overall profits are  $\Psi_t = \Psi_t^X + \Psi_t^F + \Psi_t^M$ .

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<sup>&</sup>lt;sup>5</sup>In order to evaluate the profit of exporters express prices in domestic currency, use  $S_t P_t^F$  and  $S_t \tilde{P}_t^F$  in (18).



#### 3.1.4 Public Sector

Following Forni et al. (2007) and Papageorgiou (2014) we introduce public sector firms operating in a perfectly competitive environment. They combine household labour input  $H_t^g$  with public capital  $K_t^g$  to produce homogeneous output consumed by households. Two other processes enter public goods production process: the stationary productivity shock  $\eta_t^{c^g}$  and the term  $\phi_t^{sub,g}$  evaluating the impact<sup>6</sup> of government subsidies  $Sub_t^p$  on public goods production. Therefore, public goods are produced using the following Cobb-Douglass type technology

$$C_t^g = \eta_t^{C^g} \phi_t^{sub,g} \left[ K_t^g \right]^{\sigma_g} \left[ A_t H_t^g \right]^{1-\sigma_g} .$$
<sup>(19)</sup>

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 Cavallo (2005) public goods produced by public sector firms is consumed by different types of households in quantity given by the government.

3.2 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 budget constrain. Households are of two types – Ricardians with share of  $1 - \lambda$ , and Non–Ricardians with share of  $\lambda$ .

Similarly to Cavallo (2005) and Leeper et al. (2015) the utility function is extended to include public goods. These are supplied to all households free of charge by the government help the Non-Ricardians with a lack of resources to increase their welfare. We set up the effective consumption  $\overline{C}_t^{\tau}$  of household *j* of type  $\tau \in \{r, n\}$  reflecting that Ricardians and Non-Ricardians have different propensity to consume public goods, as follows:

$$\overline{C}_t^r(j) = C_t^r(j) + \gamma^r C_t^g, \qquad \overline{C}_t^n(j) = C_t^n(j) + \gamma^n C_t^g, \qquad \gamma^r, \gamma^n \in (-1,1).$$
(20)

Here, as suggested by Papageorgiou (2014) parameters  $\gamma^r$ ,  $\gamma^n$  determine the nature of the relationship (substitutional, complementary) between public goods consumption and private consumption. We assume habit persistence in consumption as in Fuhrer (2000). Household *j* of type  $\tau \in \{r,n\}$  utility depends positively on effective consumption level  $\overline{C}_t^{\tau}(j)$  measured relatively to lagged aggregate effective consumption index  $\overline{C}_{t-1}$  which is common for all households and modulated by habit persistence factor  $\kappa^c \in (0,1)$  and habit formation shock  $\varepsilon_t^{\kappa}$ . Hence, at time *t* household *j* of type  $\tau \in \{r,n\}$  maximizes their intertemporal utility function

$$\max \quad \mathbb{E}_{t} \sum_{k=0}^{\infty} \beta^{k} \log \left[ \mathscr{C}_{t+k}(C_{t+k}^{\tau}(j)) \right] \mathscr{H}_{t+k}(H_{t+k}(j)), \qquad \tau \in \{r, n\}$$

$$\text{where} \quad \mathscr{C}_{t}(C_{t}^{\tau}(j)) = \overline{C}_{t}^{\tau}(j) - \exp\{\varepsilon_{t}^{\kappa}\} \kappa^{c} \overline{C}_{t-1}, \qquad \mathscr{H}_{t}(H_{t}(j)) = \varphi_{t}^{L} \zeta^{h} (1+v_{h})^{-1} H_{t}(j)^{1+v_{h}},$$

$$(21)$$

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. Moreover,  $\varphi_t^L$  is a demand shifter that affects the intratemporal trade–off between their consumption and labour. Households supply differentiated labour services to domestic firms so they have market power in setting their wages.

#### 3.2.1 Non-Ricardians

We assume that in each period Non– Ricardian agents consume their current disposable income (i.e. the after–tax real income adjusted by the nominally valued lump–sum transfers  $Tr_t^n$ ). They

<sup>&</sup>lt;sup>6</sup>Since our observations on direct role of public subsidies in the production sector are scarce we prefer shock-like functional form,  $\phi_t^{sub,g} = \alpha_{\phi^{sub,g}} [1 + \frac{2}{\pi} \arctan \widehat{Sub}_t^g]$ .





face the budget constraint

$$(1 - \tau_t^w) W_t(j) H_t(j) + Tr_t^n = (1 + \tau_t^c) P_t^C C_t^n(j).$$
(22)

Since there's no intertemporal optimization present the liquidity-constrained households cannot smooth their consumption over time.

#### 3.2.2 Ricardian Households

At time *t* any Ricardian household *j* maximizes their intertemporal utility function (21) subject to household budget constraint and physical capital accumulation law.

#### Household Budget Constraint

The *j*-th Ricardian household faces the following nominal budget constraint:

$$(1-\lambda)[(1-\tau_{t}^{w})W_{t}(j)_{t}H_{t}(j)+Tr_{t}^{r}]+(1-\tau_{t}^{k})\left[R_{t}^{k}\overline{K}_{t-1}^{h}(j)u_{t}(j)+Div_{t}\right] \geq \left[\frac{Debt_{t}}{R_{t}^{d}}-Debt_{t-1}\right] -S_{t}\left[\frac{FDebt_{t}(j)}{R_{t}^{f}}-FDebt_{t-1}(j)\right]+(1+\tau_{t}^{c})(1-\lambda)P_{t}^{C}C_{t}^{r}(j)+P_{t}^{i}I_{t}^{h}(j)+P_{t}^{C}\Psi(u_{t})\overline{K}_{t-1}^{h}(j).$$

$$(23)$$

The financial wealth inherited from the previous period is represented by a portfolio of oneyear net domestic bonds and foreign liabilities  $(Debt_{t-1} - S_tFDebt_{t-1})$ . The after-tax labour based nominally-valued income from renting labour service  $(1 - \tau_t^w)W_tA_t(j)H_t(j)$  is raised by the net transfers  $Tr_t^r$ . Next,  $(1 - \tau_t^k)R_t^k\overline{K}_{t-1}^h(j)u_t(j)$  is the after-tax income from renting physical capital stock installed with the effective rate of utilization  $u_t(j)$  and rental rate  $R_t^k$ . The term  $(1 - \tau_t^k)Div_t$  are net dividends distributed from the profits  $\Psi_t$  of producers reduced by the factor income of Ricardians. Ricardian households invest into securities with discount returns  $R_t^d$  and  $R_t^f$  respectively. Furthermore, they make a purchase decision about their private consumption goods  $P_t^C C_t^r$  and investment goods  $P_t^I I_t^h$ . 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).<sup>7</sup>

## **Capital Accumulation Law**

As in Christiano et al. (2001) the Ricardian household j owns and accumulates the overall physical capital stock according to the following equation

$$\overline{K}_{t}^{h}(j) = (1-\delta)\overline{K}_{t-1}^{h}(j)\eta_{t}^{A} + I_{t}^{h}(j)\left[\exp\{\zeta_{t}^{i}\} - \Upsilon^{h}\left(\xi_{t}^{i,h}I_{t}^{h}(j)/I_{t-1}^{h}(j)\right)\right],$$
(24)

where  $\eta_t^A = A_t/A_{t-1}$  denotes the growth rate of the exogenous nonstationary technological process  $A_t$  and  $\Upsilon^h$  represents the quadratic investment adjustment costs designed as follows:

$$\Upsilon^{h}\left(\xi_{t}^{i,h}I_{t}^{h}/I_{t-1}^{h}\right) = \frac{\phi_{i,h}}{2} \left[ (\xi_{t}^{i}/\eta_{A})(I_{t}^{h}/I_{t-1}) - 1 \right]^{2}.$$
(25)

Then,  $\Upsilon^h(\cdot) = (\Upsilon^h)'(\cdot) = 0$  and  $(\Upsilon^h)''(\cdot) > 0$ . Above,  $\phi_{i,h}$  is the adjustment costs scaling parameter and  $\eta_A$  is the steady-state growth rate of the nonstationary technology process  $A_t$  launched in production function of intermediate firms (1)–(2). Next, 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  $\eta_t^i$  which is an i.i.d. random variable following a stochastic process  $\zeta_t^i \sim \mathcal{N}(0, \sigma_i^2)$ . The adjustment cost depends on deviations in investment flow and reflects the time–to–build dimension to the capital accumulation procedure.

<sup>&</sup>lt;sup>7</sup>Various models e.g. Forni et al. (2007) or Stork et al. (2009) introduce an additional type of symmetric quadratic adjustment costs incurred if the aggregate nominal wage deviates from the steady state path. Furthermore, we use a simple form of cost to capital utilisation rate function  $\psi(u_t) = \rho_1^{\Psi} [\exp\{\rho_2^{\Psi}(u_t-1)\} - 1]$ .





#### 3.2.3 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.<sup>8</sup> 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:

$$H_{t} = \left\{ (\alpha_{H})^{1/\sigma_{H}} \left[ H_{t}^{p} \right]^{1-1/\sigma_{H}} + (1-\alpha_{H})^{1/\sigma_{H}} \left[ H_{t}^{g} \right]^{1-1/\sigma_{H}} \right\}^{\sigma_{H}/(\sigma_{H}-1)}.$$
 (26)

Following Cavallo (2005) and Forni et al. (2007) 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 public sector wage bill (measured relatively to do GDP) follows the AR(1)– type process

$$\frac{W_t^g H_t^g}{Y_t} = (1 - p_t^{wh_g}) \left(\frac{H_{t-1}^g W_{t-1}^g}{Y_{t-1}}\right)^{\rho_{wh_g}} \left[\frac{W^g H^g}{Y}\right]^{1 - \rho_{wh_g}} \exp\{\eta_t^{wh_g}\},$$
(27)

with the white noise process  $\{\eta_t^{wh_g}\}_{t\geq 0}$  and consolidation driven public wage bill adjustment  $p_t^{wh_g}$  (see Section 3.4.2). Households set their private sector wages to maximize their instantaneous objective function subject to the intertemporal budget constraint and the demand for labour of type *j* satisfying

$$H_t^p(j) = \left[ W_t^p(j) / W_t^p \right]^{-\vartheta_t} H_t^p.$$
<sup>(28)</sup>

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

$$(1 - \alpha_H)H_t^p = \alpha_H \left[ W_t^p / W_t^g \right]^{-\sigma_H} H_t^g.$$
<sup>(29)</sup>

#### Wage Setting

Households have market power in the labour market. The underlying gross real wage index arising from household gross labour income  $W_tH_t$  maximization problem is as follows

$$W_t = \left\{ \alpha_H \left[ W_t^p \right]^{1 - \sigma_H} + (1 - \alpha_H) \left[ W_t^g \right]^{1 - \sigma_H} \right\}^{\frac{1}{1 - \sigma_H}} .$$
(30)

Based on observations we assume that the aggregate gross nominally–valued wage rate in the public sector  $W_t^g$  partially reflects the lagged private sector nominal wage inflation  $\Pi_{t-1}^{p,w}$  and the equilibrium consumption price inflation  $\Pi^c$  while taking into account possible fiscal consolidation–related shocks as follows:

$$W_{t}^{g} = q_{t}^{w,g} W_{t-1}^{g} + \varepsilon_{t}^{w,g}, \qquad q_{t}^{w,g} \equiv (\Pi^{c})^{1-\gamma_{w,g}} (\Pi_{t-1}^{p,w})^{\gamma_{w,g}}, \qquad \varepsilon_{t}^{w,g} \sim \mathcal{N}(0, \sigma_{w,g}^{2}).$$
(31)

Note that there is no wage optimization present in the public sector and each household works for same amount of hours  $H_t^g$  receiving the same real gross wage  $W_t^g$  regardless of whether it is Ricardian or not.

As regards private sector wages, wage setting à 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:

$$W_{t+1}^{p} = q_{t+1}^{w,p} W_{t}^{p}, \qquad q_{t+1}^{w,p} = \left(\Pi^{c}\right)^{1-\gamma_{w,p}} \left(\Pi_{t}^{c}\right)^{\gamma_{w,p}} \left(\Pi_{t}^{\tau^{c}}\right)^{\gamma_{\tau^{c}}} \left(\Pi_{t}^{\tau^{w}}\right)^{\gamma_{\tau^{w}}}$$
(32)

<sup>8</sup>By contrast, Forni et al. (2007) assumed perfect substitution between public and private sectors. 17 www.rozpoctovarada.sk



$$\Pi_t^{\tau^c} = \frac{1 + \tau_t^c}{1 + \tau_{t-1}^c} \qquad \Pi_t^{\tau^w} = \frac{1 - \tau_{t-1}^w}{1 - \tau_t^w} \qquad 0 \le \gamma_{\tau^c}, \gamma_{\tau^w}, \gamma_{w,p} \le 1.$$

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 average Ricardians private sector gross wage rate. Since they face the same demand for schedule, in the equilibrium the wage rate and the hours worked are identical across both groups of households. Thus, based on the wage indexation policy applied the stochastic law of motion of aggregate private sector gross real–valued wage satisfies the relationship

$$W_{t}^{p} = \left\{ (1 - \chi_{w}) \left[ \widetilde{W}_{t}^{p} \right]^{1 - \vartheta_{t}} + \chi_{w} \left[ q_{t}^{w, p} W_{t-1}^{p} \right]^{1 - \vartheta_{t}} \right\}^{\frac{1}{1 - \vartheta_{t}}},$$
(33)

with the optimal nominally–valued gross wage  $\widetilde{W}_t^p$  and constant real gross wages (considered w.r.t. the consumption price level) in equilibrium regardless of the indexation rule used. Then, the nominally–valued private sector gross wage inflation  $\Pi_t^{p,w} = W_t^p/W_{t-1}^p$  evolves following the Phillips curve below

$$\widehat{\Pi}_{t}^{w,p} = \beta \mathbb{E}_{t} [\widehat{\Pi}_{t+1}^{w,p}] + \gamma_{w,p} \left[ \widehat{q}_{t}^{w,p} - \beta \widehat{q}_{t+1}^{w,p} \right] + \lambda_{w} \left[ \widehat{\mu}_{t}^{w,p} + \frac{\widehat{\vartheta}_{t}}{1 - \vartheta} \right],$$

$$\lambda_{w} = \frac{(1 - \chi_{w})(1 - \beta \chi_{w})}{\chi_{w}(1 + \varepsilon_{w})}, \qquad \varepsilon_{w} = \vartheta \left[ \alpha_{H}^{1/\sigma_{H}} \left[ \frac{H^{p}}{H} \right]^{1 - 1/\sigma_{h}} \left( v_{h} + \frac{1}{\sigma_{h}} \right) - \frac{1}{\sigma_{h}} \right].$$
(34)

Notice that  $\mu_t^{w,p}$  symbolizes the after–tax market private sector mark–up over the marginal rate of substitution in the private sector:

$$\widehat{\mu}_{t}^{w,p} = -\widehat{w}_{t}^{p} + \left[\frac{\tau^{w}}{1-\tau^{w}}\widehat{\tau}_{t}^{w} + \frac{\tau^{c}}{1+\tau^{c}}\widehat{\tau}_{t}^{c}\right] + \left[\widehat{\varphi}_{t}^{L} + \nu_{h}\widehat{H}_{t}\right] + \widehat{\overline{\lambda}}_{t}.$$
(35)

Above,  $\hat{\vartheta}_t$  represents the cost–push shock (see Smets and Wouters (2002)) to the private sector wage inflation observed at time t,  $w_t^p = W_t^p / P_t^c$  is the real-values wage in the private sector and  $\overline{\lambda}_t (1 + \tau_t^c)$  is the inverse of the marginal utility of consumption.

There are four 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 a presence of the wealth effect - higher effective consumption needs to be financed by higher wages. 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 increases with  $0 \le \gamma_{\tau^c}, \gamma_{\tau^w} \le 1$ .

## 3.3 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  $prem_t^d$  applied on domestic liabilities charged by the domestic investor above the baseline ECB gross interest rate<sup>9</sup>. Risk premium  $prem_t^d$  captures

<sup>&</sup>lt;sup>9</sup>The debt risk premium reflecting domestic fiscal policy conditions makes monetary policy endogenous and thus guarantees the model solvability





the evaluation of the fiscal policy credibility and public debt long-term sustainability (as it evaluates the flow of current and future expected nominal public debt–to–GDP ratios):

$$R_t^d = R_t \exp\left\{prem_t^d + \xi_t^d\right\},$$

$$prem_t^d = \alpha^d + p^0 [1 + \mathcal{P}_t / \widetilde{debt}^0], \qquad \mathcal{P}_t = \delta_d [debt_t / y_t - \widetilde{debt}^0] + (1 - \delta_d) \mathbb{E}_t \mathcal{P}_{t+1},$$
(36)

with the known value of risk premium  $p^0$  is associated with a certain known debt-to-GDP ratio  $debt^0$ , and  $\delta_d \in (0,1]$  associated with forward–lookingness of investor concerning about the future debt and fiscal policy credibility (lower  $\delta_d$  corresponds to longer time horizon considered). Furthermore,  $\xi_t^d$  is the white noise process illustrating the unpredictable financial shock to domestic securities risk premium.

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  $R_t^f$  carries a debt-elastic risk premium charged by the foreign investor above the foreign gross interest rate  $R_t^*$ ,

$$R_t^f = R_t^* \exp\left\{prem_t^f\right\}, \quad \text{where} \qquad prem_t^f = \alpha_{\phi^f} F Debt / (A_t P_t^*). \tag{37}$$

Thus in order to stabilize the model high private indebtedness is penalized by augmenting interest rates on additional borrowings.

#### 3.4 Fiscal Authority

The public sector infrastructure  $K_t^g$  is built through public investment  $I_t^g$  by government

$$K_t^g = (1 - \delta_g) K_{t-1}^g \eta_t^A + I_t^g \left[ \exp\{\xi_t^{i,g}\} - \Upsilon^g \left(\xi_t^{i,g} I_t^g / I_{t-1}^g\right) \right],$$
(38)

where  $\eta_t^A = A_t/A_{t-1}$  denotes the growth rate of the exogenous nonstationary process  $A_t$  and  $\Upsilon^g$  are the quadratic investment adjustment costs designed in a similar way as in (25). Furthermore, government purchase of goods is of two types: the productive subsidies  $Sub^p$ , and social transfers in kind  $Sub^g$  are returned back to economy and the unproductive part is consumed by the government:

$$G_t = G_t^c + Sub_t^p + Sub_t^g \,. \tag{39}$$

#### 3.4.1 National Accounting

The government levies and collects various taxes imposed on firms and households to finance their expenditures: • a fraction of them is put back to the economy in the form of infrastructure, subsidies

- a fraction of them is put back to the economy in the form of infrastructure, subsidies and social transfers in kind: public capital acting in public sector is gradually built from government investment I<sup>g</sup><sub>t</sub>; whiled subsidies Sub<sup>p</sup>, and social transfers in kind Sub<sup>g</sup> are used to support production in both sectors;
- a part of them is used to finance public wage bill  $W_t^g H_t^g$  and contributes to utility of households in the form of transfers for Ricardians  $Tr^r$  and Non-Ricardians  $Tr^n$ ;
- and the rest is unproductive consumption.

Hence the nominally-valued budget primary deficit is  $Def_t = Exp_t - Rev_t$  with

$$Exp_t = P_t^G G_t + P_t^I I_t^g + W_t^g H_t^g + P_t^C Tr_t$$
  

$$Rev_t = \sum_{\alpha \in \{c,k,w\}} \tau_t^{\alpha} \Phi_t^{\tau^{\alpha}}, \qquad \Phi_t^{\tau^c} = C_t, \qquad \Phi_t^{\tau^k} = Div_t + Z_t \overline{K}_{t-1}u_t, \qquad \Phi_t^{\tau^w} = W_t H_t$$

Taking into account the interest payments with the gross discount return  $R_t^b$  associated with the debt service, the authority issues new nominally–valued public debt:

$$Debt_t = R_t^d \left( Debt_{t-1} + Def_t \right). \tag{40}$$

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#### 3.4.2 Fiscal Rules

We postulate specific reaction functions for each type of government expenditures and taxes. Each item nominally valued expenditure item  $X_t$  (tax rate  $\tau_t$ ) of the government budget has been assigned its pre-consolidation value  $\overline{X}_t$  ( $\overline{\tau}_t$ ) following the corresponding AR(1)-type process:

$$\frac{P_t^X \overline{X}_t}{Y_t} = \left[\frac{P_{t-1}^X X_{t-1}}{Y_{t-1}}\right]^{\rho_x} \left[\frac{P^X X}{Y}\right]^{1-\rho_x} \exp\{\xi_t^x\}, \qquad \overline{\tau}_t = \tau_{t-1}^{\rho_\tau} \tau^{1-\rho_\tau} \exp\{\xi_t^\tau\}.$$
(41)

Pre–consolidation budget expenditure items  $\overline{X}_t$  are considered with their corresponding prices and measured relatively to current domestic nominal output  $Y_t$ . The pre–consolidation prescriptions of tax  $\overline{\tau}_t$  revenues consider also the corresponding nominally valued tax base  $\Phi_t^{\tau}$ expressed relatively to domestic output. These pre–consolidation variables generate the corresponding primary deficit  $\overline{Def}_t$  gradually accumulated into the public debt<sup>10</sup>

$$\overline{Debt}_{t} = \overline{R}_{t}^{d} \left( Debt_{t-1} + \overline{Def}_{t} \right) .$$
(42)

Next we establish the correction functional  $\mathscr{C}_t$  evaluating the level of necessary consolidation (as a change in nominal primary budget deficit measured relatively to GDP calculated using pre–consolidation nominal values of all budget items) necessary to achieve gradually the desired debt–to–GDP  $\tilde{d}_t^{\text{tar}}$  and primary deficit–to–GDP  $\tilde{b}_t^{\text{tar}}$  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 deficit-to-GDP ratios from the last period values)<sup>11</sup>

$$\mathscr{C}_{t} = a_{\widetilde{\Omega}} \operatorname{sgn}\left(\widetilde{\Omega}_{t}\right) \left\{ \operatorname{sgn}\left(\widetilde{\Omega}_{t}\right) \widetilde{\Omega}_{t} + a_{\Delta\Omega} \Delta \Omega_{t} + a_{\widetilde{\delta}} \operatorname{sgn}\left(\widetilde{\delta}_{t}\right) \left[ \operatorname{sgn}\left(\widetilde{\delta}_{t}\right) \widetilde{\delta}_{t} + a_{\Delta\delta} \Delta \delta_{t} \right] \right\} + \varepsilon_{t}^{\mathscr{C}},$$

$$\widetilde{\Omega}_{t} = \frac{\overline{Debt}_{t}}{Y_{t}} - \widetilde{d}_{t}^{\operatorname{tar}}, \quad \Delta \Omega_{t} = \frac{\overline{Debt}_{t}}{Y_{t}} - \frac{Debt_{t-1}}{Y_{t-1}}, \quad \widetilde{\delta}_{t} = \frac{\overline{Def}_{t}}{Y_{t}} - \widetilde{b}_{t}^{\operatorname{tar}}, \quad \Delta \delta_{t} = \frac{\overline{Def}_{t}}{Y_{t}} - \frac{Def_{t-1}}{Y_{t-1}}.$$

$$(43)$$

The initial public debt and deficit are adjusted to their post-consolidation counterparts,

$$Def_t = \overline{Def_t} - \mathscr{C}_t$$
, and  $Debt_t = \overline{Debt}_t - R_t^d \mathscr{C}_t$ 

providing that all budget items are modified as follows:

$$X_t = (1 - p_t^X)\overline{X}_t, \qquad p_t^x = \mathscr{Q}_t^x \frac{1 - \mathscr{Q}_t}{\sum_{\overline{x}} \mathscr{Q}_t^x \overline{X}_t} \mathscr{C}_t, \qquad \tau_t = (1 + p_t^\tau)\overline{\tau}_t, \qquad p_t^\tau = \mathscr{Q}_t^\tau \frac{\mathscr{Q}_t}{\sum_{\overline{\tau}} \mathscr{Q}_t^\tau \overline{\tau}_t \Phi_t^\tau} \mathscr{C}_t.$$
(44)

The parameter  $\mathscr{Q}_t$  is the given (possibly time–dependent) percentage adjustment on the revenues side,  $\mathscr{Q}_t^x$  ( $\mathscr{Q}_t^\tau$ ) denotes the prescribed percentage change in the budget expenditure (revenue) item *X* ( $\tau$ ) that has to be made in order to achieve the consolidation effort determined by (43). Moreover,  $p_t^x$  ( $p_t^\tau$ ) represents the percentage correction in the initial setting of the item *x* ( $\tau$ ) determined by the consolidation process. Therefore, providing that budget items follows rules prescribed by (44), they act as debt stabilizers.

<sup>&</sup>lt;sup>11</sup>Notice the presence of i.i.d. fiscal shock process  $\varepsilon_t^{\mathscr{C}} \sim \mathscr{N}(0, \sigma_{\mathscr{C}}^2)$  that allows the government to design its own policy, and directly affect primary balance regardless of the given consolidation procedure.



<sup>&</sup>lt;sup>10</sup>Here we prefer  $\overline{R}_t^d$  to  $R_t^d$  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.



#### 3.5 Closing the model

#### **Resource Constraints**

Market clearing for intermediate goods, imports and demand for investment goods requires

$$X_t = X_t^C + X_t^I + X_t^G + X_t^F$$
,  $M_t = M_t^C + M_t^I + M_t^F$ ,  $I_t = I_t^g + I_t^h$ 

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:

$$C_t = (1 - \lambda)C_t^r + \lambda Cc_t^n, \qquad \overline{C}_t = (1 - \lambda)\overline{C}_t^r + \lambda \overline{C}_t^n,$$

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

$$H^{g,n}_t(j^n) = H^{g,n}_t = H^g_t = H^{g,r}_t = H^{g,r}_t(j^r), \qquad j^n \in [0,\lambda], \quad j^r \in (\lambda,1].$$

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

$$H_t^{p,n}(j^n) = H_t^{p,n} = H_t^{p,r} = H_t^p, \qquad j^n \in [0,\lambda]$$

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

$$Y_{t} = P_{t}^{C}C_{t} + P_{t}^{I}I_{t} + P_{t}^{G}G_{t} + TB_{t} + W_{t}^{g}H_{t}^{G} + P_{t}^{C}\psi(u_{t})\overline{K}_{t-1}^{h}.$$
(45)

#### **Further Market Clearing Conditions**

The overall resource constraint implies that in equilibrium the current account (i.e. the trade balance adjusted for the factor income of Ricardians) balance finances the net purchasing of foreign liabilities. Therefore, the balance of payments satisfies

$$S_{t} \frac{FDebt_{t}}{R_{t}^{f}} = S_{t}FDebt_{t-1} - CA_{t}, \qquad CA_{t} = \overline{P}_{t}^{F}F_{t} - Q_{t}^{M}M_{t} - P_{t}^{e}E_{t} - \iota_{t}^{*} = TB_{t} - \iota_{t}^{*}.$$
(46)

In a standard literature on DSGE two-country models, uncovered interest rate parity is used to determine the nominal exchange rate. But this approach is not applicable in case of Slovakia which is a part of monetary union. The nominal exchange rate  $S_t$  is exogenous and its fluctuations do not reflect changes in Slovak economy. Therefore, taken the nominal exchange rate  $S_t$  as given in (37) we introduce the country risk premium  $prem_t^{sk}$  that would guarantee that the uncovered interest rate parity is always satisfied. Hence,

$$R_t^d \exp\{prem_t^{SK}\} = R_t^f \mathbb{E}_t \left[S_{t+1}/S_t\right].$$

$$\tag{47}$$

#### World and Exogenous Environment

In the context of this model, foreign demand  $\Omega_t^*$  is assumed to be tightly connected with the volume of world trade expressed by imports of Slovakia main export partners. In order to emphasize the dependence of imports on GDP we describe it as follows:

$$\Omega_t^* = \left[\Omega_{t-1}^*\right]^{\rho_{\omega^*}} \left[\overline{\Omega}_t^*\right]^{1-\rho_{\omega^*}} \exp\{\rho_{\omega^*}^y(\eta_t^{A,*} + \widehat{y}_t^*/\eta^{A,*}) + \xi_t^{\omega^*}\}.$$
(48)

Above,  $\overline{\Omega}_t^*$  is the long-run nonstationary foreign demand.





Since the Slovak economy is a small open, import-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). The foreign economy model captures the evolution of the foreign real GDP (in terms of its decomposition on the trend process  $A_t^*$  and cycle-component  $\hat{y}_t^{\kappa}$ ) and behaviour of 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  $\kappa \in \{eu, neu\}$  respectively, we have

$$\begin{split} Y_t^{\kappa} &= A_t^* + \widehat{y}_t^{\kappa}, \\ \widehat{y}_t^{\kappa} &= \alpha_{yy}^{\kappa} \widehat{y}_{t-1}^{\kappa} + (1 - \alpha_{yy}^{\kappa}) \mathbb{E}_t \widehat{y}_{t+1}^{\kappa} - \alpha_{yi}^{\kappa} \mathbb{E}_t \left[ \widehat{i}_t^{\kappa} - \widehat{\Pi}_{t+1}^{\kappa} \right] + \xi_t^{\kappa, y}, \\ \widehat{\Pi}_t^{\kappa} &= \alpha_{\pi\pi}^{\kappa} \widehat{\Pi}_{t-1}^{\kappa} + (1 - \alpha_{\pi\pi}^{\kappa}) \mathbb{E}_t \widehat{\Pi}_{t+1}^{\kappa} + \alpha_{\pi y}^{\kappa} \widehat{y}_t^{\kappa} + \xi_t^{\kappa, \pi}, \\ \widehat{i}_t^{\kappa} &= \alpha_{i\pi}^{\kappa} \widehat{\Pi}_t^{\kappa} + \alpha_{iy}^{\kappa} \widehat{y}_t^{\kappa} + \alpha_{ii}^{\kappa} \widehat{i}_{t-1}^{\kappa} + \xi_t^{\kappa, i}. \end{split}$$





# 4 Solution and Estimation

## 4.1 Model Stationarization

Correct model solution requires to determine its long–run dynamic properties. A balanced growth path is understood as long-run solution of the model where all variables are either constant or grow at a unique constant growth rate. Remark that even real nonstationary variables may differ in their steady-state growth rates. Within this model, all home-economy variables grow along a balanced growth path while foreign demand, trade and the associated relative prices grow along a different trend. This is to reflect the fact that the Slovak economy has been converging to its trading partners in terms of living standards. Thus, we stationarize the whole model using the individual variables' steady-state rates of growth.

## **Domestic Real Economy**

The steady-state growth rate of the domestic output can be immediately deduced from the intermediate firms production function (1)–(2) and under the assumption of constant population size it coincides with the steady-state growth rate  $\eta$  of the exogenous nonstationary technological process  $A_t$ . Hence, following Adolfson et al. (2005) we denote  $\eta_t^A = A_t/A_{t-1}$  and

$$\eta_{t}^{A} = \rho_{\eta^{A}} \eta_{t-1}^{A} + (1 - \rho_{\eta^{A}}) \eta^{A} + \varepsilon_{t}^{\eta^{A}}, \qquad \eta_{t}^{A} = A_{t} / A_{t-1}, \qquad \eta^{A} > 1, \quad \varepsilon_{t}^{\eta^{A}} \sim \mathcal{N}(0, \sigma_{\eta^{A}}).$$
(50)

In order to stationarize the model representative quantitative variable  $X_t$  we divide it by the nonstationary technology process  $A_t$  to obtain its stationary version  $x_t = X_t/A_t$ . Relative prices in the domestic economy (except of nominal real exchange rate, import and export prices) defined w.r.t the consumption price are stationary.

## Monetary Policy, Exchange Rates and Inflation Targets

Slovakia is a member of monetary union from January 2009 - therefore, it does not govern its own monetary policy and it takes as given the baseline risk-free ECB interest rate. Due to fixed nominal exchange rate between Slovakia and the rest of Euro-Area the modified UIP condition is used to determine the country risk premium. Since domestic and Euro-Area inflation targets coincide there is no room for the long-run trend in the real exchange rate appreciation (see Figure 2.6). Long-run inflation target is set to be 2% annually and determines the common equilibrium long-run trend growth rate of all nominal prices of goods (except of import and export prices) and factor inputs in model economy.

Furthermore, to bring the model to data we violate the Euler condition and introduce a stationary and persistent wedge into interest rate charged on domestic debt  $R_t^d$  since the equilibrium rate implied by the Euler equation is significantly higher than the data-based calibration of nominal rate. Therefore, we can have in the steady-state positive primary deficit and public debt while having current account surplus and positive external debt.

## **Trade Openness**

A balanced growth path as defined above implies constant ratios of export and import of goods and services on value added – which is evidently not satisfied in recent Slovak trade data (see Figure 2.2). Therefore to treat the trade data nonstationarity properly, referring to Andrle et al. (2009) we included in the model the export-specific process  $a_t^X$  that captures the long-run appreciation of the real economy. It drives the wedge between the growth rate of exports and imports and the the value added (aggregate technology growth). Following Adolfson et al. (2005) we denote  $\eta_t^X = a_t^X/a_{t-1}^X$  and

$$\eta_t^X = \rho_{\eta^X} \eta_{t-1}^X + (1 - \rho_{\eta^X}) \overline{\eta}_t^X + \varepsilon_t^{\eta^X}, \qquad \eta_t^X = a_t^X / a_{t-1}^X, \quad \varepsilon_t^{\eta^X} \sim \mathcal{N}(0, \sigma_{\eta^X}).$$
(51)

Furthermore, we assume that the long-run growth trend  $\overline{\eta}_t^X \equiv \eta^X > 1$ .



Next, employing the approach of Andrle et al. (2009) we establish an openness process  $a_t^O$  that stands for the trend in the nominal expenditure share of trade in value added and so it helps us to stationarize trade variable. We assume that model agents view all trade quantities already deflated by  $a_t^O$  and so it must be included only during the estimation when we need to detrend the trade-related time series. So we decompose the original nonstationary trade variables as

$$F_t = A_t a_t^X a_t^O f_t, \qquad \overline{P}_t^F a_t^X \equiv \overline{p}_t^f P_t^C, \qquad \overline{\Pi}_t^F = \overline{\Pi}_t^f / \eta_t^X, M_t = A_t a_t^X a_t^O m_t, \qquad P_t^M a_t^X \equiv P_t^m = p_t^m P_t^C, \qquad \Pi_t^M = \Pi_t^m / \eta_t^X.$$
(52)

where  $\omega_t$ ,  $f_t$ ,  $m_t$ ,  $\overline{p}_t^f$  and  $p_t^m$  represent stationary quantities of foreign demand, export, import and the corresponding relative prices expressed in domestic currency<sup>12</sup>. Then it holds that their shares w.r.t. to value added are stationary.

In order to capture changes in the composition or increasing quality of exported goods following Andrle et al. (2009) we launch the quality process  $a_t^Q$  which is used only in relating the model to the data in the measurement equations definition. Therefore, we decompose the foreign demand in terms of its stationary version  $\omega_t^*$  as follows:

$$\Omega_t^* = A_t a_t^X a_t^O a_t^Q \omega_t^*, \qquad \omega_t^* = \left[\frac{\omega_{t-1}^*}{\gamma_t^X \gamma_t^{A,*}}\right]^{\rho_{\omega^*}} (\omega^*)^{1-\rho_{\omega^*}} \exp\{\rho_{\omega^*}^y \left(\frac{\widehat{y}_t^*}{\gamma^{A,*}} + \gamma_t^{A,*}\right) + \xi_t^{\omega^*}\}.$$
(53)

## Pre-2009 Model

To treat the pre-2009 data correctly we need to modify our model to capture not only the presence of the independent monetary policy but also the appreciation of the nominal and real exchange rate (see Figure 2.6). We use a standard reaction function when describing country's monetary policy before 2009. Now the modified UIP condition is used to determine the evolution of the nominal exchange rate which appreciates in the long run as we observe from the data. Furthermore, to keep model simple, assume the same 2% long-term inflation target also before 2009. Since the real exchange rate appreciation affects import and export prices, we need to redefine the wedge between the growth rate of trade volumes and the value added. So the decomposition of the nonstationary trade variables in (52)-(53) needs to consider also the real exchange rate appreciation.

In order to solve the already stationarized non–linear model presented in this paper, we first calibrate the non–linear model, determine its deterministic steady state and then derive its (log–)linear approximation to describe its behaviour in the neighbourhood of that steady state. Then map the solution with a matrix of observables and estimate the model using Bayesian inference methods, following Forni et al. (2007) and Alitev et al. (2014).

## 4.2 Model Calibration

To calibrate the model that has been stationarized following the procedure presented in Section 4.1, i.e. to match a number of key target variables characterizing the Slovak economy, a large set of key growth rates (domestic and foreign technology growth rates), deep model 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.

<sup>&</sup>lt;sup>12</sup>The export price in domestic currency  $\overline{P}_t^F$  is nonstationary w.r.t. domestic consumption price level  $P_t^C$  but the opposite is true for the export price expressed in foreign currency,  $P_t^F$ 





Due to focusing on long-run growth of the key variables, targeted ratios of key endogenous variables and required transparency of the work have determined the analytic steady state of the stationarized model.

## **Balanced Growth Path**

First of all we characterise the model balanced growth path along which all model variables are either constant or grow at some growth pace. The post-2009 period is characterised by no monetary policy, modest GDP growth rate (but still higher than in EA14), low inflation mostly following the Euro-Area inflation and export gradually gaining its pre-crisis shares (and then remaining stable). These we need to account for these two different pictures when calibrating and then estimating and simulating the model.

The pre-2009 period is in the domestic economy characterised by 4.5 percent annual aggregate growth rate of real economy and 2 percent inflation target. We assume that volume of exports, imports and foreign demand grow by 8 percent and the interest rate is 4 percent on annual basis. Then, the model-consistent nominal exchange rate appreciation attains 6.9 percent per year. The foreign economy exhibits 2 percent annual growth, 2 percent annual inflation target and 3 percent annual interest rate.

Table 4.1 : Key Big Ratios (post 2009 period)								
Variable Name	Value	Variable Name	Value					
Growth rate of SK real economy (p.a.)	3 %	Growth rate of EU real economy	1 %					
Growth rate of SK trade volumes	5 %	Trade balance to GDP	0.04					
Aggregate consumption to GDP	0.55	Current account to GDP	0.050					
Aggregate demand for oil to GDP	0.08	Aggregate non-energy imports to GDP	0.81					
Domestic CPI	1.02	Foreign CPI	1.02					
Domestic Bonds : Gross return	1.04	ECB Rate (p.a.) : Gross return	1.02					
Primary deficit to GDP	0.001	Public debt to GDP	0.4					
Aggregate Export to GDP	0.94	Net foreign private debt to GDP	0.38					
Government purchase to GDP	0.10	Aggregate investment to GDP	0.22					
Government investment to GDP	0.035	Public-to-private sector employment ratio	0.25					
Public goods to GDP	0.14	Consumption tax rate	0.15					
Capital Tax rate	0.231	Trade balance to GDP	0.04					
Labour Tax rate	0.39	Aggregate wage bill to GDP	0.37					
Households transfers to GDP	0.14	Public sector wage bill to GDP	0.09					

The post-2009 period domestic and foreign inflation targets coincide and equal 2 percent per year. Both economies slow down having 3 percent annual growth of domestic and only 1 percent annual growth of foreign economy but the trade still grows by 5 percent annually. The long-run (gross) return on domestic bonds reaches 4 percent annually. The exchange rate is fixed and monetary policy exogenous.

## **Deep Model Parameters**

Other parameters that define the post-2009 model steady state but do not determine the evolution of the steady state along the balanced growth path are set with respect to Slovak data.

We assume that in the steady state public debt and net external (private) debt attain 40 and 38 percent of GDP respectively and the current account balance is set to 0.5 percent of GDP. The character of a small extremely open transition economy and its dependence on import of raw materials and oil is reflected in substantial 94 percent export-to-GDP and 81 percent non-oil import-to-GDP ratios while the trade balance attains approximately 4 percent of GDP. The consumption-to-GDP ratio is also lower than the figure for EU-15 countries at 55 percent,





but the 22 percent investment-to-GDP resides above the EU-15 average. Calibrations of the well-structured fiscal sector and public goods supply are based on National Accounts<sup>13</sup>. Note that the capital tax rate has been set so that the primary deficit 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 while the trade-related variables (export, import) grow 5 percent yearly. The nominal annual interest rate of Slovak bonds is 4 percent.

As regards production, imported raw materials and oil cannot be substituted easily ( $\sigma_m^c = 1/(1-.3)$ ,  $\sigma_m^i = \sigma_m^f = .1/(1-.2)$  and  $\sigma_e = 0.15$ ). Furthermore, export and investment goods rely on imports a lot – we assume the 55 percent import intensity of exports and even 60 percent in case of investment, whereas consumption goods use imports only from 35 percent. In the both sectors physical capital inputs are preferred to labour service usage ( $\sigma_k = .55$ ). Furthermore, private and public capital are built subject to the same depreciation rate.

Based on EU–SILC data the share of Non–Ricardian households is estimated at 40 percent and households are quite persistent ( $\kappa_c = .75$ ) in their preferences for consuming both private and public of goods.<sup>14</sup>. The inverse of the elasticity of substitution in consumption ( $\sigma = 1$ ) and Frisch elasticity of labour supply ( $v_h = 4/3$ ) are set consistently with standard literature. In the equilibrium, employment is concentrated mainly in the private sector (80 percent), public/private sector transition is not perfectly elastic ( $\sigma_h = 1.5$ ). The foreign economy is in the steady state described by 2 percent inflation and 2 percent interest rate.

The selection of the model economy targeted ratios of key endogenous variables is shown in Table 4.1 and all parameters and ratios are summarized in Tables H.1–H.2 in the Appendix A.

4.3 Model Estimation

To estimate the model using Bayesian approach we firstly (log-)linearise it around the deterministic steady state. The linearised solution is mapped onto a matrix of observables representing 31 quarterly time-series of domestic and foreign economies reported by Eurostat and National Bank of Slovakia between 2004Q1 and 2015Q3.

## **Data Characterisation**

Concerning Slovak economy we use data on private consumption, aggregate investment, export, non-oil import, and trade balance. We consider the time series on domestic CPI index, nominal SKK-EUR exchange rate, export and import deflators, aggregate employment, wages and private sector wages, gross return on public debt and price of oil/fuel. We employ real valued data on all model expenditure items (public wage bill, government intermediate consumption, government gross fixed capital formation, social transfers, social transfers in kind

<sup>&</sup>lt;sup>14</sup>A proper calibration of respective shares of Ricardians and Non–Ricardians is crucial. The literature provides a wide variety of estimates and calibrations ranging from 25 percent (Coenen and Straub (2005)) to 34–37 percent (Forni et al. (2007)) for the Euro–area. In this study we use the methodology proposed by Stork et al. (2009) based on EU–SILC database. We consider as Non-Ricardians those, who are long–term unemployed and non-working pensioners, 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. Therefore, we set  $\lambda = 40\%$ .



<sup>&</sup>lt;sup>13</sup>Government purchase of goods and services is set to 10 percent of GDP, the public wage bill to 9 percent of GDP, household transfers to 14 percent of GDP, government gross fixed capital formation to 3.5 percent of GDP, subsidies to private and public (i.e. social transfers in kind) sector, respectively to 1 and 5 percent of GDP. We approximated public goods supply by the subset of the total general government expenditure classified by functions (COFOG). We consider expenses on education, healthcare, recreation, housing, economic affairs, and public order and safety.



and subsidies), efficient tax rates on consumption, labour, and capital. To track country indebtedness we use time series on real valued government debt and net external private debt.

The external economy is described by the QoQ growth rates of composite imports of Slovakia 14 main trading partners, EU real GDP, EU inflation rate and ECB 3-months interest rate.

## **Data Transform**

Due to in general different growth rates of model variables and assumed impact of openness and quality technologies observed in the date we do not use standard Hodrick-Prescott filtering technique. We prefer to express the corresponding variables in the estimation procedure in growth rates rather than levels. For each domestic real observable  $\tilde{X}_t$  (except of export and import) we assume the corresponding measurement equation

$$\Delta \log \widetilde{X}_t = \log x_t - \log x_{t-1} + \eta_t^A,$$

where  $x_t$  is the detrended model variable associated with the observable  $\tilde{X}_t$  and  $\gamma_t^A$  is the growth rate of exogenous domestic labour-augmenting nonstationary technology. We treat export and import volumes time series by considering export-specific and openness technologies as follows:

$$\Delta \log \widetilde{F}_t = \log f_t - \log f_{t-1} + \eta_t^A + \eta_t^X + \eta_t^O,$$
  
$$\Delta \log \widetilde{M}_t = \log m_t - \log m_{t-1} + \eta_t^A + \eta_t^X + \eta_t^O.$$

A similar approach however augmented additionally for the quality technology  $\eta_t^Q$  is applied on foreign imports. Above,  $\eta_t^A$ ,  $\eta_t^{A,*}$ ,  $\eta_t^X$ ,  $\eta_t^Q$  and  $\eta_t^Q$  are considered for standard AR(1) processes. For consumption and labour tax rates, domestic and foreign inflation rates, ECB shortterm rate and domestic public bonds we subtract the nonlinear model-consistent steady states from the observed variables in logarithm. We use HP filter to extract the cycle component of real-valued oil price (in domestic currency) and EU output gap and map growth rate of real EU GDP onto model foreign economy real growth rate.

We employed the Fisher information matrix and its properties to identify of the set of model parameters that are suitable for the estimation procedure. When handling the pre-2009 data we need to enrich the transformation procedure also by the exchange rate appreciation.

## **Estimation Results**

We estimate the posterior distributions of the model parameters and shocks using the adaptive random walk Metropolis-Hastings algorithm with 100000 iterations and accept 23.47 percent of simulated series. Most of the parameters appear to be well-identified. Tables 4.2–4.3 and Figure H.1 (in the Appendix B.1) show the prior distributions with the estimated posterior densities for the model parameters and Table H.3 with Figure H.2 illustrate the prior distributions and the associated posteriors for model shocks.

The obtained results are in line with estimates taken from standard literature. Concretely, Ricardians receive transfers that are rather low persistent ( $\rho_{tr^r} = 0.3482$ ) and consider public goods as complements ( $\gamma^r = -0.3188$ ) while the Non-Ricardians are likely to consume them as substitutes ( $\gamma^n = 0.3233$ ). Households have persistent consumption-labour preferences ( $\rho_{\phi^L} = 0.8620$ ). Investors form their expectation about future public debt over approximately two-year time horizon when deciding about the government debt risk premium. Recent period of QE with sharply declining and extremely low ECB rate (persistently below its equilibrium) cause high volatility of the foreign interest rate. Likewise fall and stabilization of yields on Slovak government bonds (despite increasing public debt) below their equilibrium imply higher variance of both the interest rate wedge and the bond risk premium along with low country-specific risk premium (see Table H.3 in Appendix B.1).



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Prior Distribution						Posterior Distribution		
	Parameter	Туре	Mean	St. Dev.	Mean	St. Dev.	Conf.	
House	holds							
$\rho_{tr^r}$	Transfers persistence (R)	β	0.35	0.075	0.3383	0.0344	[0.2790 0.3901]	
$\gamma^r$	Propensity to consume public g. (R)	Ν	-0.3	0.05	-0.3482	.0109	[-0.373 -0.336]	
$\gamma^n$	Propensity to consume public g. (N)	Ν	0.3	0.05	0.3233	0.0109	[0.3073 0.3400]	
$\phi_{i,h}$	Investment adjustment param.	Ν	2	0.075	1.9920	0.0274	[1.9533 2.0350]	
$\rho^{\xi,i,h}$	Investment efficiency persistence	β	0.5	0.075	0.5127	0.0355	[0.4563 0.5721]	
$\rho_2^{\Psi}$	Capital utilization cost	β	0.3	0.05	0.2899	0.0149	[0.2683 0.3146]	
$\rho_{\omega^L}$	Households preference persistence	β	0.8	0.075	0.8620	0.0385	[0.8026 0.9245]	
Monet	tary Policy							
$\delta_b$	Inverse of public debt horizon	β	0.15	0.1	0.1338	0.0112	[0.1180 0.1563]	
$\rho_{\Delta R}$	Interest rates wedge persistence	β	0.6	0.075	0.5253	0.0379	[0.4638 0.5852]	
Produ	ction							
$\sigma^*$	Elast. of substit.: export vs. foreign	β	0.4	0.1	0.4413	0.0127	$[0.4195\ 0.4597]$	
$\rho_a$	Private sector TFP persistence	β	0.6	0.075	0.6332	0.0427	[0.5527 0.6937]	
$ ho_{c^g}$	Public sector technology persistence	β	0.9	0.05	0.9559	0.0079	[0.9434 0.9689]	
<b>Prices</b>	& Wages							
Xx	Share of non-optimizers (interm.)	β	0.65	0.05	0.5850	0.0109	[0.5660 0.5977]	
$\chi_m$	Share of non-optimizers (imports)	β	0.8	0.05	0.7852	0.0097	[0.7671 0.8007]	
Xf	Share of non-optimizers (exports)	β	0.7	0.05	0.6895	0.0105	[0.6751 0.7060]	
$\chi_{w,p}$	Share of non-optimizers (private wage)	β	0.4	0.05	0.2569	0.0122	[0.2385 0.2782]	
$\gamma_x$	Degree of indexation (interm. goods)	β	0.5	0.05	0.5302	0.0124	[0.5111 0.5521]	
Υm	Degree of indexation (imports)	β	0.5	0.05	0.4902	0.0266	[0.4603 0.5351]	
$\gamma_f$	Degree of indexation (exports)	β	0.5	0.05	0.4968	0.0218	[0.4710 0.5368]	
$\gamma_{w,p}$	Degree of indexation (private wage)	β	0.3	0.05	0.2928	0.0131	[0.2727 0.3096]	
$\gamma_{w,g}$	Degree of indexation (public wage)	β	0.5	0.05	0.5162	0.0220	[0.4887 0.5523]	

#### Table 4.2 : Priors and Posteriors : Parameters I.

Exporters, importers and mainly domestic producers of intermediate goods are slightly less rigid in their pricing strategy (possibly due to lower usage of labour force in the production) and change their prices each 7 (domestic producers) to 14 months. We enriched the Phillips curves by the price indexation parameters that measure the persistence of import, export and domestic production prices. We discovered that those who do not optimize their prices rely on past and steady-state inflation with approximately equal weights. Surprisingly, we find the private sector wages less rigid and even less affected by the past inflation. This can be partially explained by significantly lower influence of trade unions on labour market, relatively high unemployment, higher share of employees in small firms than in larger firms and frequent changes in the legislation. However, taking into account the fact that for the sake of simplicity the model internally assumes that only Ricardians are allowed to enter the wage negotiation process and Non-Ricardians (40 percent of the population) always accept their wage, approximately 85 percent of labour force in the private sector does not optimize. Moreover, those Ricardians who do not optimize are more likely to index their wages to the steady-state CPI inflation than to past private sector wage inflation. Motion of the gross real public wages replicates by one half the past evolution of private wages.

Persistence and volatility (see Table H.3 in the Appendix B.1) of fiscal expenditure items is in consistence with the observations of other studies (see e.g.Forni et al. (2007), Ardagna and Alesina (1998)) with some specifics observed for public investment, private sector subsidies, and unproductive government consumption (intermediate consumption) as they all have significantly high volatility. Volatility of public investment is driven by two factors: cuts in investment expenditures used to be the most popular instrument used by the government in public finance consolidation; and recently became extra subsidized from exogenous (EU) sources.





<b>Table 4.3 :</b>	<b>Priors and</b>	<b>Posteriors:</b>	<b>Parameters</b>	II.

		Pri	or Distril	bution	Posterior Distribution		
	Parameter	Туре	Mean	St. Dev.	Mean	St. Dev.	Conf.
Fiscal	Policy						
$\rho_{tr}$	(Household) Transfers persistence	β	0.3	0.075	0.3421	0.0143	[0.3198 0.3642]
$ ho_{wh}$	Public wage bill persistence	β	0.35	0.075	0.3896	0.0130	[0.3718 0.4095]
$ ho_{g^c}$	Unprod. consumption persistence	β	0.55	0.075	0.7191	0.0191	[0.6914 0.7505]
$ ho_{sub^p}$	Private sector subsidies persistence	β	0.3	0.075	0.2991	0.0113	[0.2817 0.3155]
$\rho_{sub^g}$	Public sector subsidies persistence	β	0.4	0.075	0.4308	0.0086	[0.4185 0.4445]
$ ho_{i^g}$	Gross fixed capital form. persistence	β	0.5	0.075	0.4852	0.0064	[0.4754 0.4959]
$ ho_{ au^c}$	Consumption tax persistence	β	0.5	0.075	0.5206	0.0208	[0.4909 0.5521]
$ ho_{ au^w}$	Labour tax persistence	β	0.6	0.075	0.5536	0.0176	[0.5245 0.5794]
$ ho_{ au^k}$	Capital tax persistence	β	0.7	0.075	0.5527	0.0115	[0.5402 0.5748]
$ ho_{\Omega}^{tr}$	Transfers debt sensitivity	β	0.05	0.035	0.0164	0.0050	[0.0080 0.0257]
$ ho_{\Omega}^{wh^g}$	Public wage bill debt sensitivity	β	0.05	0.035	0.0294	0.0027	[0.0248 0.0335]
$\overline{\rho_{\Omega}^{g}}$	Government purchase debt sensitivity	β	0.05	0.035	0.0828	0.0396	[0.0175 0.1428]
$ ho_{\Omega}^{\overline{i}^{g}}$	Government investment debt sensitivity	β	0.05	0.035	0.2024	0.0036	[0.1973 0.2080]
$\rho_{\rm O}^{\overline{\tau^c}}$	Consumption tax debt sensitivity	β	0.1	0.05	0.0578	0.0421	[0.0546 0.0603]
$ ho_{\Omega_{1}}^{ au_{w}}$	Labour tax debt sensitivity	β	0.1	0.05	0.0737	0.0214	[0.0683 0.0802]
$ ho_{\Omega}^{ au^k}$	Capital tax debt sensitivity	β	0.1	0.05	0.1031	0.0189	[0.0996 0.1082]
Extern	al Environment						
$\rho_{p^e}$	Oil price persistence	β	0.6	0.05	0.6936	0.0352	[0.6397 0.7539]
$\rho_{\omega^*}$	Foreign demand persistence	β	0.75	0.1	0.7716	0.0095	[0.7537 0.7863]
$\rho_{\omega^{*,y}}$	Foreign demand cycle-sensitivity	β	0.4	0.075	0.4156	0.0195	[0.3898 0.4437]
$\rho_{\iota^*}$	Factor income persistence	β	0.6	0.075	0.6618	0.0385	[0.6007 0.7248]
$\rho_v^{eu}$	EU output gap persistence	β	0.4	0.075	0.3611	0.0130	[0.3429 0.3810]
$\rho_i^{eu}$	ECB interest rate persistence	β	0.85	0.075	0.8761	0.0088	[0.8615 0.8887]
$\alpha_{\pi}^{eu}$	EU inflation persistence	β	0.4	0.075	0.3259	0.0117	[0.3121 0.3508]
Grow	th Technologies						
$ ho_{\eta^A}$	Domestic growth persistence	β	0.95	0.025	0.9590	0.0155	[0.9354 0.9847]
$\rho_{n^{A,*}}$	Foreign growth persistence	β	0.8	0.075	0.8530	0.0400	[0.7902 0.9180]
$\rho_{n^{X}}$	Export-specific growth persistence	β	0.6	0.075	0.5629	0.0454	[0.4938 0.6392]
$\rho_{n^o}$	Trade openness growth persistence	β	0.45	0.075	0.4295	0.0461	[0.3031 0.4534]
$ ho_{\eta^{\mathcal{Q}}}$	Quality growth persistence	β	0.6	0.1	0.5560	0.0820	[0.4244 0.6851]

Government unproductive consumption expenditures (i.e. intermediate consumption) volatility is relatively high also due to cuts motivated by the consolidation. Private sector subsidies used to be higher in the past caused by an inflow of foreign direct investments, many of them green-field investments and infrastructure development. However they are still supplied to private sector firms in an ad-hoc manner and are often subject to political decisions. On the other hand side, public sector subsidies (i.e. social transfers in kind) have raising trend possibly due to population ageing and building welfare state. However, capital and labour tax hikes are also used to cut public debt and deficit. On the other hand side taxes appear to be less durable than we expected ( $\rho_{\tau^c} = .5206$ ,  $\rho_{\tau^w} = 0.5536$  and  $\rho_{\tau^k} = 0.5527$ ), though consistently with standard literature, consumption tax rate is the least persistent. Concerning the growth technologies we find the domestic growth process markedly more persistent than the foreign one and the export-specific process ( $\rho_{\eta^A} = 0.9590$ ,  $\rho_{\eta^{A,*}} = 0.8530$  and  $\rho_{\eta^X} = 0.5629$ ).

Despite low volatility of foreign growth and output gap, foreign demand remains volatile and so along with fluctuating cost-push prices imply variation in domestic export and imports. A significant volatility in factor income, i.e. the difference between the country's current account and trade balance, can be explained by large inflow of foreign direct investment that were used to rebuilt the production sector and especially exporting firms. This gap has been gradually closing since 2009 as the inflow of foreign investment has been reduced while the FDI outflow



and dividend payments have become more apparent. Finally, high model volatility of the oil price is perfectly consistent with data observed.

## 4.4 Model Analysis

Based on estimated model on 2009-2015 data we computed relative and absolute contributions of individual shocks to the total variance for the key model variables. Since model variables evolve with their distinctive stochastic growth rates in case of non-stationary variables we study the forecast uncertainty of growth rates of individual variables rather than the variables themselves. We report them here on Figures 4.1–4.3 and the Appendix B.2 on Figures H.3–H.4.



## **Forecast Error Variance Decomposition**

Our observations on contributions of individual shocks to the total variance for the key model variables are summarised as follows.

Not surprisingly, uncertainty in the real GDP growth and output gap (measured as the difference between the GDP and its stochastic long-run trend path) forecast is mostly a result of the uncertainty about the evolution of the foreign economy. Concretely, more than 40 percent of the uncertainty in the prediction of the domestic output growth and output gap comes from the foreign demand volatility due to high proportion of exports on GDP and large trade-openness variations in the foreign demand. Next, price competitiveness of exporters contributes to the by more than 15 percent to the real growth volatility. Moreover, shocks in domestic productivity (that directly affects labour market, prices and demand for goods) are very important source of the uncertainly in the output gap prediction (20 percent) while their impact is relatively smaller (15 percent) in case of the real output growth uncertainty. Since production is highly dependent on commodities, changes in the very volatile and low persistent oil price are responsible for 12 percent of output growth volatility and explain almost 15 percent of the uncertainty in the output gap forecast. Furthermore, variation in the investment adjustment costs, sectoral and cost-push shocks, interest rate wedge and changes in household habit formation have minor influence on the volatility of both the real GDP growth and the output gap.

There are four large determinants of the household consumption growth uncertainty: both fluctuations in the public goods supply (these are particularly helpful for the Non-Ricardians, stronger in the short-run) and domestic productivity shock (affecting labour market, prices and demand for goods, with higher long-run impact) explain approximately 20 percent of the long-run uncertainty each. Next, changes in its consumption habit formation (i.e. variations in strength of their consumption persistence) and in the income from government transfers and





the variation in consumption growth are responsible for 15 percent of the long-run uncertainty each. Moreover, fluctuations in the foreign demand contribute to the consumption growth uncertainty by 8 percent.

Volatility in investment growth is in the short run strongly determined by the variation in the investment adjustment costs and the productivity shock (that affects the prices of goods bought by households as well as their capital and labour income and so modulates their investment decisions) with approximately 20 percent impact each. Next, fluctuations in the foreign demand (investment goods production rely mostly on imported inputs with the foreign demand changes as the main source of the uncertainty) and investment-specific technology shock (plating the role of the investment goods quality process and hence directly impacts their price) both contribute to the uncertainty by 10 percent while the interest rate wedge that drives the difference between the intertemporal marginal utility of consumption and the real interest rate is responsible for 8 percent of the long run uncertainty and even 15 percent in the short-run. Moreover, fluctuations in the oil price, changes in the effectiveness of transformation investment to capital and shifts in household labour-consumption preferences explain 10 percent in total.



Aggregate exports growth forecast volatility has one key player. Evidently, it is driven mainly by the fluctuations in foreign demand which explain around 45 percent of the forecast uncertainty. Variations in the trade openness i.e. the wedge between the world trade (or imports) and the value added is responsible for 30 percent of the uncertainty. Next, price competitiveness of exporters is quite significant as it explains almost 20 percent impact while changes in quality of exported goods contribute by approximately 10 percent. Highly import intensive export specifies to a large degree the major determinant of the import forecast uncertainty: since production of export goods uses more than 60 percent of imported intermediate goods, fluctuations in the trade openness and in the foreign demand explain almost 40 percent of the uncertainty each. Next, price competitiveness of exporters on foreign market represent additional 10 percent whereas investment adjustment costs and domestic productivity shocks influence 8 percent of the volatility each in import growth.

Current account growth volatility can be explained by the wedge between the current account and trade balance which includes the factor income and payments for the excessive capital (35 percent in the short-run and 22 percent in the long-run) and the drivers of the trade - fluctuations in the foreign demand (30 percent) and export price competitiveness (10 percent). As production of investment goods relies mostly on imports, impact of changes in the investment





adjustment on the current account growth uncertainty is evident (10 percent). Next, since oil is imported, changes in its price are also important. Furthermore, 8 percent of the uncertainty is due to shocks in the domestic productivity that affects prices of production input factors. Factors determining the uncertainty about the current account growth specify to a large degree the drivers of the external debt. In the short-run, the most important source of the uncertainty is the the wedge between the current account and trade balance that explains 35 percent of the volatility. However, its impact vanishes soon as it is not directly associated with the production and demand process. Furthermore, variations in the investment adjustment costs are important in the short run (up to 30 percent) although its long-run impact is rather small (10 percent). On the other hand side, the largest source of the long-run uncertainty comes from the foreign demand fluctuations (20 percent), domestic productivity shocks (20 percent) and oil price volatility (8 percent).



Figure 4.3 : Forecast Error Variance Decomposition: Relative Shock Contributions III

The volatility of CPI inflation (excluding taxes) results mainly from the technology shock with almost 50 percent share. Next, variations in the consumption goods-specific process (that drive the evolution of the goods quality and hence relative price) explain approximately 35 percent of the short-run and 20 percent of the CPI uncertainty. Furthermore, approximately 8 percent is driven by household preference shifts.

The private sector employment uncertainty comes especially in the short-run from the technology shock which explains approximately 40 percent of the volatility. However, its impact gradually declines as the shock vanishes and in the long-run drives the uncertainty by approximately 20 percent. On the other hand side, importance of shifts in households preferences raises over time and in the long-run their impact on the uncertainty grows to more than 25 percent. Next, since export firms are the largest employer, changes in the foreign demand have strong long-run consequences and contribute to the volatility in private sector employment by 20-30 percent. Finally, shocks in oil price and changes in the supply of public goods (that households receive for free) are responsible for 5 percent of the employment volatility each.

Shifts in households consumption-labour preferences have also due to relatively high share of wage optimizers the largest (more than 60 percent) impact on the aggregate real wage growth uncertainty. Next, fluctuations in the foreign demand technology shocks contribute to the uncertainty by 10 percent, while impact of the changes in the consumption goods-specific process (quality process) explains approximately 15 percent of the short-run and only 5 percent of the long-run uncertainty.

Growth of the public debt is in the short-run driven essentially by the volatility in the primary



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deficit (40 percent) however its influence declines to less than 20 percent in the long-run. Nonsurprisingly, changes in foreign demand have long-lasting impact on production and hence on tax revenues. Therefore its stable,20 percent importance is obvious. Similarly, shocks in domestic productivity have strong impact on tax revenues and so on the public debt growth uncertainty (up to 25 percent in the long-run). Furthermore, shocks in the capital tax rate (which has been between 2009-2015 below its long-run equilibrium) affect the debt growth significantly especially in the short run (20 percent). Minor drivers of the uncertainty are variation in the oil price and changes in the public goods production.

## Historical Evolution of Shocks

We use a simple Kalman filter to illustrate the dynamics of the model shocks between 2009–2015 (see Figures H.5–H.6 in Appendix B.3).

Our observations are following. Foreign economy partially recovered from the large fall of the output in 2009–2010, but still does not achieve their pre-crisis performance despite extremely low ECB rate (declined after a small post-crisis increase in 2012). After an increase in 2009, foreign inflation gradually falls and remain below zero.

Although foreign demand for Slovak export goods has been gradually recovering from negative shocks that had faced during the crisis, the long-run growth trend of the domestic economy as well as the productivity (that also suffered from a large fall during the crisis) stay below their potential. However, international trade more or less attains is long-run growth path with positive trade-openness, quality and export price competitiveness pressures that substantially support the export of domestic goods. Cost-push shocks of exporters and domestic producers create after 2009 negative signals that contribute to price decline while the domestic demand is motivated to prefer more domestic inputs due to positive import price cost-push shocks.

Referring to domestic monetary conditions, after initial raise of the country risk premium, public bond risk premium and interest rate wedge during the crisis, they all fall significantly.

After 2009 government increased transfers to households and replied to raising public debt by cuts in its unproductive consumption. Next, between 2012-2013 it reduced public wage bill (increased during the crisis) and investment expenditures (sharp decline in 2013) to consolidate the debt. On the other hand side, the effective consumption tax rate endures below its steadystate level.

## **Contribution of Shocks**

Furthermore, we employ the Kalman Filter to determine and analyse the contribution of individual structural shocks to most important model variables between 2009 and 2015. Figures H.7–H.10 in Appendix B.4 depict the decomposition of structural shocks for all observables of the model and additionally for the simulated QoQ growth of domestic GDP, export and import volumes. In order to illustrate more comprehensively the impact of these shocks on variables, we separate the estimated model shocks into several groups:

- *Foreign Economy*: shocks to foreign trend growth  $\varepsilon^{\eta^{A,*}}$ , output gap  $\varepsilon^{y^{eu}}$ , inflation  $\varepsilon^{\pi^{eu}}$ , ECB rate  $\varepsilon^{i^{eu}}$ , and oil price  $\varepsilon^{p^{e}}$ ;
- *International Trade*: shocks to foreign demand  $\varepsilon^{\omega^*}$ , price competitiveness  $\varepsilon^{\sigma^*}$ , export-specific process  $\varepsilon^{\eta^X}$ , trade openness  $\varepsilon^{\eta^o}$ , and quality technology  $\varepsilon^{\eta^Q}$ ;
- *Domestic Technology*: shocks to private and public sector TFP  $\varepsilon^a$ ,  $\varepsilon^{c^g}$ , trend growth  $\varepsilon^{\eta^A}$ , common technology sectoral quality shocks  $\varepsilon^{\eta^c}$ ,  $\varepsilon^{\eta^i}$ ,  $\varepsilon^{\eta^g}$ ,  $\varepsilon^{\eta^f}$  and  $\varepsilon^{\eta^m}$ ;
- *Domestic Monetary & Risk Premium*: shocks to country-specific premium  $\varepsilon^{sk}$ , risk premium on domestic bonds  $\xi^d$  and interest rate wedge  $\varepsilon^{\Delta R}$ ;
- *Preferences and Habits*: shock to households preferences  $\varepsilon^{\phi_L}$  and habit formation  $\varepsilon^{\kappa}$ ;
- *Investment and Capital*: shocks to Tobins'Q  $\varepsilon^{\overline{Q}}$ , private and public investment-capital trans-



formation efficiency  $\varepsilon^{\eta^{i,h}}$ ,  $\varepsilon^{\eta^{i,g}}$ , investment adjustment costs  $\varepsilon^{\xi^{i,h}}$  and factor income  $\varepsilon^{\iota^*}$ ;

- *Cost-Push*: cost-push shocks of exporters  $\varepsilon^{\theta^{f}}$ , importers  $\varepsilon^{\theta^{m}}$  and domestic producers  $\varepsilon^{\theta^{x}}$ , private sector wage  $\varepsilon^{\vartheta^{w,p}}$  and public sector wage-indexation rule  $\varepsilon^{w,g}$ ;
- *Fiscal*: shocks to fiscal expenditure variables, tax rates, primary deficit  $\varepsilon^{def}$  and transfers for Ricardians  $\varepsilon^{tr'}$ .

Furthermore, when describing the contribution of shocks to the QoQ growth of aggregate export and import and growth of their volumes we go deeper in this group structure and study in detail the influence of individual shocks from the Trade group. A similar approach is employed to study the shock contribution on key observables of the domestic real economy as we separate out the effect of oil price fluctuations and decompose the trade shocks on those directly associated with the foreign demand and the trade technology. Within our analysis the factor income represent the permanent wedge between the trade balance and the current account.

Andrle et al. (2009) notices that small open economy models have usually a problem to replicate the observed spill-overs of macroeconomic shocks among countries and thus tend to explain partially the decline in foreign demand by negative domestic technology shocks (mainly loss in trend growth of the domestic economy).



Simulated (using Kalman filter) contribution of shocks to model variables. Thick black line illustrates the percentage deviation of the variable from its steady state. Growth rates (measured as QoQ growth in percent) are annualised.

Our findings can be summarised as follows. Fall of the GDP growth was mainly due to losses in foreign demand. As mentioned above, negative technology shocks (trade technologies, domestic trend growth, TFP, sectoral quality shocks) partially contribute to the explanation of GDP growth fall. On the other hand side, large decrease of oil price and government reaction partly diminish the decline in output growth. During the post-crisis period (until 2014), gradually increasing foreign demand, export and domestic technologies are the main driving forces in the output recovery while domestic demand is weak and oil price high. Furthermore, the need of fiscal consolidation and debt reduction creates negative pressure on output growth between 2012-2014. However then the situation turns and lower oil price, and slightly higher domestic demand help to improve the output growth while trade and technologies do the opposite. Private consumption has lost much of its pre-crisis level, mainly due to negative shocks in domestic (changes in consumption habit formation and consumption-labour preference shifts) and foreign demand and low performing productivity. Next, referring to Andrle et al. (2009)





negative domestic technology shocks (mainly low trend growth of the domestic economy) partially explain the initially negative signals from the foreign economy and its slack recovery deepen the consumption fall in the post-crisis period. However in the post-crisis period higher foreign and domestic demand are the main sources of modest consumption growth recovery. Fiscal policy actions weaken consumption growth despite their positive impact during the crisis. Recently foreign environment, mainly low oil price, decreasing rates and inflation, and fiscal policy up to some stage compensate this negative trend in consumption fall.



Simulated (using Kalman filter) contribution of shocks to model variables. Thick black line illustrates the percentage deviation of the variable from its steady state. Growth rates (measured as QoQ growth in percent) are annualised.

Employment growth is driven by two key forces that react mainly in an opposite direction: foreign demand (which positive evolution mostly contributes to the post-crisis recovery) and domestic technologies, namely lower trend growth and productivity shock. Another important factors are oil price volatility (high oil price in the post-crisis era has negative impact of employment growth while recently low oil prices create positive pressures on employment) and domestic demand shocks, mainly shifts in household preferences that have improve employment in the recent period. Notice that fiscal policy actions have more or less negative consequences on employment.

Decline of export and import came from a significant fall in foreign demand and price competitiveness. Nevertheless these two forces (along with export-specific in case of export) helped to recovery the trade in the post-crisis period. Despite negative shocks in international trade openness export goods is consider to be of better quality. However, recently foreign demand weaken while trade openness improved. Import growth is during the post-crisis period negatively affected by higher oil price and domestic cost-push shocks but these effect are partially mitigated by decreasing foreign rates and inflation.

Non-surprisingly, a gradual decline of the baseline ECB rate is one of the reasons why the interest rate on public bonds has been stable during the post-crisis period and recently has decreased significantly. Initially rising but later on falling country risk premium and domestic debt-elastic premium - despite raising public debt - nowadays create downward pressure on interest rate. Similarly, increasing foreign demand and international trade help the debt rate to decline. Notice that changes in foreign demand and oil price significantly affect household consumption and investment activities, their labour income, firms demand for production in-







puts and profits. Therefore these changes have a strong impact of tax revenues and hence on primary deficit and debt evolution. Thus it is not surprising that two major sources of interest rate (with public debt-elastic forward-looking risk premium) movement come from the trade appreciation (foreign demand, price competitiveness, export volume trend growth, trade openness, quality of goods) and oil price. Higher primary deficit and government expenditures along with domestic productivity shocks create upward pressure on interest rate.

A similar picture can be deduced when analysing the drivers of the public debt growth. In the post-crisis period the debt grew mainly due to domestic technologies (sluggish return of the economy performance to its long-run trend) gradually recovering trade and higher risk premium on bonds, while declining ECB rate and higher oil prices slowed down the public debt growth. Nevertheless, recently the debt growth has been reduced owing to the trade, better performing domestic economy, lower risk premia and current account wedge. Oil prices, government expenditures and higher deficits have accelerated the debt growth.

High post-crisis CPI inflation is driven by oil price and cost-push shocks including those coming from the labour market. This is partially compensated by domestic technology, mainly gradually recovering trend growth of the domestic economy. However, nowadays low inflation is a result od low foreign inflation, low oil prices, and decelerating foreign demand (trade) while domestic technologies contribute to its growth. The impact of the fiscal policy on the CPI is roughly rebalanced.





## 5 Results

In order to examine model performance we firstly pay attention to the study of the responses of the key macroeconomic variable to standard shocks. Then we perform various fiscal consolidation exercises and calculate the associated fiscal multipliers. These exercises are performed on the model whose parameters and standard deviations are estimated following the procedure described in Section 4.3 using Slovak and Euro-Area data observed between 2004 and 2015.

## 5.1 Model Dynamics

First of all, we study the response of the key macroeconomic variables to standard shocks: a positive technology shock and a negative foreign demand shock of their respective estimated 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. For the sake of comparison, we also show how the economy responds to these shocks should fiscal policy aim to keep the primary deficit unchanged in every period, and adjust either transfers or labour tax rate to achieve this goal.





## 5.1.1 Positive Technology Shock

Let us first consider the performance of the economy following a positive persistent technology shock (Figure 5.1 and Figure H.11 in Appendix C.1). Following the positive technology shock, marginal costs decline, and as a result of persistent wages and capital price, firms' demand for labour and capital drop temporarily which is followed in a very short run by a small decline in consumption. Falling prices stimulate domestic and foreign demand and lead to higher usage of production inputs (labour, capital, energies, and imports). The volume of international trade raises and improves net foreign assets position. As the effects of the positive technology shock



fades out, economy returns to its equilibrium. From the fiscal point of view, the productivity shock causes government revenues decline and hence an increase of the primary deficit.

However despite real-value public debt raise, the debt/GDP ratio (which is important in the realistic fiscal rules) falls. Hence the government expecting speedy recovery of public finance either increase transfers for the Non-Ricardians or lowers labour tax rate. The choice of the fiscal instrument has a considerable impact on the economy both over time and in the cross-section. Higher transfers for the Non-Ricardian households (associated with a large and persistent consumption effect) stimulate immediately the economy but their effect vanishes soon with a minor or even negative influence on investment or labour market in the mid- and long-run. However, consumption boost induces larger revenues and hence a substantial fall of government indebtedness. On the other hand side, labour tax cuts prolong and deepen the effect of lower marginal costs and price fall and lead to an essential and long-lasting employment growth (despite its initial decline), significantly higher exports and trade growth, better net foreign debt position and stimulated private investment.

Our fiscal rules imply that output would stay higher over a prolonged period of time if labour tax is used as the means of fiscal adjustment. There is, thus a clear intertemporal trade-off here if the objective is to achieve growth of output growth, government revenues, employment and international trade. These effects are smaller in the very short-run but become apparent later on. There is also another trade-off in place: the size of the consumption response of households is affected by the choice of the consolidation instrument, since higher transfers for those who do not optimize induce a substantial welfare effect. 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.

5.1.2 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 (Figure 5.2 and Figure H.12 in the Appendix C.1). 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.

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. 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. As private sector employment weaken households face net labour income reduction and so their shrink their consumption and investment. Decreasing production output and demand for its inputs imply deterioration in all tax bases. Therefore the subsequent shortfall in tax revenues induces a fall in primary budget balance and leads to a raise in the Debt/GDP ratio even though the real-valued debt declines. In the environment of negative fiscal outlook, the government responds to this situation by either a Ricardians' transfers cut or a labour tax rate hike.

Labour tax rate increase drives the grow of real wages and a substantial and very persistent fall in private sector employment (amplified by wage negotiated by employees reflecting the labour tax increase). Therefore, the after-tax household labour income is even lower. Non-Ricardians cannot do anything but cut their consumption for a long time (although their transfers remain unchanged). Furthermore, relatively higher labour costs have an upward pressure on marginal costs and so rising prices dampen demand for goods and production inputs even more. Lower returns from capital renting do not motivates households to invest, Ricardians rather use the reduced income to offset consumption decline. The drop in production and





usage of production inputs has long-lasting effects on the economy.

On the other hand side, if the government decides to lower transfers for Ricardians, no wage pressure occurs and due to lower decline in firms' labour demand households do not face so dramatic labour income fall as in case of labour tax rise. Next, the substantial decline in production marginal costs inducing price fall makes goods more accessible for households. This supports firms' demand for production inputs and so employment and investment recovery soon. Furthermore, relatively low marginal costs enable exporters to be more competitive and the real exchange rate depreciation supports domestic production and exports. From the fiscal policy perspective, transfers cut leads to less sharp and rapidly recovered tax basis and relatively higher capital and consumption tax revenues. Thus, the effects of the Ricardians' 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.

## 5.2 Fiscal Consolidation Scenarios

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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 56 percent of GDP and the government runs a primary deficit of 3 percent of GDP with poor domestic and EU economy performance (production in both is 2 percent below its long-term trend). At the same time, both economies face zero inflation and very low interest rates (2.7 percent p.a. nominal rate for Slovak government bonds, and zero ECB rate).

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 (see Figure 5.3 and Figure H.13).<sup>15</sup>

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).



(dark line) or labour tax (blue line). Time (on x-axis) is in quarters and responses are measured as absolute deviations (in percentage points) from the variable equilibrium 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, they remain relatively lower and make domestic inputs in final goods more attractive. Non-Ricardians suffering lower income due to transfers, followed by Ricardians (owing to strong habit persistence) reduce their consumptions immediately and Ricardians (who are not touched by the reduction of transfers) prefer to invest. Increasing domestic and foreign

<sup>15</sup>The steady state is shifted in intervals corresponding to four percentage-point decreases in the public debtto-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 differences compared with using a simple log-linear approximation around the deterministic steady state of the mod**q**l. For presentation purposes, we smooth out the obtained series.





demand for the export and investment goods requires higher production inputs which acts to quickly raise and then stabilize employment and capital stock. The recovery of the foreign demand (initially weaken by low performance of the foreign economy) is due to significantly lower export prices fast and stimulates export. Better current account position contributes to downsize the external debt. Despite a significant fall in the household consumption (especially the Non-Ricardians) in the short-run, the economy (domestic and foreign demand, relative prices and labour market) stabilises soon.

## 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 persistently contributes to shrinking of export and so substantially worsens the country's current account position. This leads to a 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, capital tax base and revenues quickly recovery from their initial fall and remain permanently above those achieved when labour tax rate is used. Indeed, higher firms' demand for capital and its price stimulate household investment. As a result of a large initial drop in consumption, in the short-run both the consumption base and tax revenues drop, but as the transfers cuts get smaller they soon exceed the levels corresponding to the case of fiscal consolidation using labour tax rate raise.

On the other hand, if government raises labour tax rate to reduce the public debt the labour tax base shrinks markedly although the revenues are higher. The deterioration effect of higher labour tax on labour market is very persistent due to permanent contraction of employment.

## 5.3 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 3.4.2 and Taylor-like rules. We model the realistic policy rules in rather parsimoniously fashion by simplifying the correction functional (43) to be responsive to deviations in debt/GDP only <sup>16</sup>. 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. Hence, any detrended expen-

<sup>&</sup>lt;sup>16</sup>The correction functional is simplified by setting  $\alpha_{\Delta\Omega} = \alpha_{\tilde{\delta}} = \alpha_{\Delta\delta} = 0$ , so  $\mathscr{C}_t = \alpha_{\tilde{\Omega}}\overline{\Omega}_t$  for  $\tilde{\Omega}_t = \overline{debt}_t/y_t - \Omega_t^{\text{tar}}$ , where the pre-consolidation  $\overline{debt}_t$  is defined in sense of (42).





diture item x or tax rate  $\tau$  evolves accordingly the subsequent prescriptions

$$x_{t} = \rho_{x}x_{t-1} + (1 - \rho_{x})x - \alpha_{\Omega}^{x} [debt_{t-1}/y_{t-1} - debt/y] + \xi_{r}^{x}, \qquad \alpha_{\Omega}^{x} > 0,$$
  

$$\tau_{t} = \rho_{\tau}\tau_{t-1} + (1 - \rho_{\tau})\tau + \alpha_{\Omega}^{\tau} [debt_{t-1}/y_{t-1} - debt/y] + \xi_{r}^{\tau}, \qquad \alpha_{\Omega}^{\tau} > 0.$$
(54)

Activity	Taylor Rules					Realistic Rules				
Activity	1	4	12	16	20		4	12	16	20
transfers	0.62	0.68	0.51	0.51	0.50	0.48	0.60	0.58	0.58	0.59
public wage bill	0.77	0.71	0.59	0.60	0.61	0.67	0.66	0.54	0.55	0.55
public investment	0.35	0.52	0.78	0.82	0.84	0.20	0.37	0.74	0.81	0.85
unprod. consumption	0.55	0.50	0.42	0.43	0.43	0.49	0.48	0.40	0.40	0.40
subsidies (private sector)	0.50	0.42	0.32	0.33	0.33	0.43	0.40	0.30	0.30	0.30
subsidies (public sector)	0.56	0.51	0.42	0.43	0.44	0.50	0.49	0.41	0.41	0.41
consumption tax	-0.32	-0.39	-0.37	-0.36	-0.35	-0.82	-1.17	-1.36	-1.36	-1.36
capital tax	-0.65	-0.93	-1.28	-1.28	-1.29	-1.12	-1.49	-1.95	-1.94	-1.93
labour tax	-0.71	-0.96	-1.18	-1.18	-1.18	-1.03	-1.47	-1.95	-1.95	-1.94

#### Table 5.1 : Standard implied fiscal multipliers

#### 5.3.1 Steady-state fiscal multipliers

Table 5.1 summarizes implied fiscal multipliers at various horizons for all fiscal instruments from our benchmark simulation. Following Uhlig (2010), we calculate the implied net present value multiplier employing successively both fiscal rules<sup>17</sup> for each expenditure (revenue) item of government budget  $x_t$  ( $\tau_t$ ) as follows:

$$\sum_{k=0}^{T} \beta^{k} (y_{t+k} - y) , \qquad \frac{\sum_{k=0}^{T} \beta^{k} (y_{t+k} - y)}{\sum_{k=0}^{T} \beta^{k} (x_{t+k} - x)} , \qquad \frac{\sum_{k=0}^{T} \beta^{k} (y_{t+k} - y)}{\sum_{k=0}^{T} \beta^{k} (\tau_{t+k} \Phi_{t+k}^{\tau} - \tau \Phi^{\tau})} , \qquad k = 0, 1, \dots, T$$

We see that in both cases the obtained values rather reasonable, in consistence with standard literature and regardless the choice of the fiscal rule key implications do not differ.

In general, tax changes have large long-run consequences. Evidently, accordingly to both rules the labour and capital tax raise turn out to be more harmful than consumption tax hike. Hence, the consumption tax is the best debt consolidation revenue instrument with the smallest negative externalities in short and long-run. Variations in direct taxes significantly and persistently affect the labour market and investment activities.

Cuts in public investment appear to be the most harmful among expenditure instruments in the long-run although the associated losses on output are the smallest in the short-run. The evolution of the public investment multiplier reflects the *time-to-build* character of the capital. Furthermore, in a short-run this is accompanied by the private investment crowding-in that partially offsets negative implications of downsized public investment. This decrease influence the output not only through lower investment but mainly induce fall in the aggregate consumption due to Ricardians' complementarity in the consumption of public goods.

However, in the short-run public wage bill cuts are the most detrimental. It results from a fall in the public sector employment and hence lower households' labour income and public goods

<sup>&</sup>lt;sup>17</sup>Technically, to calculate fiscal multiplier for a specific expenditure item x we keep all remaining budget expenditure instruments and tax rates constant and allow only the studied instrument to evolve. Providing that the fiscal policy is driven by the Taylor-like rules we simulate the model response on the fiscal shock associated with the studied budget item of the estimated one standard deviation. If realistic rules are used, we simulate the model response on the shock to the budget constraint with the magnitude of estimated one standard deviation.





supply. Later on this is partially compensated by slightly higher usage of the labour services by private sector firms that create some positive effect on output. Therefore the long-rum impact of public wage bill cuts is not so deleterious. Finally, very similar response of output on reduction in the unproductive consumption or social transfers in kind is caused by very low efficiency of the transfers in kind.

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 5.1 and their evolution is illustrated on Figure H.14 in Appendix C.3.

## 5.3.2 Fiscal multipliers in a recession

In the alternative simulation starting off from the steady state, the implied multipliers show somewhat different patterns. Their relatively large magnitude in the short-run is due to denominator effect as (by design) they are adjusted gradually to lower the debt from the initial level 56 percent of GDP by 6 percentage points in approximately 6 years (see Figures 5.4-5.5 below). This objective is reached perfectly if realistic fiscal rules are employed but the opposite is true for standard Taylor-like rules.

#### Table 5.2: Implied fiscal multipliers in a recession

A attaction	Taylor Rules					Realistic Rules				
Activity	1	4	12	16	20		4	12	16	20
transfers	0.70	0.58	0.51	0.53	0.54	0.51	0.84	1.00	0.90	0.81
public wage bill	0.70	0.57	0.49	0.52	0.53	0.60	0.84	0.81	0.74	0.65
public investment	0.53	0.42	0.44	0.50	0.53	0.54	0.85	1.02	0.92	0.82
unprod. consumption	0.66	0.53	0.43	0.45	0.46	0.44	0.73	0.90	0.82	0.73
subsidies (private sector)	0.56	0.42	0.32	0.34	0.35	0.45	0.75	0.90	0.78	0.66
subsidies (public sector)	0.66	0.53	0.43	0.45	0.46	0.52	0.83	0.97	0.86	0.75
consumption tax	-1.13	-0.86	-0.47	-0.46	-0.46	-0.45	-0.84	-1.11	-0.98	-0.87
capital tax	-1.22	-0.92	-0.51	-0.49	-0.49	-0.52	-0.92	-1.23	-1.12	-1.02
labour tax	-1.77	-1.39	-0.91	-0.88	-0.87	-0.74	-1.27	-1.67	-1.50	-1.37

Cuts in public investment and transfers for Non-Ricardians appear to be the most harmful among expenditure instruments in the long-run. Reduction in transfers for Ricardians leads to a substantial fall in private goods consumption of both types of households. Similarly to the case of standard multipliers, the evolution of the public investment multiplier reflects the *time-to-build* character of the capital. Furthermore, in a short-run this is accompanied by the private investment crowding-in that partially offsets negative implications of downsized public investment. This decrease influence the output not only through lower investment but mainly induce fall in the aggregate consumption due to Ricardians' complementarity in the consumption of public goods.

In the short-run public wage bill cuts are very detrimental (especially in case of realistic rules). This is a result of lower public sector employment (and so decline in household labour income) and and public goods supply. Later on this is partially compensated by slightly higher usage of the labour services by private sector firms that create some positive effect on output (so the implied multiplier decreases). Therefore the long-rum impact of public wage bill cuts is not so deleterious.

Tax changes have large long-run consequences. The detrimental effect of labour income tax hikes is evident also in a high-debt, low-growth context regardless the fiscal rule. Essentially, it is the worst consolidation instrument. Furthermore, higher capital tax rate is more damaging







than the consumption tax rate increase. Hence, changes in direct taxes significantly and persistently affect the labour market and private investment. The obtained results are summarized in Table 5.2 and their evolution is illustrated on Figure H.15.

5.3.3 Fiscal Rules: Do they matter?

Tables 5.1–5.2 show that the choice of underlying fiscal rules design is essential in the fiscal multipliers estimation. Although to the eye it may seem that Taylor rules can well approximate realistic rules presented in this paper, opposite is true.

The analysis of the differences between the realistic fiscal rules and standard Taylor-like rules and the consequences on implied multipliers reveals the major role of the debt gap sensitivity parameters. We emphasize that in both types of fiscal rules we compare the debt/GDP to either the current debt target (measured relatively to GDP) or steady-state debt/GDP ratio. This approach is more appropriate than using level-based measures and leads to more realistic evolution of the debt and fiscal variables. The crucial difference between these two rules resides in the design of the debt gap sensitivity and the associated adjustment term. The adjustment term reflects that realistic fiscal rules are *target oriented* whereas Taylor-like rules are *instrument oriented*.

Indeed, the adjustment term evaluates the amount of correction necessary to achieve gradually the objective - debt reduction - within a certain time horizon. Thus, change in the individual







instrument is relatively larger for the budget items with lower steady state values (or revenues, in case of tax rates) and vice versa. This rule is less dependent of autoregressive parameters and does not rely on historical paths of fiscal variables. This type of fiscal rules is therefore very useful when fiscal consolidation is needed.

On the contrary, Taylor-like rules do a good job if the economy is in its steady state. Nevertheless, their performance is quite poor if fiscal consolidation is needed (see Figure 5.5) and are not suitable for the debt stabilization. Values of the autoregressive and debt sensitivity coefficients arise from historical time series and past fiscal policy decisions and do not consider the consolidation effort. Actually, debt sensitivity parameters (typical for each instrument) and the corresponding debt/GDP gap term is rather a technical necessity (guaranteeing the existence of the model solution) than a realistic feature. Typically, when consolidation is needed debt remains relatively far from its steady state and thus linear relationships estimated in the normal times (when the economy is close to its equilibrium) do not hold. Many studies, even those with a well-structured fiscal block, prefer simple autoregressive processes in order to describe the evolution of individual expenditure items (e.g. Forni et al. (2007), Erceg and Linde (2011)) while having simple Taylor-like rules for tax rates or vice-versa (e.g. Stork et al. (2009) and Alitev et al. (2014)).

Therefore since the public debt is quite far from the desired steady state we prefer realistic rules to simulate various fiscal scenarios and provide fiscal assessment.





## 6 Concluding remarks

We have set out a medium-scale DSGE model designed and calibrated to capture developments in the Slovak economy and estimated it using Slovak data.

We calculated the relative and absolute contribution of the model shocks to the total variance of the key variables. This was necessary to treat properly the forecast uncertainty when predicting the evolution of the individual variables and determine the sources of the potential risk. Furthermore, we used the estimated model to identify the structural economic shocks that drive the economy. Fall of the GDP growth in 2009 was mainly due to losses in foreign demand, higher risk premia and negative technology shocks, namely fall in the long-term growth. During the post-crisis period, gradually increasing foreign demand, export and domestic technologies are the main driving forces in the output recovery while domestic demand is weak and oil price high. Then the situation turns and lower oil price, and slightly higher domestic demand help to improve the output growth while trade and technologies do the opposite. Private consumption has lost much of its pre-crisis level, mainly due to negative shocks in domestic demand, low performing productivity and high oil price. Next, negative signals from the foreign economy and its slack recovery deepen the consumption fall in the post-crisis period. On the other hand side, decreasing ECB rates and foreign inflation along with increasing foreign demand for domestic production up to some stage compensate this negative trend in consumption fall. We have observed that decline of export and import during the crisis came from a significant fall in foreign demand and price competitiveness. Nevertheless these two forces helped to recovery the trade in the post-crisis period.

We employed the estimated model to study the response of the economy to a technology shock and to a foreign demand shock under alternative fiscal adjustment 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 in the environment of low growth, inflation and interest rates, and computed the corresponding implied fiscal multipliers. Generally, we have found these multipliers to be in line with standard DSGE literature. We found that raising taxes is more harmful for the growth in the short and long term than expenditure cuts. Among tax measures, direct taxes have larger impact on the economy than the consumption tax and labour income tax hike is the most injurious especially for the economy in a recession. Furthermore, we confirmed a substantial role of public goods (produced using public capital, public sector labour force and social transfers in kind) in the economy and its complementarity or substitutional impact on consumption of Ricardians and Non-Ricardians. Cuts in public investment and transfers for Non-Ricardian households are the most harmful in the long-run for the real economy in a high-debt, low-growth context when fiscal consolidation is needed. Most negative short-run externalities are associated with reduction in the public wage bill and transfers.

There is an interesting further research agenda emerging from this work. First, an empirical exercise will allow us to determine the key driving forces of business cycle dynamics in Slovakia. Furthermore, we need to trace the impact of these driving forces on model key variables during last decade. This exercise will help us to carry out conditional and unconditional forecasts and various scenario analysis. 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 services, labour force participation, unemployment and labour market interactions seem to be extensions worthwhile to consider too.

Finally, the assessment this model is not limited to the policy simulations and scenario analysis only but our aim is to use it to provide forecasting.





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## Appendix A Model Steady State

 Table H.1:
 Post-2009 Model Steady-State I.

Variable	Description	Sector	Value	Input
$\eta^A$	Domestic real economy growth rate (p.a.)	External	1.03	$\checkmark$
$\eta^X \eta^A$	Trade volumes growth rate (p.a.)	External	1.05	$\checkmark$
$\eta^{A,*}$	Foreign real economy growth rate (p.a.)	External	1.01	$\checkmark$
$\overline{\omega}^{eu}$	Weight of Euro Area in foreign economy	External	1	$\checkmark$
$mc^mm$	Aggregate demand for imports (excl. energy)	Production	0.81	$\checkmark$
$\overline{p}^{f}f$	Aggregate exports to GDP	Production	0.94	$\checkmark$
$\Pi^{CPI}$	Domestic CPI Inflation	Prices	1.02	$\checkmark$
$R^d$	Gross Returns on domestic bonds (p.a.)	Monetary	1.04	$\checkmark$
$\Pi^*$	Foreign inflation	External	1.02	$\checkmark$
$R^{eu}$	Baseline Interest Rate	Monetary	1.02	$\checkmark$
с	Aggregate consumption of private goods to GDP	Household	0.55	$\checkmark$
debt	Domestic public debt	Fiscal	0.40	$\checkmark$
$\widetilde{dabt}^{0}$	Known dobt /CDP ratio	Monotory	0 427	/
$n^0$	Known gross risk promium for a given debt/CDP	Monotary	0.427	v
р а	Energy weight in production of intermediate good	Production	0.011	v
$u_e$	Not external (private) debt	Fiscal	0.00	v
juebi	Covernment purchase to CDP	Fiscal	0.56	v
g w <sup>g</sup> h <sup>g</sup>	Componentions for amployees to CDP: public sector	Fiscal	0.10	v
w-n- tr	Transfors for households to CDP	Fiscal	0.09	V
$\tau^{c}$	Consumption tax rate	Fiscal	0.14	v
$ au^w$	Labour tax rate	Fiscal	0.15	v
w <sup>p</sup> h <sup>p</sup>	Compensations for employees to GDP: private sector	Labour	0.32	• ./
h	Aggregate Jahour supply	Labour	0.20	• ./
$h^{g}/h^{p}$	Public-to-Private sector employment	Labour	0.02	• ./
$\kappa^{c}$	(Efficient) consumption habit persistence	Household	0.25	• ./
i	Aggregate investment	Production	0.75	• ./
i <sup>g</sup>	Government gross fixed cap formation	Fiscal	0.035	• ./
$\sigma^k$	Capital / Labour share : private sector	Production	0.55	
$\sigma^{c^g}$	Capital / Labour share : public sector	Production	0.55	
σ.	Elasticity of substitution: energy vs. capital+labour	Production	0.00	• ./
$\sigma_{e}$	Elast of substitution (consumption): imports vs. domestic	Production	1/(1-3)	• •
σ;	Elast of substitution (consumption): imports vs. domestic	Production	1/(1-2)	
$\sigma_i$	Elast of substitution (export): imports vs. domestic	Production	1/(1.2) 1/(1-2)	<b>,</b>
$\sigma^h$	Flast of substitution (labour): private vs. public firms	Labour	0.5	
19	Private sector wage markup	Labour	5	• ./
θ <sub>w</sub> θ <sub>s</sub>	Inverse of price markup : exports	Production	0 9900	• ./
$C^{g}$	Public goods consumption	Production	0.14	• •
V <sub>h</sub>	Frisch elasticity	Household	4/3	• •
$m^{c}/c$	Share of imports on consumption goods	Production	0.35	• •
$m^i/i$	Share of imports on investment goods	Production	0.60	• •
$m^{f}/f$	Share of imports on export goods	Production	0.55	• •
sub <sup>p</sup>	Government subsidies to private sector	Fiscal	0.01	√
sub <sup>g</sup>	Government subsidies to public sector	Fiscal	0.05	• •
ca	Current Account	Fiscal	0.005	• •
	Importe visibilities production of consumption and	Droduction	0.4990	
$\alpha_c$	Imports weight in production of consumption good	Production	0.400U 0.6767	
$\alpha_i$	Imports weight in production of investment good	Production	0.0707	
$\alpha_f$	Inports weight in production of export good	Monotor	0.0304	
η <u></u>	A correcte Maco Bill	Labaur	0.9904	
wh	Aggregate wage bill	Labour	0.37	





Table H.2 :	Post-2009	Model	Steady-State II.
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Variable	Description	Sector	Value	Input
$g^c$	Unproductive government purchase to GDP	Fiscal	0.04	
$R^{f}$	Gross Returns on foreign bonds (p.a.)	Monetary	1.1085	
$lpha_H$	Private Sector weight in aggregate labour supply	Labour	0.7679	
$c^r$	Aggregate consumption of Ricardians	Household	0.54	
$c^n$	Aggregate consumption of Non-Ricardians	Household	0.54	
$p^e e$	Aggregate demand for energy	Production	0.09	
def	Primary deficit to GDP	Fiscal	0.001	
β	Discount factor (p.a.)	Household	0.9808	
$\eta^c$	Consumption goods common technology process	Production	0.4604	
$\eta^i$	Investment goods common technology process	Production	0.6181	
$\eta^{f}$	Export goods common technology process	Production	0.5853	
$\eta^{g}$	Government goods common technology process	Production	0.2638	
δ	Capital depreciation ratio (p.a.)	Household	0.0449	
$\eta^m$	Import goods common technology process	Production	1.0325	
$\eta^{c^g}$	Public goods common technology process	Production	1.0007	
exp	Government expenditures	Fiscal	0.3650	
$\Pi^c, \Pi^i, \Pi^g, \Pi^x$	Domestic Price Inflations	Prices	1.02	
$\Pi^w, \Pi^{w,p}, \Pi^{w,g}$	Domestic Wage Inflations	Labour	1.02	
$\overline{\Pi}^{f}, \Pi^{f}, \Pi^{m}$	Export/Import Price Inflation	Prices	1.02	
$\overline{\Pi}^{F}, \Pi^{M}$	Export/Import Price Inflation (nonstationary)	Prices	0.9715	
$prem^{f}$	External Debt Risk Premium (p.a.)	Monetary	0.0832	
prem <sup>sk</sup>	Country-specific Risk Premium (p.a.)	Monetary	0.0638	
$prem^d$	Government Debt Risk Premium (p.a.)	Monetary	0.0194	
$h^g$	Aggregate public sector labour supply	Labour	0.1240	
$h^p$	Aggregate private sector labour supply	Labour	0.4960	
$i^h$	Household (private) investment	Household	0.185	
$\iota^*$	Net factor income	External	0.0350	
m	Aggregate demand for import	Production	0.8363	
$\theta_m$	Inverse of price markup : imports	Production	0.9685	
$\theta_x$	Inverse of price markup : domestic producers	Production	0.7386	
tb	Trade balance	Fiscal	0.04	
$tr^n$	Government transfers for the Non-Ricardians to GDP	Fiscal	0.1025	
tr'	Government transfers for the Ricardians to GDP	Fiscal	0.0375	
$\tau^{\kappa}$	Consumption tax rate	Fiscal	0.2306	
$\phi^{\tau^{*}}\tau^{c}$	Consumption tax revenues to GDP	Fiscal	0.0825	
$\phi^{ au^\kappa}  au^k$	Capital tax revenues to GDP	Fiscal	0.1372	
$\phi^{ au^w} au^w$	Labour tax revenues to GDP	Fiscal	0.1443	
rev	Aggregate revenues to GDP	Fiscal	0.3640	
wh	Aggregate compensations for employees to GDP	Fiscal	0.3600	
$r^k$	Real return on capital (p.a.)	Production	0.0834	
div	Dividends	Household	0.2528	
Ψ	Aggregate profits to GDP	Production	0.2878	
$oldsymbol{\psi}^{_J}$	Profits of exporters to GDP	Production	0.0094	
$\psi^m$	Profits of importers to GDP	Production	0.0263	
$\psi^x$	Profits of domestic producers to GDP	Production	0.2520	
W	Real wage (both sectors)	Labour	0.5968	
w <sup>p</sup>	Keal wage : private sector	Labour	0.5645	
$W^{\delta}$	Keal wage : public sector	Labour	0.7258	
<i>K</i> "	Household capital to GDP	Households	4.0931	
К <sup>8</sup> У h	Government capital to GDP	Fiscal	0.7399	
ς"	Labour disutility scaling factor	riouseholds	0.4656	





## Appendix B Empirical Analysis

## **B.1** Priors & Posteriors





Posterior Density Lower Bound Upper Bound





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	Table H.3 : Priors and	Posterio	ors : Shoc	ks			
		Prie	or Distri	bution	Posterior Distribution		
	Parameter	Type	Mean	St. Dev.	Mean	St. Dev.	
Housek	ıolds						
$\sigma_{tr^r}$	Transfers variance (Ricardians)	IG	0.4	0.075	0.4092	0.0336	
$\sigma_{n^{i,h}}$	Investment shock variance	IG	0.65	0.1	0.6354	0.1162	
$\sigma_0$	Tobin's q shock variance	IG	0.5	0.075	0.4906	0.0680	
$\sigma^{\xi,\tilde{i},h}$	Investment efficiency variance	IG	1.25	0.2	1.0641	0.1321	
$\sigma^{\phi^L}$	Household preference shock	IC	0.5	0.1	0.8601	0.0905	
Monet	ary Policy	ю	0.0	0.1	0.0001	0.0705	
Enk	Country premium shock variance	IG	1	0.15	1.1675	0.0927	
$\sigma_{a}$	Public bonds risk premium variance	IG	1	0.15	0.4906	0.0460	
$\sigma_{prema}$	Interest rate wedge variance	IG	0.5	0.1	0.3834	0.0607	
Produc	tion	10	0.0	0.1	0.0001	0.0007	
σ	Private sector TFP shock variance	IG	07	0 075	0.5593	0.0413	
$\sigma_{u}$	Export vs foreign dem elasticity shock	IG	0.5	0.075	0.3513	0.0360	
σ.,	Public sector technology shock variance	IG	1	0.15	2 2789	0.2503	
Prices	& Wages	10	1	0.10	2.2707	0.2000	
σor	Cost-push shock (intermediate goods)	IG	0.25	0.05	0 2326	0.0276	
σοπ	Cost-push shock (imports)	IG	0.25	0.05	0.1950	0.0207	
σ <sub>ef</sub>	Cost-push shock (exports)	IG	0.25	0.05	0.1900	0.0207	
$\sigma_{\theta}$	Cost-push shock (private wage)	IG	0.25	0.15	0.7919	0.1811	
$\sigma_{v'',p}$	Shock to public wage indexation	IG	0.75	0.15	0.3018	0.0263	
Fiscal 1	Policy	ю	0.0	0.075	0.0010	0.0200	
σ <sub>min</sub>	Government investment shock variance	IG	0.9	0.15	0.9297	0.2030	
$\sigma_{\eta^{i,g}}$	Transfers shock variance	IG	0.5	0.1	0.3397	0.0407	
$\sigma_{rr}$	Public wage bill shock variance	IG	0.75	0.1	0.4624	0.0431	
$\sigma_{whs}$	Subsidies to private sector variance	IG	1	0.125	2 6652	0.2032	
$\sigma_{subp}$	Subsidies to public sector variance	IG	1	0.125	0.9992	0.0817	
$\sigma_{subs}$	Government unprod consumption shock	IG	1	0.125	1 4588	0.1258	
σ <sub>g</sub> e	Gov Gross capital formation shock	IG	15	0.120	1.5460	0.0940	
$\sigma_{l^{\circ}}$	Consumption tax shock variance	IG	0.5	0.075	0.7646	0.0609	
σι	Capital tax shock variance	IG	0.5	0.070	0.6780	0.1001	
$\sigma_{\tau^{\kappa}}$	Labour tax shock variance	IG	0.2	0.075	1.0693	0.0401	
σι	Primary deficit shock variance	IG	1	0.15	0.5675	0.0505	
<b>Extern</b>	al Environment	10	1	0.10	0.0070	0.0000	
$\sigma_{n^{e}}$	Oil price shock	Ν	3.5	0.5	3.4897	0.0529	
$\sigma_{\mu^*}$	Foreign demand shock variance	IG	1	0.15	0.8317	0.0764	
$\sigma_{i*}$	Factor income variance	IG	4	0.5	4.3225	0.3043	
$\sigma^{eu}_{u}$	EU output gap shock variance	IG	0.05	0.05	0.0550	0.0076	
$\sigma_{e}^{eu}$	ECB interest rate shock variance	IG	1	0.1	1.6829	0.1074	
$\sigma^{eu}_{-}$	EU inflation shock variance	IG	0.05	0.05	0.0306	0.0038	
Growtl	h Technologies	-0	2.00			0.0000	
σ <sub>m</sub> A	Domestic growth variance	IG	0.01	0.005	0.0238	0.0087	
$-\eta^{\alpha}$ $\sigma_{\alpha}$	Foreign growth variance	IG	0.05	0.05	0.0583	0.0069	
$\sigma_{\eta^{A,*}}$	Export-specific growth variance	IG	0.00	0.05	0.0653	0.0218	
$\sigma_{\eta^{X}}$	Trade openness growth variance	IC	0.1	0.075	0.7481	0.0616	
$\sigma_{\eta 0}$	Quality growth variance	IC	0.0	0.075	0.7077	0.0394	
$\mathbf{u}_{\eta}Q$	Quanty growin variance	IG	0.4	0.073	0.2712	0.0304	





## **B.2** Forecast Error Variance Decomposition



#### Figure H.3: Relative Shock Contributions I.



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Figure H.4 : Relative Shock Contributions II.







## **B.3** Filtered Shocks



#### Figure H.5: Filtration of estimated shocks I.

 $\varepsilon^{\eta^A}$ 

 $\varepsilon^{\eta^{\lambda}}$ 

 $\varepsilon^{\phi^L}$ 

Etr'

est h

 $\varepsilon^Q$ 

 $\varepsilon^{\eta_f}$ 

 $e^{\theta_x}$ 

SAA.









## **B.4** Shock Contribution



Simulated (using Kalman filter) contribution of shocks to model variables. Thick black line illustrates the percentage deviation of the variable from its steady state. Growth rates (measured as QoQ growth in percent) are annualised.



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Simulated (using Kalman filter) contribution of shocks to model variables. Thick black line illustrates the percentage deviation of the variable from its steady state. Growth rates (measured as QoQ growth in percent) are annualised.







#### Figure H.9: Contribution of Shocks III. (cont.)

#### Figure H.10: Contribution of Shocks IV.



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## Appendix C Model Dynamics and Fiscal Policy Simulations

Labour tax - realistic rules ----- Labour tax - constant budget Transfers - realistic rules = = = + . Transfers - constant budget Blue lines represent model responses when government adjusts labour tax rate, dark lines illustrate the response if government changes transfers, under realistic fiscal policy rules. Dashed lines correspond to reactions when a constant budget rule is used.







#### Figure H.12: Negative Foreign Demand Shock.

Blue lines represent model responses when government adjusts labour tax rate, dark lines illustrate the response if government changes transfers for Non-Ricardians, under realistic fiscal policy rules. Dashed lines correspond to reactions when instead of realist policy rules a simple constant budget rule is used. Time (on x-axis) is in quarters and responses are measured as absolute deviations (in percentage points) from the variable equilibrium value. Purple line depicts the negative EU output shock.







Blue lines represent model responses when government adjusts labour tax rate, dark lines illustrate the response if government changes transfers for Ricardians, under realistic fiscal policy rules. Dashed lines correspond to reactions when instead of realist policy rules a simple constant budget rule is used. Time (on x-axis) is in quarters and responses are measured as absolute deviations (in percentage points) from the variable equilibrium value. Purple line depicts the negative EU output shock.





## C.3 Fiscal Multipliers



Figure H.15: Fiscal Multipliers in a Recession Fiscal Multipliers in a Recession (Taylor Rules) Fiscal Multipliers in a Recession (Realistic Rules) 0.8 1.2 0.7 transfers
 public wage bill
 public investment 0.8 0.6 0.6 gov. consumption private subsidies public subsidies 0.5 0.4 0.4 0.2 0.3 0 2 6 10 12 14 16 18 20 5 10 15 20 4 Quarters Quarters Fiscal Multipliers in a Recession (Taylor Rules) Fiscal Multipliers in a Recession (Realistic Rules) 0 0 -0.5 -0.5 consumption tax capital tax -1 labour tax -1.5 -1.5 -2 -2.5 -2 10 15 20 10 15 20 5 5 Quarters Quarters

Plots on the left illustrate the evolution of the fiscal multipliers calculated under the assumption of current initial conditions if Taylor-like fiscal rules are employed, plots on the right represent fiscal multipliers obtained using realistic fiscal rules.







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