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Growth-Friendly Fiscal Strategies for the Czech Economy*

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Abstract

I build a structural fiscal DSGE model to address three important issues of Czech fiscal policy. First, I calculate fiscal multipliers for several revenue and expenditure categories of the government budget, the largest of which after the first year are government consumption (0.6), government investment (0.5), and social security contributions paid by employers (0.4). Second, I use fiscal multipliers to derive the appropriate composition of growth-friendly fiscal strategies, e.g., the composition of temporary fiscal consolidation is more revenue-based, raising mainly consumption tax (a share of 30% in the composition) and wage tax (17%), accompanied by cuts in other social benefits (35%) on the expenditure side. Third, I show that fiscal devaluation can boost real GDP growth by 0.4 percentage points in the first year, when a budget-neutral tax shift of the magnitude of 1% of GDP occurs from direct taxes to consumption tax and capital tax. These results corroborates that the government can easily support the economy by appropriately adjusting fiscal instruments.

Keywords: Bayesian estimation, DSGE, fiscal consolidation, fiscal devaluation, fiscal multipliers, fiscal policy, fiscal stimulus, fiscal strategy

JEL classification: C11, E32, E62, F41

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1 Introduction

The interaction between fiscal and monetary policy is of crucial importance for policy-makers in the government and central bank. The government often implements new fiscal measures or adjusts the parameters of fiscal instruments on both revenue and expenditure sides of the government budget. Adopted fiscal measures or adjustments generally have different impacts on the real economy, and consequently call for a different response from monetary policy. This fact is reflected in the literature by various estimates of fiscal multipliers, which are well-summarized in a meta-analysis by Gechert and Will (2012). The literature is, however, quite silent about the implications of calculated fiscal multipliers for policy recommendations for the government. To my knowledge, there are only several contributions in this field (Cournede, Goujard, and Pina 2013; Drudi, Funda, Haroutunian, Osterloh, Rodríguez-Vives, Scheubel, and Warmedinger 2015), where fiscal multipliers are used to rank fiscal instruments according to their usefulness to the economy, e.g. the government should give higher priority to those fiscal instruments which are more growth-friendly. By using such ranking methods, one can easily construct appropriate fiscal strategies for the government that are more effective at stimulating or dampening economic growth.

Utilising own set of fiscal multipliers, this paper represents presumably the first attempt to propose growth-friendly fiscal strategies for the Czech Republic. Additionally, I analyze the issue of fiscal devaluation, meaning a shift from direct to indirect taxes for the Czech Republic. Specifically, I address several important research questions. First, how much does fiscal discretion contribute to GDP growth? In other words, what is the size and sign of fiscal multipliers? Second, what is the suitable composition of growth-friendly fiscal strategy for the government based on calculated values of fiscal multipliers? More specifically, what fiscal instruments should the government target during fiscal consolidation or fiscal stimulus? Third, could the Czech economy be better off with fiscal devaluation? What is the real GDP gain in such a case?

Addressing these research questions, I build a structural DSGE model, which is closely adaptation from Ambriško, Babecký, Ryšánek, and Valenta (2015). This model is essentially an extended version of the Czech National Bank's (CNB) g3 model (Andrle, Hlédik, Kameník, and Vlček 2009) with a more comprehensive fiscal block. Fiscal extensions reside in the following features: i) ”rule-of-thumb” households in the manner of Galí, López-Salido, and Vallés (2007), ii) productive government consumption and capital (Barro 1981; Baxter and King 1993), iii) unemployment in as proposed by Galí (2011), iv) a rich set of fiscal instruments on the revenue and expenditure side of the government budget, v) estimated fiscal rules with feedback effects. The model is estimated by Bayesian techniques on Czech data over the period 2000-2015, covering more than 10 fiscal variables.

Regarding the results, the real GDP fiscal multipliers from the model suggest that the largest multipliers after the first year are associated with government consumption (0.6), government investment (0.5), and social security contributions paid by employers (0.4). These are followed by consumption tax, wage tax, and unemployment benefits with fiscal multipliers roughly equal to 0.3. Lower fiscal multipliers are found for other social benefits, lump-sum taxes (both 0.2), and capital tax (0.1). These values of fiscal multipliers are slightly higher than those calculated in a similar paper by Klyuev and Snudden (2011), in which the authors used the IMF's GIMF model calibrated for the Czech Republic.

I assign the calculated fiscal multipliers fiscal scores according to a simplified European Central Bank (ECB) methodology (Drudi et al. 2015)[1]. This provides a ranking of the fiscal instruments according to their usefulness to the real economy, e.g., which fiscal instruments are the least harmful to real GDP during fiscal consolidation and which are the most beneficial to boosting real GDP during fiscal stimulus. I then use the fiscal scores to derive an appropriate composition of growth-friendly fiscal strategies in the phases of fiscal consolidation and stimulus. Concerning one-year fiscal consolidation, the composition of appropriate growth-friendly strategy is more revenue-based, with hikes in consumption tax (a share of 30% in the composition) and wage tax (17%). On the expenditure side, cuts in other social benefits (35%) are desired. The composition of appropriate one-year fiscal stimulus is more expenditure-based, fostering mainly government consumption (a share of 45% in the composition). On the revenue side, the cuts in consumption tax

[1]The simplification is made in the scope for fiscal adjustment, which is unconstrained in my adaptation. The original methodology sets the scope for fiscal adjustment in the selected fiscal instrument with respect to the chosen benchmark (the EU average).

(16%) and social security contributions paid by employers (13%) are prescribed.

Given the lack of empirical literature on fiscal devaluations for the Czech Republic, I use the model to evaluate the impact of a hypothetical budget-neutral tax shift from direct to indirect taxes on the Czech economy. The model's simulations show that the government can easily support the economy when it appropriately adjusts the composition of taxes from direct to indirect. Specifically, real GDP growth can be boosted by 0.4 percentage points in the first year when a tax shift in magnitude of 1% of GDP occurs from direct taxes to consumption tax and capital tax. Further, the model evaluates fiscal devaluation from 2008, finding that positive real GDP gains from tax changes were reversed by accompanied expenditure cuts.

The paper is organized as follows. Section 2 reviews relevant literature, Section 3 outlines the structural DSGE model with an emphasis on fiscal features, and Section 4 provides estimates of fiscal multipliers, derives appropriate growth-friendly fiscal strategies, and quantifies the impacts of hypothetical and past fiscal devaluations on the Czech economy. The last section summarizes the main findings and suggests several ideas for possible future research.

2 Related Literature Review

Fiscal multipliers are covered extensively in the empirical literature, with estimates emanating from various models, such as structural VAR models, RBC models, DSGE models, structural macroeconometric models or single equation approaches. Fiscal multipliers are quite sensitive with respect to the underlying model, which is well documented in a meta regression analysis by Gechert and Will (2012). The highest fiscal multipliers are usually found with macroeconometric models, whereas DSGE models tend to report the lowest multipliers. Nevertheless, different types of models suggest that the average fiscal multiplier is less than one.

Concerning the Czech Republic, there is growing literature on fiscal multipliers. A fiscal multiplier of 0.6, which is assumed in the CNB's macroeconomic forecast, was estimated in Hřebíček, Král, and Říkovský (2005) using both regression analysis and structural simulation. Prušvic (2010) ascertained the government expenditure multiplier at a slightly lower value of 0.5. A comprehensive set of fiscal multipliers is provided by Klyuev and Snudden (2011), where the authors calibrated the IMF's GIMF model for the Czech Republic and found the highest multipliers for government consumption and investment, both reaching 0.4. Using the SVAR model, Valenta (2011) estimated the fiscal multiplier for government spending in the range of 0.3–0.6. Franta (2012) employed various identification schemes in structural VAR models and calculated fiscal multipliers for government spending and revenue shocks; however, these fiscal multipliers are in many cases unrealistically high, attaining values above 1. Fiscal multipliers from the estimated DSGE model are available in Ambriško et al. (2015), with the highest fiscal multipliers of 0.6 calculated for both government consumption and social contributions paid by employers. Recently, Babecký, Franta, and Ryšánek (2016) applied the DSGE model from Ambriško et al. (2015) to generate the priors for the structural VAR model and obtained the highest fiscal multiplier for government investment in the value of 1.

There are several methodologies that provide policy recommendations for the government using the values of fiscal multipliers. The methodology developed by the OECD (Cournede, Goujard, and Pina 2013) advocates choosing fiscal instruments during consolidations that jointly minimize adverse impacts on economic growth, equity, and the current account. Fiscal instruments are selected sequentially, from the most to the least desirable, within reasonably defined limits until consolidation needs are covered. Another methodology suggested by the ECB (Drudi et al. 2015)[2] is solely focused on the growth prospects of fiscal consolidation, and selects only those fiscal instruments into the consolidation strategy in which there is some scope for adjustment. The scope for adjustment is derived as a deviation from a benchmark position (the EU average). Both methods are applied for a group of countries and thus fiscal consolidation in a given country is set with respect to the average fiscal position of the group of countries. Nevertheless, these methods can be easily simplified so as to be applied only for one selected country, without resorting to the assumption of convergence to some chosen fiscal benchmark. Besides focusing on fiscal consolidations, the ECB methodology can be easily extended for the case of fiscal stimulus, which is demonstrated in this paper.

[2]The methodology was originally proposed by the ECB staff at the Working Group on Public Finance (wgpubf@ecb.int) at its 2014 March Meeting, and is still under development.

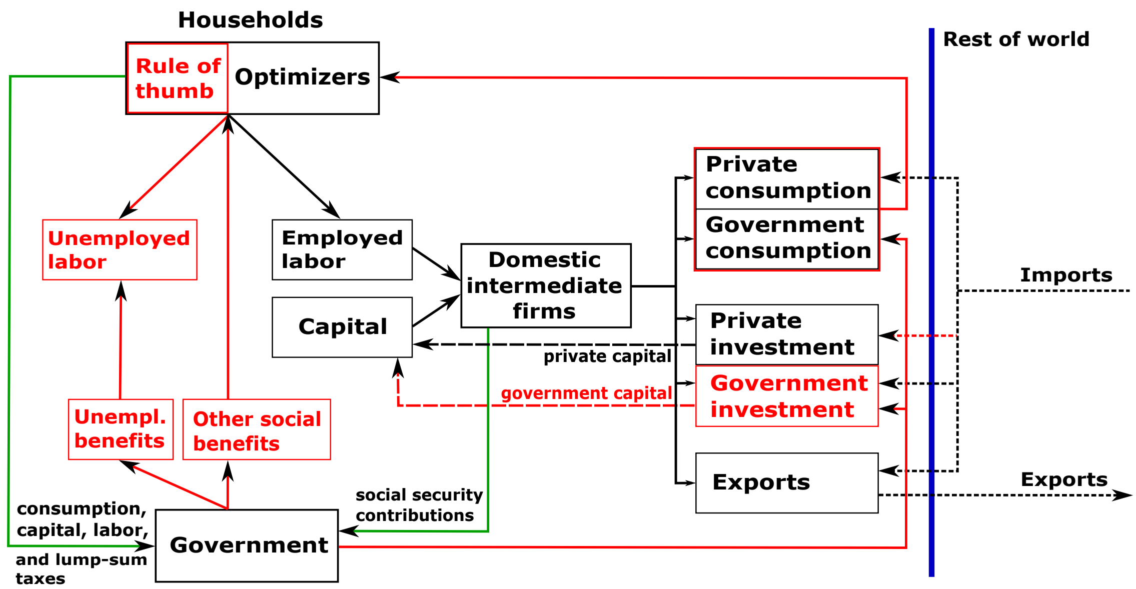
The literature on fiscal devaluations is rich, but currently lacks some empirical evidence for the Czech Republic. The overview of quantitative studies on fiscal devaluations with the effects on economic growth, employment, and net export in both the short- and long-term are found in Koske (2013). In this overview, short-term effects of fiscal devaluations on real GDP amount to 0.7 percentage points. More recently, Gomes, Jacquinot, and Pisani (2016) assessed fiscal devaluations in Spain using a dynamic general equilibrium EAGLE model and estimated an increase in real GDP of 0.9% over 3 years. Further, Vukšić and Holzner (2016) employed a partial equilibrium model to inspect the likely effects of fiscal devaluations for seven countries in Southeastern Europe and found a positive impact on output growth between 0.15-0.25 percentage points. An interesting theoretical contribution by Farhi, Gopinath, and Itskhoki (2014) shows that fiscal devaluations can robustly replicate real allocations achieved under a nominal exchange rate devaluation, even with a fixed exchange rate regime.

3 Structural DSGE Model

The structural model in this paper is my simplified adaptation from Ambriško et al. (2015)[3], which further draws from the models developed by Andrle et al. (2009), Coenen et al. (2012), Galí (2011), and Galí et al. (2007). The small open economy is populated by two types of representative households, the first called optimizers or Ricardian households that can save, and the second called "rule-of-thumb" consumers or non-Ricardian households that cannot save and that consume all of their disposable income. The households consume a final consumption good, which is made from private consumption and government consumption goods. The members of households monopolistically supply a differentiated unit of labor to an employment agency, and the wage setting follows Calvo contracts. Apart from private capital, there is government capital, which freely enters intermediate domestic goods production. Government expenditures are divided into government consumption, government investment, unemployment benefits, and other social benefits. Gov-

[3]The main difference resides in the fiscal rules used, which are simplified and more general in this paper. Specifically, in this paper the cross-correlations between taxes are not imposed in the fiscal rules.

Figure 1: The Scheme of the Model



ernment revenues come from consumption, labor, capital and lump-sum taxes, and social security contributions paid by employers. The government balances its budget by issuing bonds or by adjusting taxes. In the fiscal rules, fiscal instruments (taxes or expenditures) react to the deviations of government debt and output from their respective targets. The central bank operates under an inflation targeting regime and follows a standard Taylor interest rate rule. The features of the model are shown in Figure 1, where black parts overlap with the g3 model, red parts represent the fiscal sector, and green parts depict tax revenues.

The exposition of the model in the main text focuses mainly on fiscal features; for the rest of the model see the Appendix A.

3.1 Households

The economy is populated by a continuum of households indexed by $h \in [0,1]$. The households on the interval $[0,\gamma]$ are rule-of-thumb households, and those on $(\gamma,1]$ are Ricardian households (also labelled as optimizers). Each household has a continuum of members indexed by a pair $(i,j) \in [0,1] \times [0,1]$, where index i stands for the labor type and index j determines the disutility of work, specified as j^{ϕ_n} when the member is employed and zero otherwise, where $\phi_n \geq 0$ is the elasticity of the marginal disutility of work. Both types of households maximize their lifetime utility function given by:

$$
\begin{aligned}
E_0 \sum_{t=0}^{\infty} \beta^t U_{h,t}^k &= E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_{h,t}^k - \exp(\varepsilon_t^{hk}) \chi^k C_{t-1}) - \theta \int_0^1 \int_0^{L_t^k(i)} j^{\phi_n} dj di \right] = \\
&= E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_{h,t}^k - \exp(\varepsilon_t^{hk}) \chi^k C_{t-1}) - \frac{\theta}{1+\phi_n} \int_0^1 L_t^k(i)^{1+\phi_n} di \right]
\end{aligned} \tag{1}
$$

where $\beta \in (0,1)$ is the discount factor, superscript $k \in \{r, o\}$ distinguishes rule-of-thumb and optimizer households, $C_{h,t}^k$ is the household-specific consumption aggregate, C_{t-1} is the lagged economy-wide level of consumption, $L_t^k(i) \in [0,1]$ is the fraction of members of type i who are employed in households of type k, $\theta > 0$ is a parameter associated with the disutility of labor supply, $\chi^k \in [0,1)$ is the habit parameter, and $\varepsilon_t^{hk} \sim N(0, \sigma^{hk})$ is an exogenous shock to the internal habit formation. Household consumption is made up of private and government consumption goods as follows:

$$
C_t^k = \left[(\alpha_C)^{\frac{1}{\upsilon_C}} \left(C_t^{pk} \right)^{\frac{\upsilon_C - 1}{\upsilon_C}} + (1-\alpha_C)^{\frac{1}{\upsilon_C}} \left(G_t^k \right)^{\frac{\upsilon_C - 1}{\upsilon_C}} \right]^{\frac{\upsilon_C}{\upsilon_C - 1}}, \tag{2}
$$

where $\alpha_C \in (0,1]$ is the share of the private good in the consumption aggregate, and $\upsilon_C > 0$ is the elasticity of substitution between the private and government consumption good. The government good is equally available to all households, hence $G_t^o = G_t^r = G_t$, and is provided free of charge.

The households of **optimizers** respect the following budget constraint:

$$
\begin{aligned}
& (1+\tau_t^C) P_t^C C_t^{po} + P_t^I I_t^{po} + B_t^o \\
\leq\ & (1 - \tau_t^W + \tau_t^{UB}) \int_0^1 W_t(i) L_t^o(i) di + \\
& + \left[(1-\tau_t^K) P_t^K + \tau_t^K \delta^p P_t^I \right] K_{t-1}^{po} + \\
& + R_{t-1} B_{t-1}^o + P_t^C O B_t^o - P_t^C T_t^o + D_t^o,
\end{aligned} \tag{3}
$$

where C_t^o is the optimizers' consumption; I_t^{po} denotes optimizers' investment in private capital K_t^{po}; P_t^C, P_t^I are the unit prices of consumption and investment goods; P_t^K is the rental rate of capital; R_t is the domestic nominal gross interest rate; $W_t(i), L_t(i)$ are the nominal wage and optimizers' hours worked for labor of type i; τ_t^C, τ_t^W, τ_t^K are effective tax rates on consumption, wage and capital; τ_t^{UB} is unemployment benefit rate; OB_t^o are optimizers' other social benefits; δ^p is the depreciation rate of private capital; B_t^o are nominal domestic bonds issued by the government and held by optimizers; T_t^o, D_t^o are optimizers' lump-sum taxes and dividends from monopolistic firms.

Optimizers own and accumulate a private stock of capital. The capital law of motion involves the type of intertemporal adjustment costs found in Kim (2003):

$$K_t^{po} = \left(K_{t-1}^{po}\right)^{1-\delta^p} \left(\frac{I_t^{po}}{\delta^p}\right)^{\delta^p} - \frac{\eta}{2}\left(\frac{I_t^{po}}{I_{t-1}^{po}} - 1\right)^2 K_{t-1}^{po}, \tag{4}$$

where $\eta \geq 0$ is the investment adjustment cost parameter. Furthermore, the depreciation of capital is exempted from capital tax, as stated in the budget constraint for optimizers.

Rule-of-thumb households spend their entire budget on consumption:

$$\begin{aligned}(1+\tau_t^C)P_t^C C_t^{pr} \quad \leq \quad & (1-\tau_t^W+\tau_t^{UB})\int_0^1 W_t(i)L_t^r(i)di + \\ & +P_t^C OB_t^r - P_t^C T_t^r,\end{aligned} \tag{5}$$

where $C_t^r, L_t^r(i), OB_t^r, T_t^r$ are the rule-of-thumbs' consumption, hours worked for labor of type i, other social benefits and lump-sum taxes.

3.2 Fiscal Block

Government expenditures comprise government consumption, government investment, unemployment benefits and other social benefits provided to households, and interest payments paid on issued debt. The government can issue bonds to finance its expenditures. Government revenues are made up of consumption, labor, capital and lump-sum taxes, and social security contributions paid by employers. The total government budget balance can be computed by subtracting government expenditures from government revenues:

$$
\begin{aligned}
BB_t &= \tau_t^C P_t^C C_t^p + \left(\tau_t^W + \tau_t^S\right) W_t L_t + \tau_t^K \left(P_t^K - \delta^p P_t^I\right) K_{t-1}^p + \\
&\quad + P_t^C T_t - P_t^G G_t - P_t^I I_t^g - \tau_t^{UB} W_t L_t + \\
&\quad - P_t^C OB_t - (R_{t-1} - 1) B_{t-1}, \qquad (6)
\end{aligned}
$$

The primary government budget balance equals the total government budget balance plus interest payments:

$$PB_t = BB_t + (R_{t-1} - 1) B_{t-1} \qquad (7)$$

The government's budget constraint follows:

$$B_{t-1} - BB_t = R_{t-1} B_{t-1} - PB_t = B_t \qquad (8)$$

Note that in equilibrium the level of government debt is constant and the government's budget is balanced. Government capital evolves according to a similar law of motion as private capital:

$$K_t^g = \left(K_{t-1}^g\right)^{1-\delta^g} \left(\frac{I_t^g}{\delta^g}\right)^{\delta^g} - \frac{\eta}{2} \left(\frac{I_t^g}{I_{t-1}^g} - 1\right)^2 K_{t-1}^g, \qquad (9)$$

where $\delta^g > 0$ is depreciation rate for government capital. Total capital K_t is the CES aggregate of private (K_t^p) and exogenously given government capital (K_t^g):

$$K_t = \left[(\alpha_K)^{\frac{1}{v_K}} \left(K_t^p\right)^{\frac{v_K - 1}{v_K}} + (1 - \alpha_K)^{\frac{1}{v_K}} \left(K_t^g\right)^{\frac{v_K - 1}{v_K}}\right]^{\frac{v_K}{v_K - 1}}, \qquad (10)$$

where $\alpha_K \in [0, 1]$ is the share of private capital in the capital aggregate and $v_K > 0$ is the elasticity of substitution between private and government capital.

The government sets all fiscal instruments on the expenditure and revenue side by fiscal rules. All fiscal instruments react to deviations of output and real debt from their steady states. Additionally, unemployment benefits respond also to deviations of unemployment rate from its natural rate. Allowing for feedback effects, fiscal instruments can act procyclically or countercyclically on the economy. The set of fiscal rules is as follows:

$$\begin{aligned}
\frac{G_t}{\bar{G}} &= \left(\frac{G_{t-1}}{\bar{G}}\right)^{\rho_g} \left(\frac{Y_t}{\bar{Y}}\right)^{-\phi_{yg}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{bg}} \exp(\varepsilon_t^g) \\
\frac{I_t^g}{\bar{I}^g} &= \left(\frac{I_{t-1}^g}{\bar{I}^g}\right)^{\rho_{ig}} \left(\frac{Y_t}{\bar{Y}}\right)^{-\phi_{yig}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{big}} \exp(\varepsilon_t^{ig}) \\
\frac{\tau_t^{UB}}{\tau^{UB}} &= \left(\frac{\tau_{t-1}^{UB}}{\tau^{UB}}\right)^{\rho_{ub}} \left(\frac{Y_t}{\bar{Y}}\right)^{-\phi_{yub}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{bub}} \left(\frac{u_t}{u}\right)^{\phi_u} \exp(\varepsilon_t^{ub}) \\
\frac{OB_t}{\bar{OB}} &= \left(\frac{OB_{t-1}}{\bar{OB}}\right)^{\rho_{ob}} \left(\frac{Y_t}{\bar{Y}}\right)^{-\phi_{yob}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{bob}} \exp(\varepsilon_t^{ob})
\end{aligned} \tag{11}$$

$$\begin{aligned}
\frac{\tau_t^C}{\bar{\tau}^C} &= \left(\frac{\tau_{t-1}^C}{\bar{\tau}^C}\right)^{\rho_{tc}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{ytc}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{btc}} \exp(\varepsilon_t^{tc}) \\
\frac{\tau_t^K}{\bar{\tau}^K} &= \left(\frac{\tau_{t-1}^K}{\bar{\tau}^K}\right)^{\rho_{tk}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{ytk}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{btk}} \exp(\varepsilon_t^{tk}) \\
\frac{\tau_t^W}{\bar{\tau}^W} &= \left(\frac{\tau_{t-1}^W}{\bar{\tau}^W}\right)^{\rho_{tw}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{ytw}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{btw}} \exp(\varepsilon_t^{tw}) \\
\frac{\tau_t^S}{\bar{\tau}^S} &= \left(\frac{\tau_{t-1}^S}{\bar{\tau}^S}\right)^{\rho_{tw}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{yts}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{bts}} \exp(\varepsilon_t^{ts}) \\
\frac{T_t}{\bar{T}} &= \left(\frac{T_{t-1}}{\bar{T}}\right)^{\rho_t} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{yt}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{bt}} \exp(\varepsilon_t^t)
\end{aligned} \tag{12}$$

where for $x \in \{g, ig, ub, ob, tc, tk, tw, ts, t\}$, the coefficients $\phi_{yx}, \phi_{bx}, \phi_u$ are feedbacks to output, debt, and unemployment, respectively. $\rho_x \in [0, 1)$ represent autoregression coefficients, and ε_t^x are normal innovations. If ϕ_{yx} is positive (negative), then a given fiscal instrument has a countercyclical (procyclical) component.

Having two types of households in the model, the following redistribution of lump-sum taxes is assumed:

$$T_t^o - \bar{T}^o = T_t^r - \bar{T}^r \tag{13}$$

3.3 Calibration

The parameters of the model were either calibrated or estimated on Czech data. In this section calibrated parameters of the model are described. For comparison purposes, the calibration mainly follows Andrle et al. (2009). The complete list of calibrated parameters and steady state ratios can be found in Table 1 in the

Appendix.

Discount factor β is set so that the annualized equilibrium real interest rate equals 3%. The disutility of labor supply parameter θ was set to 5 to pin down the steady state labor supply at a value of roughly 1/3. The habit parameter is the same for both types of households and equals 0.75. A high value of habit parameter is found, for example, in the estimated DSGE model for the Czech Republic in Brázdik (2013). The capital share of output α equals 1/3, which reflects an observed share of fixed investment in GDP. In the absence of empirical estimates, the share of the private good in the consumption good α_C and the share of private capital in the capital composite α_K is assumed to equal 0.8, which is close to the values chosen by Coenen, Straub, and Trabandt (2011). The depreciation of capital, both private and government, is set to an annualized value of 6%, which is in line with the estimates for the Czech Republic available in Hájková (2008) or Lízal (1999). The investment adjustment cost parameter η equals 0.2, and is calibrated to account for high volatility of investment with respect to output. The gross inflation target is unitary since the model works with detrended variables.

On the revenue side, the model works with effective (or implicit) tax rates, and their steady states are set as follows: consumption tax at 25%, wage tax at 29%, capital tax at 15%, and social security contributions paid by employers at 30%. More detailed information about time series for effective tax rates in the Czech Republic is provided in the next chapter 3.4. Other fiscal parameters were estimated, which concerns mainly output and debt feedback parameters in the fiscal rules. Nonetheless, posterior mean of debt feedback coefficient for consumption tax ϕ_{btc} turned out quite high (0.39), and for more reasonable impulse responses to consumption tax shock this debt feedback parameter was calibrated to lower value of 0.25.

The steady state value for the unemployment rate is set to 6.5%, which is the long-run average for the Czech Republic. The steady state ratio of government consumption to intermediate output was set to 25%, the share of government investment in output equals 3%, unemployment benefits represent 0.3% of output, other social benefits make up 14% of output, and the debt (bonds) is calibrated to 60% of output. These ratios can be expressed in nominal terms and with respect to the model's implied nominal GDP value, and the resulting ratios are in line with Czech data. For example, the steady state nominal debt to GDP ratio is roughly 45%, close to the current level of government debt.

The share of imported goods in private consumption was set to 15%, the share of imported inputs, which feeds into the total investment composite, equals 70%, and the share of imported goods in the export good was calibrated to 55%. These shares were calibrated to match observed shares in Czech data. There is a significant degree of stickiness in each production sector, with the Calvo signaling parameters calibrated between 0.5 and 0.8 to account for different persistences in observed price deflators. The elasticities between goods' varieties are set to 6, implying 20% mark-ups in production sectors. This is plausible mark-up for European economies; for instance, Christopoulou and Vermeulen (2012) estimated the average markup for manufacturing sector at 20% in selected European countries over the period 1993–2004. The elasticity between labor varieties is pinned down from equation (48) – substituting the steady state value of the natural rate of unemployment and the estimated value of the inverse of the Frisch elasticity gives a wage markup of approximately 18%, which can be translated into an elasticity of labor varieties of 6.4. The elasticities η_C, η_I, η_X between domestic and imported goods in consumption, investment and export composite goods are all set to 0.5, since these goods are deemed to be complements rather than substitutes. The price elasticity of exports θ_X equals 1.2, because export goods compete with other foreign goods. This choice is empirically supported by Tomšík (2000), where he found higher price elasticity for exports than for imports in the Czech Republic. The elasticity of the risk premium with respect to foreign bonds is set at a relatively low value of 0.005, which guarantees slow reversion of the holdings of foreign bonds to its steady-state.

Exogenous processes involve different degrees of persistence captured by the ρ coefficients. The exact values are provided in the Appendix. The persistence of productivity is set at 0.9, which is in line with the real business cycle literature. The persistences of fiscal variables roughly follow the estimates from observed data, except for non-observed lump-sum taxes, where the persistence of 0.75 is chosen arbitrarily. The persistences of foreign exogenous variables are calibrated to account for a different degree of their historical variability. The UIP sluggishness is set so as to generate a more realistic response of nominal exchange rate to the UIP shocks. The persistence parameter in the risk premium is set to 0, and hence the risk premium is more sensitive to changes in the holdings of foreign currency bonds.

3.4 Data

The model is estimated on a set of 25 variables, covering the period 2000–2015 at quarterly frequency. The data used are on an accrual basis and consist of real GDP components (private consumption and investment, government consumption and investment, exports, imports), price deflators, nominal wages, financial variables (3-month PRIBOR rate, nominal exchange rate, 3-month EURIBOR rate, foreign demand and producers price index for the Euro Area), and fiscal variables. Fiscal variables include effective tax rates (on consumption, capital, wage, and social security paid by employers), social benefits, unemployment benefits, primary budget balance, and government debt.

The data were collected from various sources: the Czech Statistical Office (CZSO), the Ministry of Finance (MoF), CNB, and Eurostat. Some source data published by the CZSO are already seasonally adjusted; the remaining data were seasonally adjusted by the TRAMO/SEATS method. The series for exchange rate, domestic and foreign interest rates were not seasonally adjusted. An overview of the data and their respective sources is available in Table 2 in the Appendix.

Effective tax rates were constructed from the CZSO data, using a slightly adjusted methodology suggested by Mendoza, Razin, and Tesar (1994)[4]. The effective tax rate on consumption is constructed as follows:

$$\tau_t^C = \frac{IT_t - IT_t^K}{C_t^{np} + G_t^n - CoE_t - (IT_t - IT_t^K)}, \tag{14}$$

where IT_t are indirect taxes (category D.2 in government national accounts), IT_t^K are indirect taxes of a capital nature (real property transfer tax, real property tax, and tax on emission allowances), C_t^{np} is nominal private consumption, G_t^n is nominal government consumption, and CoE_t are compensation of government employees.

[4] Additionally, I work with the effective rate on social contributions paid by employers, whereas in Mendoza, Razin, and Tesar (1994) all social contributions are included in the effective rate on labor income.

Indirect taxes of a capital nature are available only in annual terms. Thus, for the purpose of the calculation it is assumed that their quarterly profile is even. The effective rate on social contributions paid by employers equals:

$$\tau_t^S = \frac{SCE_t}{W_t}, \tag{15}$$

where SCE_t are social contributions paid by employers (category D.611), and W_t are wages and salaries (gross wages without social contributions paid by employers). The series for the effective wage tax rate is calculated as:

$$\tau_t^W = \frac{DT_t - DT_t^K + SCH_t}{W_t}, \tag{16}$$

where DT_t are direct taxes (category D.5), DT_t^K are direct taxes of a capital nature (corporate income tax, tax on interest and dividends, and real property tax[5]), and SCH_t are social contributions paid by households (category D.613). As direct taxes of a capital nature are only available yearly, they were interpolated into the quarters using the quarterly profile of total direct taxes. Finally, the effective tax rate on capital is computed as follows:

$$\tau_t^K = \frac{CT_t + IT_t^K + DT_t^K}{NOS_t}, \tag{17}$$

where CT_t are capital taxes (category D.91), and NOS_t is net operating surplus. Net operating surplus is not available quarterly; however, there is a quarterly series for gross operating surplus, which was used as a proxy for constructing a quarterly series for net operating surplus. All of the above effective tax rates are shown in Figure 2 in the Appendix.

Unemployment benefits were gathered from the MoF cash data, and adjusted into accrual terms by shifting paid benefits one month back in time (e.g. unemployment benefits paid in January correspond to the previous month, when a person was unemployed – in this example December).

Government investment is only reported by CZSO in nominal terms; therefore, the deflator for total investment is used as a proxy to construct real government

[5]Real property tax is recorded in both direct and indirect taxes, with a larger amount appearing under indirect taxes.

investment. Private investment is subsequently calculated as the difference between real total investment and real government investment.

3.5 Bayesian Estimation

Except for effective tax rates and domestic and foreign interest rates, input data are detrended by an HP-filter with the standard smoothing parameter $\lambda = 1600$ used for quarterly data. Observed data are linked to the model variables through the measurement equations. In these equations, the model variables are the sum of observed data and the measurement error. Observed data and model variables are expressed in the first differences, except for effective tax rates and domestic and foreign interest rates, which are linked on the levels. The standard deviation of the specific measurement error is calibrated at roughly one fourth of the standard deviation of the corresponding observed data.

The prior distributions for the estimated parameters of the model are chosen as follows. For parameters constrained on the interval $\langle 0, 1\rangle$, the beta distribution is used. This concerns the share of rule-of-thumb households in the economy γ and the interest rate smoothing parameter ρ_i. The beta distribution for the share of rule-of-thumb households has a mean of 0.4[6]. Due to the non-negativity constraint, the standard errors of shocks have priors from inverse gamma distributions. For the remaining parameters, the priors take the form of normal distribution. To be more specific, the elasticities of substitution between the private and government components in the CES aggregates for consumption and capital, υ_C and υ_K, have prior means set close to 1[7]. The prior mean for the elasticity of the marginal disutility of work ϕ_n equals 2.5. The mean of prior for the inflation feedback coefficient is calibrated at 2. The prior means for the debt feedback coefficients in the fiscal rules all equal 0.25, which is warranted to have a stable solution of the model. The prior means for output feedback coefficients in the fiscal rules are centered at 0, so as not to *apriori* rule out that a selected fiscal instrument can be pro- or counter-cyclical.

[6] The selected mean of the distribution is justified by a Gallup poll, where 40% of approximately 1,000 Czechs questioned said that they did not expect to make ends meet (Ipsos Tambor 2012). A roughly similar share of 37% was used by Štork and Závacká (2010) in the calibration of their model.

[7] If the elasticity is exactly 1, then the specification for consumption and capital aggregates collapses into a Cobb-Douglas form.

The prior mean for the unemployment feedback coefficient is set at 1 so as to reflect that unemployment benefits should move in line with the unemployment rate.

For the Bayesian estimation of the selected parameters, a DYNARE toolbox for MATLAB was employed.[8] Given the chosen priors and observed data, the posterior kernel is simulated with the Metropolis-Hastings algorithm. In this algorithm 300,000 replications are set in each of five parallel chains. The scale parameter of the jumping distribution's covariance matrix was tuned to roughly obtain an average acceptance ratio of 26% in the Metropolis-Hastings algorithm. The figures 3–6 in the Appendix show priors and posterior distributions and the results of the multivariate convergence diagnostic test.

The results of estimation are also summarized in Table 3 in the Appendix. The posterior mean of the share of rule-of-thumb households γ equals 32%, which is below its prior. The posterior mean of the inverse of Frisch elasticity ϕ_n is slightly above the prior mean, suggesting lower elasticity of hours worked to the wage. There is only a minor shift in the posterior means for the elasticities in CES aggregates for consumption υ_C and capital υ_K from their unitary prior means, indicating that the observed data are not very informative with respect to these parameters. Concerning monetary policy, the posterior mean for the inflation feedback coefficient in the policy rule ϕ_π is found at 1.9, which is slightly lower than its prior mean. The posterior mean for the interest rate smoothing parameter ρ_i turned out higher than its prior, which reflects the relatively low volatility of the monetary policy rate in the Czech Republic.

Regarding fiscal parameters, the posterior means for the output feedback coefficients are found to be mainly positive, suggesting that the respective fiscal instruments are more or less counter-cyclical. Such a result is intuitive for unemployment benefits, which tend to be counter-cyclical on the economy. The only exception with a negative posterior mean for the output feedback coefficient is in the case of consumption tax. For consumption tax there are several episodes in the Czech economy (e.g. VAT hikes during consolidations in 2012–2013 or the lower VAT rate on selected goods introduced in 2015), which support this procyclical behavior. The posterior means of all debt feedback coefficients are found to be positive, which

[8] For details about the toolbox see www.dynare.org.

helps to stabilize government debt outside of equilibrium and leads to a stable solution of the model. The posterior mean of the unemployment feedback coefficient ϕ_u is slightly positive; nevertheless, it is well below its prior.

3.6 Steady State

Given the calibrated and estimated[9] parameters of the model, the steady state of the model is computed. Since the model involves several price levels in production sectors, one price level is taken as a numeraire, and the remaining prices are expressed with respect to this numeraire, which ensures stationarity of the model. Using substitutions within the system of steady state versions of the optimality conditions, it is possible to numerically compute steady state values for all the model variables. Having computed the steady state, the system of optimality conditions is log-linearized around the steady state and solved using the IRIS toolbox.[10]

Since the model works with detrended variables, there is no inflation in the steady state. Furthermore, the steady state consumption of the two types of households is allowed to differ, with the consumption of optimizers being higher than the consumption of rule-of-thumb households, reflecting the idea that optimizers are wealthier than rule-of-thumb households. Specifically, $\frac{C^o}{C^r} = 1.25$, the value also used by Coenen, Straub, and Trabandt (2011). The desired level of the steady state consumption ratio is delivered by adjusting lump-sum taxes for rule-of-thumb households in the steady state. In this model, the actual steady state lump-sum taxes for rule-of-thumb households are negative, which means that rule-of-thumb households are subsidized by lump-sum transfers in the equilibrium.

4 The Results

In this section, the values of fiscal multipliers are presented, which are implied by the structural DSGE model. Subsequently, fiscal multipliers are used to derive fiscal scores according to the simplified ECB methodology (Drudi et al. 2015), which provide policy implications for the implementation of growth-friendly fiscal

[9]Estimated parameters are evaluated at their posterior means.

[10]IRIS is a toolbox for macroeconomic modeling and forecasting in MATLAB developed by Beneš (2012). Further information on the IRIS toolbox is available at www.iris-toolbox.com.

strategies. Finally, the model is used to evaluate the likely impacts of past and hypothetical fiscal devaluations, meaning a shift from direct to indirect taxation.

4.1 Fiscal Multipliers

In this paper, impact fiscal multipliers are defined as follows:

$$fm_{i,t} = \frac{\frac{\Delta RGDP_t}{\overline{RGDP}}}{\frac{\Delta\left(F_t P_t^F\right)}{\overline{GDP}}} \tag{18}$$

where F_t denotes the selected fiscal instrument and P_t^F its price. The nominator in the definition is the change in real GDP with respect to the level of real GDP in the steady state, and the denominator is the change in nominal fiscal revenue or expenditure expressed in percent of nominal GDP in the steady state. Exact expressions for fiscal revenues or expenditures can be drawn from the equation for the government budget balance (6); for instance, capital tax revenues equal $\tau_t^K \left(P_t^K - \delta^p P_t^I\right) K_{t-1}^p$.

The model's implied fiscal multipliers are listed in Table 4 in the Appendix. The fiscal multipliers are calculated according to Uhlig (2010), so these are net-present-value multipliers accumulated over time, discounted by the steady state real interest rate:

$$fm_{i,T} = \frac{\sum_{t=1}^{T} \frac{\Delta RGDP_t}{\overline{RGDP}\left(\overline{R}\right)^t}}{\sum_{t=1}^{T} \frac{\Delta\left(F_t P_t^F\right)}{\overline{GDP}\left(\overline{R}\right)^t}} \tag{19}$$

Notice that one can interpret this kind of fiscal multiplier as the average discounted change in real GDP over the average discounted change in fiscal revenue/expenditure. Fiscal multipliers are listed with effects on real GDP for individual revenue and expenditure items of the government budget. The fiscal multipliers are calculated for the case of a temporary, one-year fiscal stimulus and for the case of a longer-lasting 10-year fiscal stimulus. The unexpected shocks to the fiscal instruments are set so that the *ex-ante* worsening of the government budget balance in the first year equals 1% of nominal GDP, and the value of the corresponding fiscal instrument is kept constant during the affected period. Moreover, the estimated fiscal rule is initially turned off for two years (keeping unaffected fiscal instruments at their steady states), so as to isolate the effects of affected fiscal instruments. Otherwise, keeping the fiscal rule turned on from the beginning would make the results somewhat blurred by feedback effects as defined in the fiscal rule. The estimated fiscal rule is treated as a good approximation of the fiscal policy settings in the long run, hence the fiscal rule is turned off at the beginning of the simulations. This also means that the fiscal stimuli in the first two years are fully debt financed by issuing new government bonds. After two years the fiscal rule is turned on, and the government budget is balanced by adjusting fiscal instruments according to equations (11)–(12).

Regarding the effect of a temporary fiscal stimulus on real GDP, the largest effects after the first year occur with government consumption and government investment, with the fiscal multipliers reaching 0.6 and 0.5, respectively. Next, social contributions paid by employers has a fiscal multiplier of 0.4, followed by consumption tax, wage tax and unemployment benefits with a corresponding fiscal multiplier of 0.3. The fiscal multipliers for other social benefits and lump-sum taxes attain values of 0.2. The fiscal multiplier for capital tax 0.1 is the lowest. All values of the fiscal multipliers with effects on real GDP are well below 1.

The values of fiscal multipliers for government consumption and investment are not far from the CNB estimates of around 0.6 reported in Hřebíček et al. (2005), which are obtained from empirical estimates using regression analysis and structural simulation. On the other hand, these fiscal multipliers are slightly higher than the ones estimated by Klyuev and Snudden (2011) for the Czech Republic using the GIMF model. For instance, the one-year temporary fiscal multipliers for government consumption and investment are larger (0.6 and 0.5) compared to their estimates (0.4 for both government consumption and investment). On the revenue side, one-year fiscal multipliers for consumption tax and wage tax (0.3) are roughly 2–3 times higher than the estimates based on the GIMF model. According to both models, in this paper and the GIMF model, the capital tax has the smallest fiscal multiplier (0.05 vs. 0.02). In fact, these estimates of fiscal multiplier for capital tax are roughly in line with the range found by Coenen et al. (2012) for the euro area (0.03–0.06).

Lastly, I relate the values of fiscal multipliers in this paper to Ambriško et al. (2015), reminding that both papers share a similar model. Some fiscal multipliers in this paper are higher (namely in case of consumption and wage tax, lump-sum tax, unemployment benefits and other social benefits), which is given by higher estimated share of "rule-of-thumb" households in this paper. On the other hand, fiscal multiplier for the social contributions paid by employers is lower in this paper (in the first year 0.4 vs. 0.6), which is mainly driven by lower calibrated value for the persistence of social contributions in my paper. In both papers, fiscal multipliers for government consumption and government investment attain roughly same values in the short run.

Comparing fiscal multipliers with the results reported in a meta analysis by Gechert and Will (2012) based on the examination of 89 studies suggests that the rather low values of the fiscal multipliers for the Czech economy could be attributed to its high import intensity of GDP. Furthermore, in what follows these DSGE-based fiscal multipliers should be viewed as lower bound estimates compared to those produced by macroeconometric models, single equation approaches or VARs.

The fiscal multipliers for a 10-year fiscal stimulus have similar values in the short run as in the case of a temporary, one-year fiscal stimulus. In the long run, the fiscal multipliers for the 10-year fiscal stimulus are somewhat lower, and for other social benefits, capital tax and lump-sum taxes the long run effect on real GDP is slightly negative. Lower fiscal multiplier values for a permanent stimulus are confirmed by several other structural models – see Coenen et al. (2012) for an overview of the effects of fiscal stimuli in DSGE models. The underlying reason is that longer lasting stimulus translates into higher government debt, which has to be financed by higher taxes. A large increase in taxes leads to a negative wealth effect, which crowds out private demand.

4.2 The Composition of Fiscal Strategy

Inspecting the values of fiscal multipliers, one can easily choose fiscal instruments that would be desired for fiscal consolidation or stimulus. Concerning the case of one-year effects on real GDP it is desirable to support the domestic economy mainly by increasing government consumption and government investment, and further by decreasing social security contributions paid by employers. For a longer-lasting fiscal stimulus, the highest effects on real GDP are similarly recorded for government consumption and government investment. Conversely, as regards an appropriate, growth-friendly fiscal consolidation strategy, hikes in capital taxes or cuts in other social benefits seem desirable given the low values of the fiscal multipliers in the long-run.

However, these policy recommendations are somewhat simplified. In reality, using only a few fiscal instruments for fiscal consolidation or stimulus is not a good idea. The reason is the following: imagine that the government has to consolidate its public finance by some substantial amount - if it chooses only one fiscal instrument, then some tax might be raised to an unrealistically high level (possibly behind the peak on its Laffer curve) or some government spending might be cut below some essential level (or even completely). Similarly, the government might decide to support the economy through fiscal stimulus. If it chooses only one fiscal instrument, then some government spending might be raised to an unrealistically high level or some tax might be cut too much (or even eliminated). Therefore, it is preferable to spread fiscal adjustment (consolidation or stimulus) over a wider spectrum of fiscal instruments.

Specific allocation of fiscal adjustment into individual fiscal instruments can be done with the help of the scoring method, such as the one proposed by Drudi et al. (2015). The underlying idea is that during consolidations those fiscal instruments which are the most detrimental to the economy are penalised, and consequently in the composition of fiscal consolidation are represented with a lower share. Similarly, during fiscal stimulus those fiscal instruments which are the most beneficial to the economy are prioritized, and in the composition of fiscal stimulus gain a higher share.

4.2.1 Fiscal Consolidation

In the case of fiscal consolidations, the fiscal multipliers can be simply assigned into fiscal scores according to the following formula:

$$fs_{i,T}^{cons} = \frac{fm_T^{\max} - fm_{i,T}}{fm_T^{\max} - fm_T^{\min}}, \tag{20}$$

where i denotes the selected fiscal instrument, $fm_T^{\min}$ and $fm_T^{\max}$ are the smallest and the largest fiscal multipliers among all fiscal instruments in time period T of interest (e.g. one year or long-run). Note that the highest fiscal score (1) is attached to the fiscal instrument, which attains the lowest fiscal multiplier; e.g., it is the least detrimental to real GDP growth during fiscal consolidation. Fiscal scores are linear in nature, growing in line with the difference between the largest and selected fiscal multiplier. This assumption can be possibly relaxed, if one thinks that penalization should be much stronger for those fiscal instruments which are more harmful to real GDP. The calculated fiscal scores for fiscal consolidations are listed in Table 5 in the Appendix.

Fiscal scores themselves do not directly point to the composition of fiscal consolidation. The last step is to take the model's shares of fiscal revenues/expenditures in nominal GDP (or in the government budget), multiply them by the respective fiscal scores, and normalize the resulting numbers to sum up to 100%. The composition of temporary and longer-lasting fiscal consolidation proposed by the model for the Czech economy can be found in Tables 7–8 in the Appendix. The lump-sum taxes were removed from the composition, as these are hard to find in the economy.

Concerning one-year consolidation, the composition of appropriate growth-friendly consolidation is slightly more revenue-based, raising mainly consumption tax (a share of 30% in the composition) and wage tax (17%). On the expenditure side, the cuts in other social benefits (35%) are desired. When a policy maker cares more about the long-run effects of one-year consolidation, then in the composition of growth-friendly consolidation a large share is attached to cuts in other social benefits (45%), followed by hikes in consumption tax (20%) and social contributions paid by employers (13%).

Regarding ten-year consolidation, the appropriate growth-friendly consolidation is more expenditure-based, with the largest share attributed to the cuts in other social benefits (54%). These are followed in the composition of fiscal consolidation by raising consumption tax (31%) and social contributions paid by employers (9%). If the policy maker is more focused on the long-run effects, then the appropriate composition of growth-friendly consolidation prescribes the largest share to cuts in other social benefits (44%), followed by raises of consumption tax (39%) and cuts in government investment (7%). In the case, where the policy maker is more interested in the immediate effects of longer-lasting consolidation, then the composition of longer-lasting fiscal consolidation is virtually the same as in the case of one-year consolidation. This similarity stems from the fact that the changes in the fiscal instruments are simulated as unexpected, and initially the fiscal rule is turned off for two years.

For large fiscal reforms, a suggested composition of fiscal strategies is appropriate only for one fiscal reform. After the reform, the suggested composition of fiscal strategies will be different for the next fiscal reform, and therefore should be recalculated ideally with a newly calibrated and estimated model. For small fiscal reforms, the suggested composition of fiscal strategies can be applied repeatedly due to small shifts in fiscal revenues/expenditures in the government budget.

4.2.2 Fiscal Stimulus

In the case of fiscal stimulus, the fiscal multipliers are transformed into fiscal scores as follows:

$$fs_{i,T}^{stim} = \frac{fm_{i,T} - fm_T^{\min}}{fm_T^{\max} - fm_T^{\min}} \tag{21}$$

The highest fiscal score is attached to the fiscal instrument, which attains the highest fiscal multiplier; e.g. it has the largest impact on real GDP growth during fiscal stimulus. Fiscal scores for fiscal stimulus are provided in Table 6 in the Appendix. These scores are again, by the same logic as in the case of fiscal consolidations, translated into the composition of temporary or longer-lasting fiscal stimuli, which are provided in Tables 7–8 in the Appendix.

Looking at one-year stimulus the composition of appropriate fiscal stimulus is more expenditure-based, fostering mainly government consumption (a share of 45% in the composition). On the revenue side, the cuts in consumption tax (16%) and social security contributions paid by employers (13%) are desirable. If the policy maker is more interested in the long-run effects of one-year stimulus, the composition of fiscal stimulus is similar. Besides a desired increase in government consumption (a share of 43%), the cuts in consumption tax gain a larger part of the composition (21%).

The suggested composition of fiscal stimulus for ten-year stimulus is slightly more expenditure-based. The largest share of the composition of fiscal stimulus is attached to increases in government consumption (41%), followed by cuts in consumption tax and wage tax (both roughly 16%). If the policy maker focuses more on the long-run effects, then in the composition of appropriate fiscal stimulus the largest share is attached to government consumption (50%), followed by cuts in social security contributions paid by employers (19%) and wage tax (17%). In the case, where the policy maker is more interested in the immediate effects of longer-lasting stimulus, then the composition of fiscal stimulus for ten-year stimulus is analogous to the composition of one-year consolidation, and is more expenditure-based.

4.3 Fiscal Devaluation

For practical purposes and given the lack of the empirical literature, I use the model to evaluate the impact of a shift from direct to indirect taxation on the Czech economy. In the literature[11], such a shift in taxes is called a fiscal devaluation. The transmission mechanism behind the fiscal devaluation is simple. A decrease in direct taxes is reflected in lower unit labor costs, reduces domestic producer prices, and increases the price competitiveness of exported goods. On the other hand, higher indirect taxes make the imported goods more expensive, while leaving exported goods unaffected. The prices of domestically produced goods remain roughly unchanged, since the shifts in direct and indirect taxes are in opposite directions.

A simulation of the fiscal devaluation can provide some advice as to whether the government can strengthen the economy (in terms of real GDP growth), when it changes the composition of its taxes, while keeping the government budget unaffected. I run several simulations to illustrate the results of fiscal devaluation.

In the first simulation, consumption tax is raised, and taxes associated with wages (wage tax and social security contributions paid by employers) are decreased. The shift in taxes is permanent, and the fiscal rules for the remaining fiscal instruments are turned off (e.g. fiscal instruments are kept at their steady states). The *ex-ante* increase in consumption tax is calibrated so as to bring an additional 1% of GDP into the government budget. This is achieved by raising the effective tax rate

[11] See for instance Koske (2013).

on consumption by approximately 1.5 percentage points. The decreases in taxes associated with wages are set so as to withdraw 1% of GDP from the government budget, with the contribution of wage tax and social security contributions paid by employers being the same (0.5% of GDP). In effective rates, both tax rates on wage and social contributions paid by employers drop roughly by 2 percentage points. Overall, the *ex-ante* changes in selected taxes keep the government budget neutral. This simulation is depicted by blue lines in Figure 7 in the Appendix. This simulation shows that real GDP growth increases approximately by 0.3 percentage point in the first year, when the tax shift occurs from direct to indirect taxes. Nevertheless, this positive gain on real GDP growth is only temporary, as the economy gradually converges to the new steady state. The improvement in the net exports is the main driver behind the rise in GDP. Private consumption is initially depressed because of the higher consumption tax. Part of investment goods is imported, which might explain a temporary drop in private investment. Although the exchange rate depreciates on impact, the CPI inflation slows because the effect of lower domestic producer prices dominates.

In the second simulation, both consumption tax and capital tax are raised, and taxes associated with wages are decreased (as in the first simulation). The contributions of hikes in consumption tax and capital tax to the government budget are equal (0.5% of GDP). The effective tax rate on consumption increases by approximately 1.5 percentage points, whereas the effective tax rate on capital raises by a substantial 10 percentage points. The drops in effective tax rates on wage and social contributions paid by employers are similar to those in the first simulation. The tax shift from direct taxes to consumption tax and capital tax is shown by red lines in Figure 7 in the Appendix. In this simulation, real GDP growth accelerates by 0.4 percentage points in the first year, which makes this variant of hypothetical fiscal devaluation the preferred one. In this simulation, lower CPI inflation with a milder increase in consumption tax leads to an increase in private consumption. On the other hand, higher capital tax is responsible for a drop in private investment. The trade balance improves by a smaller extent as compared to the first simulation, since imports are affected less with the lower increase in consumption tax.

In the Czech Republic, a kind of fiscal devaluation, but more tilted towards decreases in direct taxes, can be identified in the so-called Stabilization Reform of 2008. At that time, a reduced VAT rate was increased from 5% to 9% (resulting in an estimated +0.6 % of GDP in the government budget)[12]. Conversely, personal income tax was decreased by the introduction of a 15% flat tax rate (-0.6 % of GDP), corporate income tax rate was lowered from 24% to 21% (-0.4 % of GDP), and a cap on social contributions was imposed (-0.1 % of GDP). The estimated responses of these tax shifts on the economy are depicted by golden lines in Figure 7 in the Appendix, with real GDP gaining 0.2 percentage point in 2008. Nonetheless, this Stabilization Reform was also accompanied by significant cuts in government expenditure, namely in pensions (-0.5 % of GDP) and government consumption (-0.1 % of GDP). If these expenditure cuts are reflected along with tax changes, then the positive impact of fiscal devaluation on real GDP disappeared, as is shown by black lines in the same figure.

Quantitative impacts of hypothetical fiscal devaluation lie in the range of other empirical estimates, e.g., summarised in Koske (2013). Overall, the model's simulations confirm the argument that the government can easily support the economy when it appropriately shifts the composition of taxes from direct taxes to consumption tax and/or capital tax.

5 Conclusion

I build a structural fiscal DSGE model, which is a simplified adaptation from Ambriško, Babecký, Ryšánek, and Valenta (2015) and essentially represents an extension of the CNB's core g3 model (Andrle, Hlédik, Kameník, and Vlček 2009) with a more comprehensive fiscal block. Fiscal extension is based on the inclusion of "rule-of-thumb" households and unemployment, the richer set of fiscal instruments on the revenue and expenditure side of the government budget, productive government consumption and capital, and estimated fiscal rules with feedback effects. The model is estimated by Bayesian techniques on Czech data, covering 25 time series over the period 2000–2015.

The model is used to address several important questions. First, what is the size

[12] *Ex-ante* estimates, listed in the parentheses, are adopted from the Ministry of Finance.

of fiscal multipliers in the Czech Republic? Second, what is a suitable composition of growth-friendly fiscal strategy for the Czech government based on calculated values of fiscal multipliers? Third, could the Czech economy be better off with fiscal devaluation (a shift from direct to indirect taxation)?

The real GDP fiscal multipliers from the model suggest that the largest multipliers after the first year of a temporary fiscal stimulus are associated with government consumption (0.6), government investment (0.5), social security contributions paid by employers (0.4), followed by consumption tax, wage tax and unemployment benefits (all roughly 0.3), then by other social benefits, lump-sum taxes (both 0.2), and capital tax (0.1).

These fiscal multipliers are assigned fiscal scores according to a simplified ECB methodology (Drudi et al. 2015), which provide a ranking of the fiscal instruments according to their usefulness to the real economy, e.g., which fiscal instruments are the least harmful to real GDP during fiscal consolidation and which are the most beneficial to boost real GDP during fiscal stimulus. Fiscal scores are then used to derive an appropriate composition of growth-friendly fiscal strategies in the phases of fiscal consolidation and stimulus.

Concerning temporary fiscal consolidation, the composition of an appropriate growth-friendly strategy is more revenue-based, raising consumption tax (a share of 30% in the composition) and wage tax (17%), and accompanied by cuts in other social benefits on the expenditure side (35%). The composition of temporary fiscal stimulus is more expenditure-based, fostering mainly government consumption (a share of 45% in the composition), followed by cuts in consumption tax (16%) and social security contributions paid by employers (13%) on the revenue side.

Given the lack of the empirical literature, the model is used to evaluate the impact of a hypothetical shift from direct to indirect taxation on the Czech economy. The model's simulations show that the government can easily support the economy when it appropriately shifts the composition of taxes from direct to indirect taxes. More specifically, real GDP growth can be boosted by approximately 0.4 percentage points in the first year when a budget-neutral tax shift in magnitude of 1% of GDP occurs from direct taxes associated with wages to consumption tax and capital tax. Furthermore, the model evaluated the past fiscal devaluation identified in the Czech

Republic's 2008 Stabilization Reform and found that the positive real GDP gains from tax changes were reversed by accompanied expenditure cuts.

This paper could be extended in several directions. The robustness of the results could be further checked in terms of the underlying model mechanisms and assumptions, e.g., determining what influence complementarity/substitutability between private and government consumption/capital has in the measured values of fiscal multipliers, and consequently in the appropriate setup of growth-friendly fiscal strategies. One could also further refine the fiscal part of the model, e.g., it is possible to further expand government labor services and to model them explicitly as a production input.

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Appendix A The Rest of the Model

A.1 Production Sectors

There are several production sectors in the economy. All monopolistic firms are owned by optimizers, and firms' profits are rebated to them as dividends.

A.1.1 Domestic Intermediate Goods

There is a continuum of domestic intermediate goods firms $z \in [0,1]$, which combine capital $K_{t-1}(z)$ and labor $L_t(z)$ inputs into a single variety of intermediate good according to Cobb-Douglas production technology:

$$Y_t(z) = \varsigma_t \left(A_t L_t(z)\right)^{1-\alpha} K_{t-1}(z)^{\alpha}, \tag{22}$$

where ς_t and A_t are the total factor productivity shock and labor-augmenting technology process, and labor input is defined as $L_t(z) = (\int_0^1 [L_t(z,i)]^{\frac{\epsilon_W - 1}{\epsilon_W}} di)^{\frac{\epsilon_W}{\epsilon_W - 1}}$, where ϵ_W is the elasticity of substitution for labor services between individual households. Firm z's labor demand for labor type i is downward sloping:

$$L_t(z,i) = \left[\frac{W_t(i)}{W_t}\right]^{-\epsilon_W} L_t(z), \tag{23}$$

where $W_t = (\int_0^1 [W_t(i)]^{1-\epsilon_W} di)^{\frac{1}{1-\epsilon_W}}$ is the aggregate wage index. Due to common production technology, sector-wide production equals:

$$\int_0^1 Y_t(z)dz = \varsigma_t \left(A_t L_t\right)^{1-\alpha} K_{t-1}{}^{\alpha} \tag{24}$$

Intermediate firms minimize the total costs of production $P_t^K K_{t-1}^p(z) + (1 + \tau_t^S) W_t L_t(z)$, given their production function in (22). Note that labor costs include social security contributions paid by employers, represented by the effective tax rate τ_t^S. Cost minimization yields the following factor demands:

$$\frac{P_t^K}{P_t^Y} = RMCY_t \alpha \frac{Y_t}{K_{t-1}} \left(\frac{\alpha_K K_{t-1}}{K_{t-1}^p}\right)^{\frac{1}{\upsilon_K}} \tag{25}$$

$$(1+\tau_t^S)\frac{W_t}{P_t^Y} = RMCY_t(1-\alpha)\frac{Y_t}{L_t}, \tag{26}$$

where the firm's index z is omitted because of symmetry, and $RMCY_t$ denotes real marginal costs in intermediate production.

The prices of intermediate goods are sticky *à la* Calvo (1983). In each period, firm z has the opportunity to optimally adjust prices with probability $1-\xi_Y$. The remaining firms, which are not allowed to optimally adjust their prices in a given period, automatically index prices using the last-known sector-wide inflation Π_t^Y (e.g. $P_t^Y(z) = P_{t-1}^Y(z)\Pi_{t-1}^Y$). This pricing implies the following Phillips curve:

$$\log\frac{\Pi_t^Y}{\Pi_{t-1}^Y} = \beta\log\frac{\Pi_{t+1}^Y}{\Pi_t^Y} + \frac{(1-\xi_Y)(1-\beta\xi_Y)}{\xi_Y}\log(RMCY_t\Theta^Y) + \varepsilon_t^Y, \tag{27}$$

where Θ^Y is the price markup and ε_t^Y is the cost-push shock.

Intermediate production is sold to the consumption, investment, government, and export-producing sectors as inputs for further production:

$$Y_t = Y_t^C + Y_t^I + Y_t^G + Y_t^X \tag{28}$$

A.1.2 Imported Goods

A continuum of imported goods firms $z^N \in [0,1]$ imports varieties of foreign intermediate goods according to the CES production technology:

$$N_t(z^N) = a_t^N\left[\int_0^1 [o_t(f)]^{\frac{\theta-1}{\theta}}\,df\right]^{\frac{\theta}{\theta-1}}, \tag{29}$$

where a_t^N is a stationary productivity shock, $o_t(f)$ denotes the imported CES bundle from country $f\in[0,1]$, and $\theta>1$ is the elasticity of substitution across imported bundles. Sector-wide imported goods production is sold on to the consumption, investment, and export sectors:

$$\int_0^1 N_t(z^N)dz^N = N_t^C + N_t^I + N_t^X \tag{30}$$

Sticky prices of intermediate goods result in a standard Phillips curve analogous to the one in the domestic intermediate goods sector.

A.1.3 Consumption Goods

There is a continuum of consumption goods firms $z^C \in [0,1]$, which combine imported and domestic intermediate goods into private consumption goods with CES technology. Sector-wide private consumption equals:

$$\int_0^1 C_t^p(z^C)dz^C = \left[(\omega_C)^{\frac{1}{\eta_C}}\left(N_t^C\right)^{\frac{\eta_C-1}{\eta_C}} + (1-\omega_C)^{\frac{1}{\eta_C}}\left(Y_t^C\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}, \tag{31}$$

where ω_C is the share of imported goods in the private consumption bundle and $\eta_C > 0$ is the elasticity of substitution between domestic and imported intermediate goods. The prices of private consumption goods are sticky, and a similar Phillips curve, as in other production sectors, can be obtained.

A.1.4 Investment Goods

Similarly to consumption goods firms, investment goods firms $z^I \in [0,1]$ buy imported and domestic intermediate inputs and produce varieties of investment goods. Sector-wide investment goods production is defined as:

$$\int_0^1 I_t(z^I)dz^I = a_t^I\left[(\omega_I)^{\frac{1}{\eta_I}}\left(N_t^I\right)^{\frac{\eta_I-1}{\eta_I}} + (1-\omega_I)^{\frac{1}{\eta_I}}\left(Y_t^I\right)^{\frac{\eta_I-1}{\eta_I}}\right]^{\frac{\eta_I}{\eta_I-1}}, \tag{32}$$

where ω_I is the share of imported inputs in the investment bundle, $\eta_I > 0$ is the elasticity of substitution between domestic and imported intermediate goods, and a_t^I is the stationary investment-specific technology shock. Investment goods production is sold to households and government, that is, $I_t = I_t^p + I_t^g$. Prices of investment goods are sticky as in the other production sectors.

A.1.5 Export Goods

Export goods firms $z^X \in [0,1]$ put together imported and domestic intermediate goods into varieties of export goods using the CES technology. Sector-wide export goods production is equal to:

$$\int_0^1 X_t(z^X)dz^X = \left[(\omega_X)^{\frac{1}{\eta_X}}\left(N_t^X\right)^{\frac{\eta_X-1}{\eta_X}} + (1-\omega_X)^{\frac{1}{\eta_X}}\left(Y_t^X\right)^{\frac{\eta_X-1}{\eta_X}}\right]^{\frac{\eta_X}{\eta_X-1}}, \tag{33}$$

where ω_X is the share of imported goods in the export goods bundle, and $\eta_X > 0$ is the elasticity of substitution between domestic and imported intermediate goods. In contrast to other production sectors, the prices of export goods are sticky in foreign currency, which gives the following Phillips curve:

$$\log\frac{\widetilde{\Pi}_t^X}{\widetilde{\Pi}_{t-1}^X} = \beta\log\frac{\widetilde{\Pi}_{t+1}^X}{\widetilde{\Pi}_t^X} + \frac{(1-\xi_X)(1-\beta\xi_X)}{\xi_X}\log\left(RMCX_t\Theta^X\right) + \varepsilon_t^X, \tag{34}$$

where $\xi_X > 0$ is the Calvo signal parameter, Θ^X is the export price markup, $RMCX_t$ are real marginal costs in the export goods sector, ε_t^X is the export cost-push shock, and the link $\Pi_t^X = \frac{S_t}{S_{t-1}}\widetilde{\Pi}_t^X$ holds between export goods inflation in domestic currency and export goods inflation in foreign currency, with S_t denoting the nominal exchange rate (defined as the price of foreign currency expressed in the domestic currency).

Demand for domestic export goods moves in line with foreign demand as follows:

$$X_t = \left(\frac{P_t^X}{P_t^*}\right)^{-\theta_X} N_t^*, \tag{35}$$

where $\theta_X > 0$ is the price elasticity of exports, N_t^* is exogenous foreign demand, and P_t^* is the exogenously-given foreign price level (expressed in the domestic currency).

A.1.6 Government Goods

Government goods firms $z^G \in [0,1]$ transform domestic intermediate inputs into varieties of government goods. Sector-wide government goods production equals:

$$\int_0^1 G_t(z^G)dz^G = a_t^G Y_t^G, \tag{36}$$

where a_t^G is the stationary government technology shock. Government goods are freely available to all households; one can think of roads, hospitals, the police, the fire brigade, and other public goods and services that yield some utility to households. The pricing of government goods involves nominal rigidities similarly to the other production sectors.

A.2 Wage Contracts

By assumption, both types of households supply their labor services to an employment agency, which costlessly bundles labor services into the CES aggregate. Wages are set by the employment agency in the Calvo manner, so each period the employment agency is able to renegotiate nominal wages for its workers with probability $1-\xi_W$. Nominal wages for the remaining workers, for which the employment agency did not have the chance to renegotiate wages, are automatically indexed to the last-known sector-wide wage inflation. Having determined wages, the employment agency distributes workers to the firms according to their demand, sending those workers with the lowest disutility of work first. At the end, the employment agency collects the wage income and pools it equally among all households. Therefore, the wage is common to both types of households, i.e., $W_t = W_t^o = W_t^r$, and together with the assumption of same preferences across households this implies that the employed labor supply of optimizers and rule-of-thumb households is $L_t^o = L_t^r = L_t$.

Formally, when renegotiating wages, the employment agency chooses the new nominal wage $W_t^*(i)$ for workers of type i to maximize the following objective function:

$$\max_{W_t^*(i)} E_t \sum_{s=0}^{\infty} (\beta\xi_W)^{t+s} \left\{ \begin{array}{c} (1-\gamma)\left[\lambda_{t+s}^{co}(i)(1-\tau_{t+s}^{WUB})W_t^*(i)\frac{W_{t+s-1}}{W_{t-1}}L_{t+s}^o(i)\right] \\ +\gamma\left[\lambda_{t+s}^{cr}(i)(1-\tau_{t+s}^{WUB})W_t^*(i)\frac{W_{t+s-1}}{W_{t-1}}L_{t+s}^r(i)\right] \\ -\left[(1-\gamma)\theta\frac{\left(L_{t+s}^o(i)\right)^{1+\phi_n}}{1+\phi_n} + \gamma\theta\frac{\left(L_{t+s}^r(i)\right)^{1+\phi_n}}{1+\phi_n}\right] \end{array} \right\} \tag{37}$$

subject to the labor demand condition:

$$L_t(i) = \left[\frac{W_t(i)}{W_t}\right]^{-\epsilon^W} L_t, \tag{38}$$

where a net wage tax $\tau_t^{WUB} = \tau_t^W - \tau_t^{UB}$ is introduced to simplify the algebra. In other words, the employment agency cares about the weighted utility of workers of type i coming from net labor income less disutility from supplying labor across all type of households, which are either optimizers' or rule-of-thumb households. The aggregation takes over all possible states in which the new optimal wage is not renegotiated and is indexed by the sector-wide wage inflation over time s (in the term $\frac{W_{t+s-1}}{W_{t-1}}$). The first order condition gives the following expression:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_W)^{t+s} \frac{L^o_{t+s}(i)^{1+\phi_n}}{W^*_t(i)} \begin{bmatrix} \left(\frac{1-\gamma}{MRS^o_{t+s}(i)} + \frac{\gamma}{MRS^r_{t+s}(i)}\right) * \\ *(1-\tau^{WUB}_{t+s})W^*_t(i)\frac{W_{t+s-1}}{W_{t-1}} - \Theta^W \end{bmatrix} = 0, \qquad (39)$$

where $\Theta^W = \frac{\epsilon^W}{\epsilon^W - 1}$ is the desired (flexible) wage markup and $MRS^o_t(i)$, $MRS^r_t(i)$ are the marginal rates of substitution between labor and consumption for labor type i in the optimizers' and rule-of-thumb households. Log-linearizing this condition, and using the definition for the aggregate wage index W_t (defined in Section A.1.1), one can obtain the following wage Phillips curve:

$$\log \frac{\Pi^W_t}{\Pi^W_{t-1}} = \beta \log \frac{\Pi^W_{t+1}}{\Pi^W_t} - \frac{(1-\xi_W)(1-\beta\xi_W)}{\xi_W(1+\epsilon^W\phi_n)} \log \frac{\Theta^W_t}{\Theta^W} + \varepsilon^W_t, \qquad (40)$$

where $\Theta^W_t = \frac{(1-\tau^{WUB}_t)W_t}{P_t MRS_t}$ is the average wage markup (the ratio of the after-tax real wage to the average marginal rate of substitution between labor and consumption for both types of households MRS_t) and ε^W_t is the wage cost-push shock. Wage inflation is rising with expected higher wage inflation in the next period, and is decreasing with deviation of the average wage markup from the desired/flexible wage markup.

The household-relevant marginal rate of substitution between consumption and employment for type i workers in households of type k can be expressed as:

$$MRS^k_t(i) = -\frac{U^k_{n(i),t}}{U^k_{c,t}} = \frac{\theta\left[L^k_t(i)\right]^{\phi_n}}{\lambda^{ck}_t}, \qquad (41)$$

where λ^{ck}_t is the shadow price of consumption (the Lagrange multiplier associated with the budget constraint for the respective type of household k). Taking logs and integrating over all labor and household types:

$$mrs_t = \log\theta + \phi_n l_t - \tilde{\lambda}^c_t, \qquad (42)$$

where $mrs_t = \int_0^1 mrs_t(i)di$ is the log average marginal rate of substitution, $l_t = \int_0^1 l_t(i)di$ is log aggregate employment, and $\tilde{\lambda}^c_t = \gamma \log \lambda^{cr}_t + (1-\gamma)\log \lambda^{co}_t$ is the log average shadow price of consumption.

A.2.1 Unemployment

The unemployment introduced into this model uses the framework of Galí (2011), where unemployment is a result of workers' market power, i.e., wages are set above their competitive levels, and unemployment fluctuations arise because of slow adjustment of nominal wages. For any member of the household it is optimal to participate in the labor market if his after-tax real wage is higher than his disutility of work, deflated by the shadow price of consumption:

$$\frac{(1-\tau_t^{WUB})W_t(i)}{P_t^C} \geq \frac{\theta j^{\phi_n}}{\lambda_t^c} \tag{43}$$

For a marginal supplier of labor type i, who is indifferent to working and not working and is denoted as $L_t^P(i)$, the following holds:

$$\frac{(1-\tau_t^{WUB})W_t(i)}{P_t^C} = \frac{\theta \left[L_t^P(i)\right]^{\phi_n}}{\lambda_t^{ck}} \tag{44}$$

Taking logs and integrating over all labor types i and households k:

$$\log(1-\tau_t^{WUB}) + w_t - p_t^c = \log\theta + \phi_n l_t^P - \tilde{\lambda}_t^c, \tag{45}$$

where $w_t = \int_0^1 w_t(i)di$ is the log aggregate wage index and $l_t^P = \int_0^1 l_t^P(i)di$ is the log aggregate participation or labor force. The unemployment rate is defined as the difference between the log aggregate labor force and employment:

$$u_t = l_t^P - l_t \tag{46}$$

Combining equations (42) and (45) with the expression for the average wage markup, the following simple relationship between the wage markup and the unemployment rate arises:

$$\log\Theta_t^W = \phi_n u_t \tag{47}$$

This expression can be substituted back into the wage Phillips curve (40), so wage inflation can be directly related to unemployment fluctuations. Wage inflation is decreasing when the unemployment rate is high. In the absence of wage rigidities, the concept of the natural rate of unemployment u_t^n is defined. Assuming a constant desired wage markup Θ^W, it follows that the natural rate of unemployment is constant as well and can be expressed as:

$$u^n = \frac{\log \Theta^W}{\phi_n} \tag{48}$$

A.3 Foreign Block

The model features a version of the uncovered interest rate parity (UIP) condition as follows:

$$S_t R_t = (E_t S_{t+1})^{\rho_s} (S_{t-1})^{1-\rho_s} R_t^* prem_t \exp(\varepsilon_t^{uip}) \tag{49}$$

$$prem_t = (prem_{t-1})^{\rho_p} \exp(-\zeta_B B_t^* + \varepsilon_t^{prem}), \tag{50}$$

where S_t is the nominal exchange rate, R_t^* is the foreign gross nominal interest rate, $prem_t$ is the foreign debt-elastic risk premium, $\rho_s \in [0,1]$ is a parameter that introduces partial sluggishness into the UIP relationship, $\rho_p \in [0,1)$ is the persistence parameter in the risk premium, B_t^* denotes holdings of foreign currency bonds expressed in the domestic currency, $\zeta_B > 0$ is the parameter measuring the elasticity of the risk premium with respect to holdings of foreign bonds, and $\varepsilon_t^{uip}, \varepsilon_t^{prem}$ are normally distributed shocks.

The trade balance equals the value of exports less the value of imports:

$$TB_t = P_t^X X_t - P_t^* N_t, \tag{51}$$

where P_t^* is the foreign price level expressed in domestic currency, i.e., $P_t^* = S_t \widetilde{P}_t^*$, where $\widetilde{P}_t^*$ is the foreign price level in foreign currency.

The net foreign debt law of motion is given by the following relationship:

$$B_t^* = \frac{S_t}{S_{t-1}} B_{t-1}^* R_{t-1}^* + TB_t \tag{52}$$

Because this model represents a small open economy, the foreign variables – specifically foreign inflation, the foreign gross nominal interest rate, and foreign demand

– are exogenously given:

$$\begin{aligned} \widetilde{\Pi}_t^* &= \left(\widetilde{\Pi}_{t-1}^*\right)^{\rho_{ps}} \exp(\varepsilon_t^{ps}) \\ \frac{R_t^*}{\bar{R}} &= \left(\frac{R_{t-1}^*}{\bar{R}}\right)^{\rho_{rs}} \exp(\varepsilon_t^{rs}) \\ \frac{N_t^*}{\bar{N}^*} &= \left(\frac{N_{t-1}^*}{\bar{N}^*}\right)^{\rho_{ns}} \exp(\varepsilon_t^{ns}), \end{aligned} \tag{53}$$

where $\widetilde{\Pi}_t^* = \widetilde{P}_t^*/\widetilde{P}_{t-1}^*$, the steady states for foreign inflation and foreign nominal interest rates equal the steady states of their domestic counterparts, the ρ's from $[0,1)$ measure the persistences of the exogenous processes, and ε's are normally distributed shocks.

A.4 Monetary Policy

The central bank operates under a regime of inflation targeting and sets the nominal gross interest rate according to the following Taylor rule:

$$R_t = (R_{t-1})^{\rho_i} \left[\bar{R} \left(\frac{\Pi_{t+4}^{C4}}{\overline{\Pi}} \right)^{\phi_\pi} \right]^{1-\rho_i} \exp(\varepsilon_t^M), \tag{54}$$

where $\bar{R}$ is the steady state nominal gross interest rate, $\Pi_t^{C4} = P_t^C/P_{t-4}^C$ is year-on-year CPI inflation, which excludes changes in indirect taxation, $\overline{\Pi}$ is the inflation target, $0 \leq \rho_i < 1$ is the interest rate smoothing parameter, $\phi_\pi > 1$ is the feedback coefficient for inflation deviations from the inflation target, and ε_t^M is a normally distributed monetary policy shock. The central bank targets the year-on-year deviation of CPI inflation from its target four periods ahead.

A.5 Aggregation

The aggregate per-capita level of household-relevant variables is given by $X_t = \int_0^1 X_t(h)dh$, which can be translated into the following individual relationships:

$$\begin{aligned}
C_t &= \gamma C_t^r + (1-\gamma)C_t^o \\
C_t^p &= \gamma C_t^{pr} + (1-\gamma)C_t^{po} \\
G_t &= \gamma G_t^r + (1-\gamma)G_t^o \\
OB_t &= \gamma OB_t^r + (1-\gamma)OB_t^o \\
T_t &= \gamma T_t^r + (1-\gamma)T_t^o \\
L_t &= \gamma L_t^r + (1-\gamma)L_t^o,
\end{aligned} \tag{55}$$

and because only optimizers save, accumulate private capital, and own firms, the remaining aggregate quantities are defined as:

$$\begin{aligned}
B_t &= (1-\gamma)B_t^o \\
K_t^p &= (1-\gamma)K_t^{po} \\
I_t^p &= (1-\gamma)I_t^{po} \\
D_t &= (1-\gamma)D_t^o
\end{aligned} \tag{56}$$

Nominal GDP can be calculated by evaluating the individual expenditure components:

$$GDP_t = P_t^C C_t^p + P_t^I I_t + P_t^G G_t + P_t^X X_t - P_t^* N_t \tag{57}$$

As in Ambriško et al. (2015), the real GDP growth is approximated by a chain-weighted link:

$$\begin{aligned}
\frac{RGDP_t}{RGDP_{t-1}} = &\frac{P_{t-1}^C C_{t-1}^p}{GDP_{t-1}} \frac{C_t^p}{C_{t-1}^p} + \frac{P_{t-1}^I I_{t-1}}{GDP_{t-1}} \frac{I_t}{I_{t-1}} + \frac{P_{t-1}^G G_{t-1}}{GDP_{t-1}} \frac{G_t}{G_{t-1}} + \\
&+ \frac{P_{t-1}^X X_{t-1}}{GDP_{t-1}} \frac{X_t}{X_{t-1}} - \frac{P_{t-1}^* N_{t-1}}{GDP_{t-1}} \frac{N_t}{N_{t-1}}
\end{aligned} \tag{58}$$

Appendix B

Table 1: Calibrated Parameters and Steady State Ratios

Parameter / Ratio	Description	Value
Preferences		
β	Discount factor	0.9938
θ	Disutility of labor supply	5
χ^o	Habit parameter for optimizers	0.75
χ^r	Habit parameter for rule-of-thumb households	0.75
α_C	Share of private good in consumption good	0.8
Technology		
α	Capital share	0.3333
α_K	Share of private capital in capital composite	0.8
δ^p	Depreciation rate for private capital	0.0153
δ^g	Depreciation rate for government capital	0.0153
η	Investment adjustment cost	0.2
Monetary policy		
$\bar{R}$	Nominal gross interest rate	1.0062
$\overline{\Pi}$	Inflation target	1
Fiscal policy, unemployment		
τ^C	Consumption tax rate	0.25
τ^W	Wage tax rate	0.29
τ^S	Social security contributions paid by employers	0.30
τ^K	Capital tax rate	0.15
τ^{UB}	Unemployment benefit rate	0.0089
ϕ_{btc}	Debt feedback for consumption tax rate	0.25
u^n	Natural rate of unemployment	0.065
Shares		
ω_C	Share of imported goods in private consumption	0.15
ω_I	Share of imported inputs in investment	0.70
ω_X	Share of imported goods in exports	0.55
Ratios		
G/Y	Government consumption to output	0.25
I^g/Y	Government investment to output	0.03
OB/Y	Other social benefits to output	0.14
B/Y	Government debt to output	0.60

Table 1 – Continued from Previous Page

Parameter / Ratio	Description	Value
Calvo setting		
ξ_Y	Intermediate good stickiness	0.50
ξ_C	Consumption good stickiness	0.65
ξ_I	Investment good stickiness	0.40
ξ_G	Government good stickiness	0.75
ξ_X	Export good stickiness	0.60
ξ_N	Import good stickiness	0.60
ξ_W	Wage stickiness	0.80
Elasticity		
ϵ^W	Between labor varieties	6.4
$\epsilon^Y, \epsilon^C, \epsilon^I, \epsilon^G, \epsilon^X, \epsilon^N$	Between goods varieties	6
η_C	Between domestic and imported goods for consumption good	0.5
η_I	Between domestic and imported goods for investment good	0.5
η_X	Between domestic and imported goods for export good	0.5
θ_X	Price elasticity of exports	1.2
ζ_B	Risk premium w.r.t. foreign bonds	0.005
Persistence		
ρ_a	Technology	0.9
ρ_g	Government consumption	0.8
ρ_{ig}	Government investment	0.6
ρ_{ub}	Unemployment benefits	0.7
ρ_{ob}	Other social benefits	0.8
ρ_{tc}	Consumption tax	0.7
ρ_{tw}	Wage tax	0.75
ρ_{ts}	Social security contributions	0.75
ρ_{tk}	Capital tax	0.7
ρ_t	Lump-sum tax	0.75
ρ_s	UIP sluggishness	0.7
ρ_p	Risk premium	0
ρ_{ps}	Foreign inflation	0.3
ρ_{rs}	Foreign gross nominal interest rate	0.8
ρ_{ns}	Foreign demand	0.75

Figure 2: Effective Tax Rates (in %)

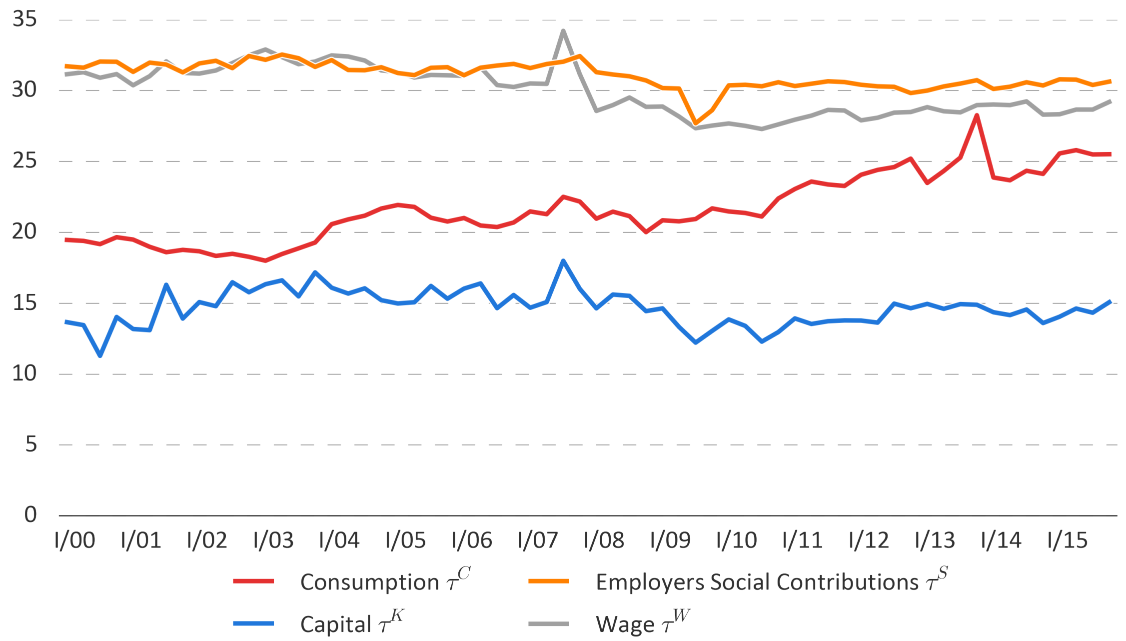


Table 2: Input Data

Time series	Range	Source
Real GDP components		
Private consumption	2000Q1 – 2015Q4	CZSO
Private investment	2000Q1 – 2015Q4	CZSO
Government consumption	2000Q1 – 2015Q4	CZSO
Government investment	2000Q1 – 2015Q4	CZSO
Exports	2000Q1 – 2015Q4	CZSO
Imports	2000Q1 – 2015Q4	CZSO
Deflators		
Private consumption deflator	2000Q1 – 2015Q4	CZSO
Investment deflator	2000Q1 – 2015Q4	CZSO
Government consumption deflator	2000Q1 – 2015Q4	CZSO
Export deflator	2000Q1 – 2015Q4	CZSO
Import deflator	2000Q1 – 2015Q4	CZSO
Labor market		
Nominal wages	2000Q1 – 2015Q4	CZSO
Unemployment benefits	2000Q3 – 2015Q4	MoF
Effective tax rates		
Consumption tax rate	2000Q1 – 2015Q4	Own
Wage tax rate	2000Q1 – 2015Q4	Own
Social security tax rate	2000Q1 – 2015Q4	Own
Capital tax rate	2000Q1 – 2015Q4	Own
Other fiscal variables		
Social benefits	2000Q1 – 2015Q4	CZSO
Primary budget balance	2000Q1 – 2015Q4	CZSO
Government debt	2000Q2 – 2015Q4	CZSO
Financial and foreign variables		
3M PRIBOR	2000Q1 – 2015Q4	CNB
CZK/EUR exchange rate	2000Q1 – 2015Q4	CNB
3M EURIBOR	2000Q1 – 2015Q4	EUROSTAT
GDP EA	2000Q1 – 2015Q4	EUROSTAT
PPI EA	2000Q1 – 2015Q4	EUROSTAT

Figure 3: Priors and Posteriors of Estimated Parameters

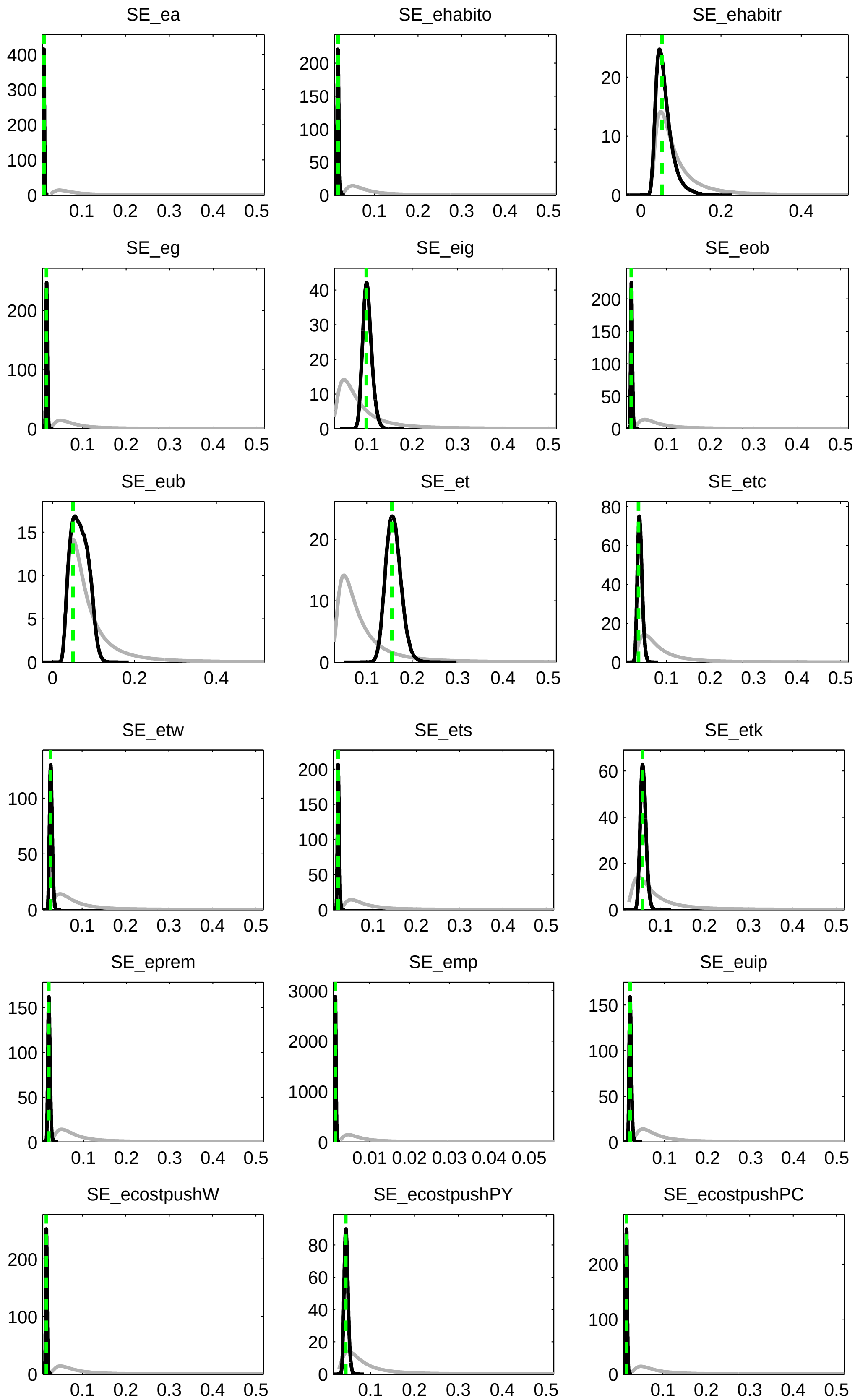


Figure 4: Priors and Posteriors of Estimated Parameters (Continued)

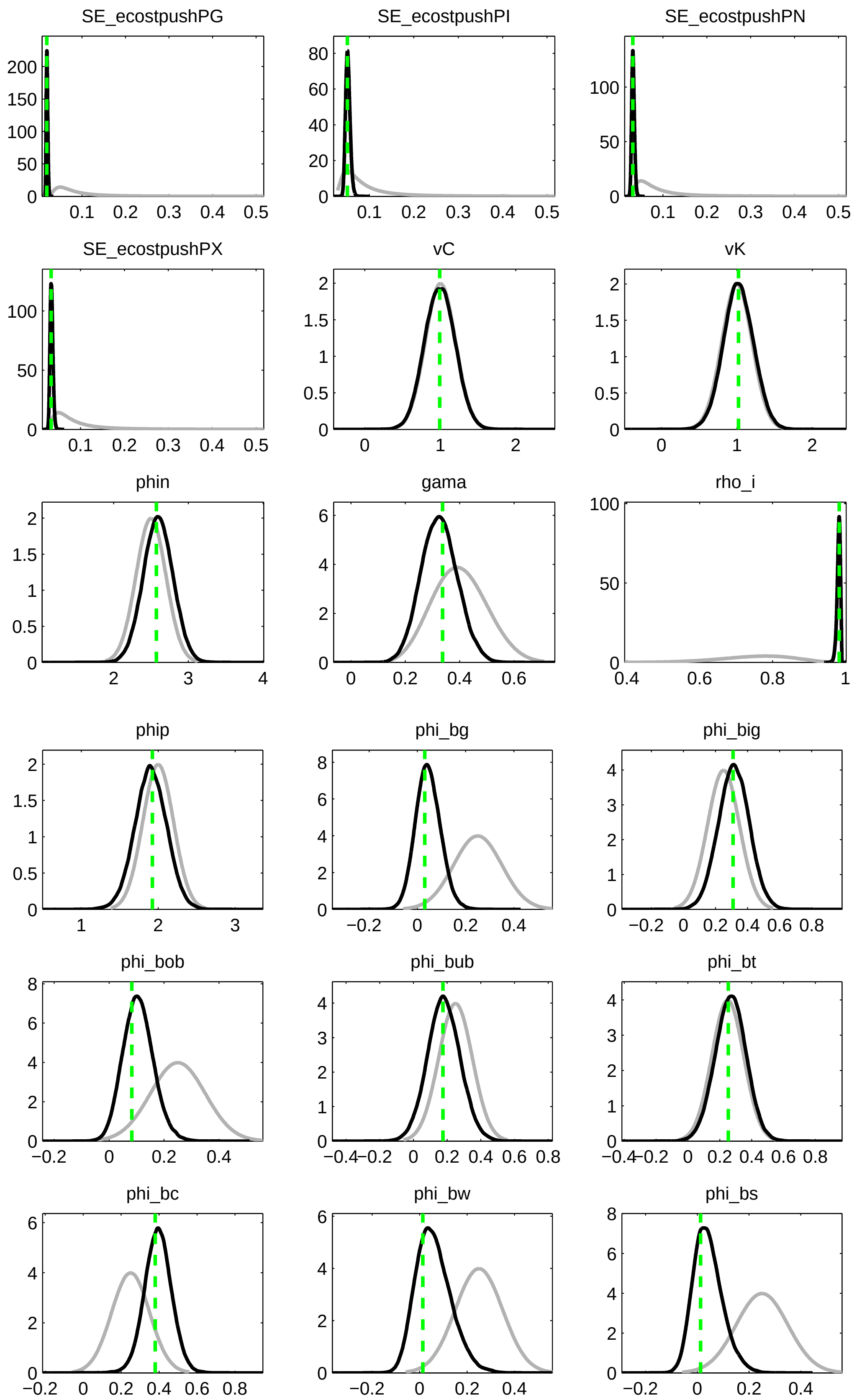


Figure 5: Priors and Posteriors of Estimated Parameters (Continued)

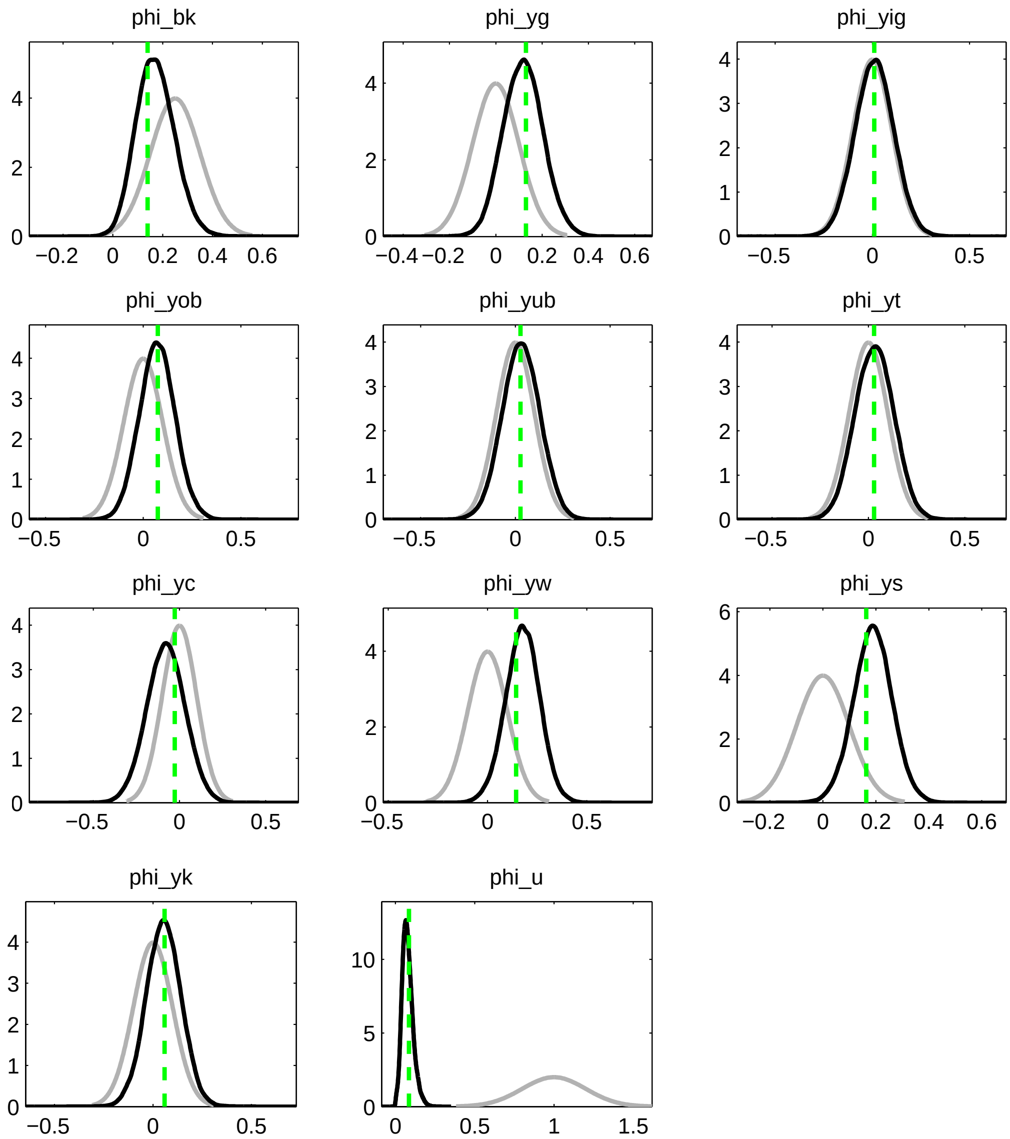


Figure 6: Multivariate Convergence Diagnostics

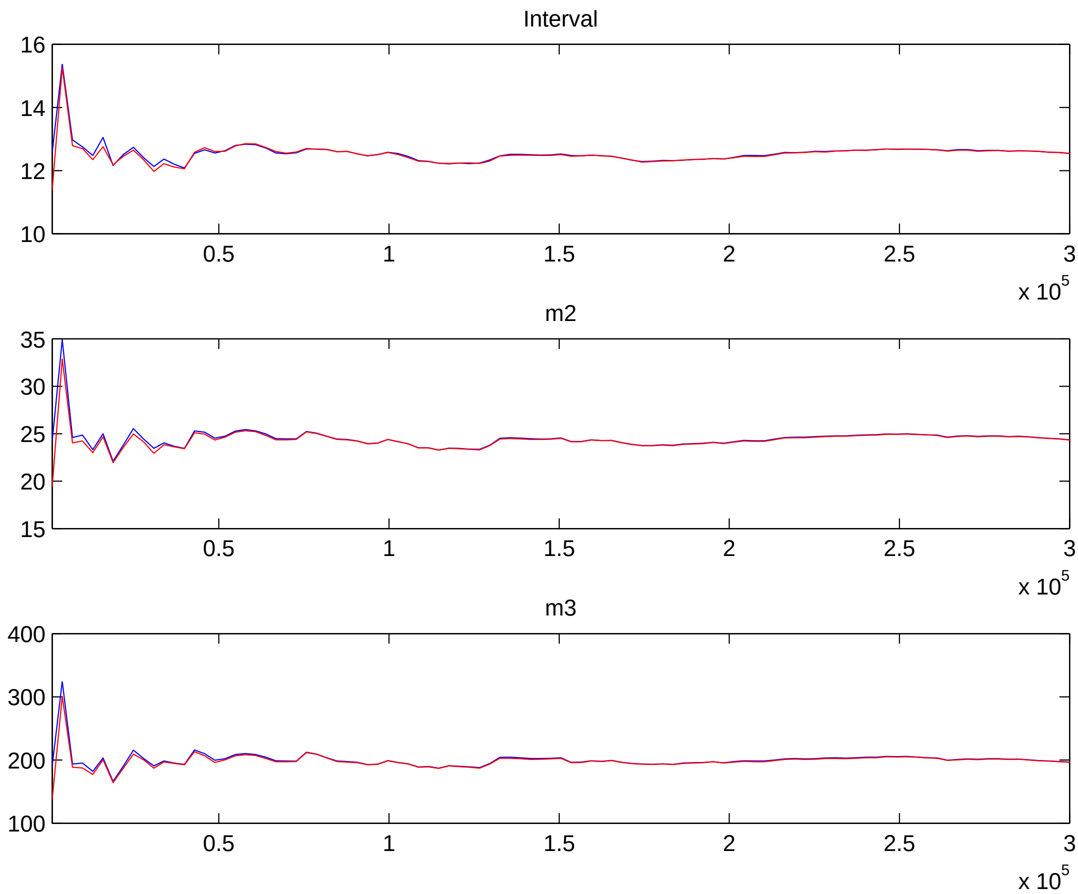


Table 3: Estimated Parameters

Parameter		Prior distribution	Posterior distribution			
equation	/ figure		mode	mean	10%	90%
Share of rule-of-thumb households						
γ	gama	B(0.4,0.1)	0.34	0.32	0.24	0.41
Inverse of Frisch elasticity						
ϕ_n	phin	N(2.5,0.2)	2.57	2.59	2.34	2.85
Elasticities in CES aggregates						
υ_C	vC	N(1,0.2)	0.99	0.99	0.74	1.25
υ_K	vK	N(1,0.2)	1.02	1.02	0.77	1.28
Monetary policy rule						
ϕ_π	phip	N(2,0.2)	1.93	1.90	1.64	2.17
ρ_i	rho_i	B(0.75,0.1)	0.98	0.98	0.98	0.99
Output feedback coefficients						
ϕ_{yg}	phi_yg	N(0,0.1)	0.13	0.12	0.01	0.23
ϕ_{yig}	phi_yig	N(0,0.1)	0.01	0.01	-0.12	0.14
ϕ_{yob}	phi_yob	N(0,0.1)	0.07	0.07	-0.05	0.19
ϕ_{yub}	phi_yub	N(0,0.1)	0.03	0.03	-0.10	0.16
ϕ_{yt}	phi_yt	N(0,0.1)	0.03	0.03	-0.10	0.16
ϕ_{ytc}	phi_yc	N(0,0.1)	-0.03	-0.08	-0.22	0.06
ϕ_{ytw}	phi_yw	N(0,0.1)	0.14	0.18	0.06	0.28
ϕ_{yts}	phi_ys	N(0,0.1)	0.16	0.19	0.09	0.28
ϕ_{ytk}	phi_yk	N(0,0.1)	0.06	0.05	-0.06	0.17
Debt feedback coefficients						
ϕ_{bg}	phi_bg	N(0.25,0.1)	0.03	0.04	-0.02	0.11
ϕ_{big}	phi_big	N(0.25,0.1)	0.31	0.31	0.19	0.44
ϕ_{bob}	phi_bob	N(0.25,0.1)	0.08	0.11	0.04	0.18
ϕ_{bub}	phi_bub	N(0.25,0.1)	0.18	0.18	0.06	0.31
ϕ_{bt}	phi_bt	N(0.25,0.1)	0.25	0.27	0.14	0.39
ϕ_{btc}	phi_bc	N(0.25,0.1)	0.38	0.39	0.30	0.48
ϕ_{btw}	phi_bw	N(0.25,0.1)	0.01	0.06	-0.03	0.16
ϕ_{bts}	phi_bs	N(0.25,0.1)	0.01	0.04	-0.03	0.12
ϕ_{btk}	phi_bk	N(0.25,0.1)	0.14	0.17	0.08	0.27
Unemployment feedback coefficient						
ϕ_u	phi_u	N(1,0.2)	0.09	0.08	0.04	0.12

Table 3 – Continued from Previous Page

Parameter		Prior distribution	Posterior distribution			
equation	/ figure		mode	mean	10%	90%
Standard errors of shocks						
ε_t^a	ea	IG(0.1,0.2)	0.01	0.01	0.01	0.02
ε_t^{ho}	ehabito	IG(0.1,0.2)	0.02	0.02	0.01	0.02
ε_t^{hr}	ehabitr	IG(0.1,0.2)	0.05	0.06	0.04	0.09
ε_t^{uip}	euip	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^{prem}	eprem	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^M	emp	IG(0.01,0.2)	0.001	0.001	0.001	0.002
ε_t^g	eg	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^{ig}	eig	IG(0.1,0.2)	0.10	0.10	0.09	0.11
ε_t^{ob}	eob	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^{ub}	eub	IG(0.1,0.2)	0.05	0.07	0.04	0.09
ε_t^t	et	IG(0.1,0.2)	0.16	0.16	0.14	0.18
ε_t^{tc}	etc	IG(0.1,0.2)	0.04	0.04	0.03	0.05
ε_t^{tw}	etw	IG(0.1,0.2)	0.03	0.03	0.03	0.03
ε_t^{ts}	ets	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^{tk}	etk	IG(0.1,0.2)	0.06	0.06	0.05	0.07
ε_t^W	ecostpushW	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^Y	ecostpushPY	IG(0.1,0.2)	0.04	0.05	0.04	0.05
ε_t^C	ecostpushPC	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^G	ecostpushPG	IG(0.1,0.2)	0.02	0.02	0.02	0.02
ε_t^I	ecostpushPI	IG(0.1,0.2)	0.05	0.05	0.05	0.06
ε_t^N	ecostpushPN	IG(0.1,0.2)	0.03	0.03	0.03	0.04
ε_t^X	ecostpushPX	IG(0.1,0.2)	0.03	0.03	0.03	0.04

Table 4: Real GDP Fiscal Multipliers

	Years				Peak	LR
	1	2	5	10		
One-year stimulus						
Expenditures (+):						
Government consumption	0.62	0.61	0.41	0.44	0.64	0.63
Government investment	0.48	0.55	0.47	0.45	0.55	0.42
Unemployment benefits	0.31	0.43	0.40	0.36	0.43	0.43
Other social benefits	0.22	0.23	0.06	0.05	0.23	0.15
Taxes (-):						
Consumption tax	0.32	0.43	0.55	0.47	0.55	0.44
Wage tax	0.32	0.47	0.46	0.41	0.47	0.43
Social contributions employers	0.43	0.60	0.23	0.34	0.61	0.41
Capital tax	0.05	0.13	-0.04	-0.05	0.13	0.03
Lump-sum tax	0.22	0.24	0.10	0.08	0.24	0.12
10-year stimulus						
Expenditures (+):						
Government consumption	0.62	0.62	0.33	0.29	0.64	0.38
Government investment	0.48	0.52	0.29	0.27	0.52	0.17
Unemployment benefits	0.31	0.40	0.24	0.23	0.40	0.28
Other social benefits	0.22	0.23	-0.07	-0.11	0.23	-0.08
Taxes (-):						
Consumption tax	0.32	0.36	0.12	0.08	0.36	0.01
Wage tax	0.32	0.42	0.28	0.27	0.42	0.31
Social contributions employers	0.43	0.53	0.19	0.19	0.54	0.32
Capital tax	0.05	0.11	-0.15	-0.17	0.11	-0.08
Lump-sum tax	0.22	0.23	-0.06	-0.10	0.23	-0.08

Note: LR means long-run. These are cumulative net-present-value fiscal multipliers calculated as the discounted cumulative change in real GDP over the discounted cumulative change in the corresponding fiscal instrument in nominal terms. The *ex-ante* fiscal stimulus lasts for one/ten year(s) and is calibrated so that the budget balance worsens by 1% of nominal GDP in the first year.

Table 5: Fiscal Scores for Consolidation

	Years				LR
	1	2	5	10	
One-year consolidation					
Expenditures:					
Government consumption	0.00	0.00	0.24	0.06	0.00
Government investment	0.25	0.13	0.14	0.04	0.35
Unemployment benefits	0.54	0.38	0.25	0.21	0.33
Other social benefits	0.70	0.79	0.83	0.81	0.80
Taxes:					
Consumption tax	0.53	0.38	0.00	0.00	0.32
Wage tax	0.53	0.29	0.15	0.12	0.33
Social contributions employers	0.33	0.02	0.54	0.25	0.37
Capital tax	1.00	1.00	1.00	1.00	1.00
Lump-sum tax	0.70	0.77	0.76	0.75	0.85
10-year consolidation					
Expenditures:					
Government consumption	0.00	0.00	0.00	0.00	0.00
Government investment	0.25	0.20	0.08	0.04	0.46
Unemployment benefits	0.54	0.43	0.19	0.13	0.22
Other social benefits	0.70	0.76	0.83	0.87	1.00
Taxes:					
Consumption tax	0.53	0.51	0.44	0.46	0.80
Wage tax	0.53	0.39	0.10	0.04	0.15
Social contributions employers	0.33	0.18	0.29	0.22	0.13
Capital tax	1.00	1.00	1.00	1.00	1.00
Lump-sum tax	0.70	0.76	0.81	0.85	1.00

Note: Fiscal scores are derived from fiscal multipliers according to the following formula: $fs_{i,T}^{cons} = (fm_T^{\max} - fm_{i,T})/(fm_T^{\max} - fm_T^{\min})$, where i denotes selected fiscal instrument, $fm_T^{\min}$ and $fm_T^{\max}$ are the smallest and the largest fiscal multipliers among all fiscal instruments in time period T.

Table 6: Fiscal Scores for Stimulus

	Years				LR
	1	2	5	10	
One-year stimulus					
Expenditures:					
Government consumption	1.00	1.00	0.76	0.94	1.00
Government investment	0.75	0.88	0.86	0.96	0.65
Unemployment benefits	0.46	0.63	0.75	0.79	0.67
Other social benefits	0.30	0.21	0.17	0.19	0.20
Taxes:					
Consumption tax	0.47	0.63	1.00	1.00	0.68
Wage tax	0.47	0.71	0.85	0.88	0.67
Social contributions employers	0.67	0.98	0.46	0.75	0.63
Capital tax	0.00	0.00	0.00	0.00	0.00
Lump-sum tax	0.30	0.23	0.24	0.25	0.15
10-year stimulus					
Expenditures:					
Government consumption	1.00	1.00	1.00	1.00	1.00
Government investment	0.75	0.80	0.92	0.96	0.54
Unemployment benefits	0.46	0.57	0.81	0.87	0.78
Other social benefits	0.30	0.24	0.17	0.13	0.00
Taxes:					
Consumption tax	0.47	0.49	0.56	0.54	0.20
Wage tax	0.47	0.61	0.90	0.96	0.85
Social contributions employers	0.67	0.82	0.71	0.78	0.87
Capital tax	0.00	0.00	0.00	0.00	0.00
Lump-sum tax	0.30	0.24	0.19	0.15	0.00

Note: Fiscal scores are derived from fiscal multipliers according to the following formula: $fs_{i,T}^{stim} = (fm_{i,T} - fm_T^{\min})/(fm_T^{\max} - fm_T^{\min})$, where i denotes selected fiscal instrument, $fm_T^{\min}$ and $fm_T^{\max}$ are the smallest and the largest fiscal multipliers among all fiscal instruments in time period T.

Table 7: The Composition of Temporary Fiscal Strategy (in %)

	Consolidation		Stimulus	
	1Y	LR	1Y	LR
Government consumption	0.0	0.0	**45.2**	**42.6**
Government investment	4.5	7.1	8.2	6.6
Unemployment benefits	0.5	0.4	0.3	0.4
Other social benefits	**35.4**	**44.9**	8.9	5.7
Consumption tax	**29.5**	**19.8**	**15.8**	**21.5**
Wage tax	**16.5**	11.6	8.8	**11.7**
Social contributions employers	10.8	**13.3**	**12.9**	11.5
Capital tax	2.7	3.0	0.0	0.0
Expenditures	40.4	52.3	62.5	55.2
Taxes	59.6	47.7	37.5	44.8

Note: The assumed fiscal consolidation/stimulus is temporary and lasts for one year. 1Y, LR mean one-year and long-run. In the long-run the composition of fiscal strategy represents the case where the policy maker is interested in the long-run effects, as opposed to immediate effects in the first year. The composition is calculated from fiscal scores valid for fiscal consolidation/stimulus multiplied by the model's shares of fiscal revenues/expenditures in nominal GDP, and normalized to sum up to 100%.

Table 8: The Composition of Longer-lasting Fiscal Strategy (in %)

	Consolidation			Stimulus		
	1Y	10Y	LR	1Y	10Y	LR
Government consumption	0.0	0.0	0.0	**45.2**	**40.7**	**49.8**
Government investment	4.5	1.0	**7.2**	8.2	9.3	6.5
Unemployment benefits	0.5	0.2	0.2	0.3	0.4	0.5
Other social benefits	**35.4**	**53.8**	**43.5**	8.9	3.5	0.0
Consumption tax	**29.5**	**31.4**	**39.0**	**15.8**	**16.3**	7.2
Wage tax	**16.5**	1.7	4.1	8.8	**16.1**	**17.5**
Social contr. employers	10.8	**8.7**	3.7	**12.9**	13.6	**18.5**
Capital tax	2.7	3.3	2.3	0.0	0.0	0.0
Expenditures	40.4	54.9	50.9	62.5	54.0	56.8
Taxes	59.6	45.1	49.1	37.5	46.0	43.2

Note: In all cases the assumed fiscal consolidation/stimulus lasts for ten years. 1Y, 10Y, LR mean one-year, ten-year and long-run. In the long-run the composition of fiscal strategy represents the case when the policy maker is interested in the long-run effects, as opposed to the effects in the first year or over 10 years. The composition is calculated from fiscal scores valid for fiscal consolidation/stimulus multiplied by the model's shares of fiscal revenues/expenditures in nominal GDP, and normalized to sum up to 100%.

Figure 7: The Simulations of Fiscal Devaluations

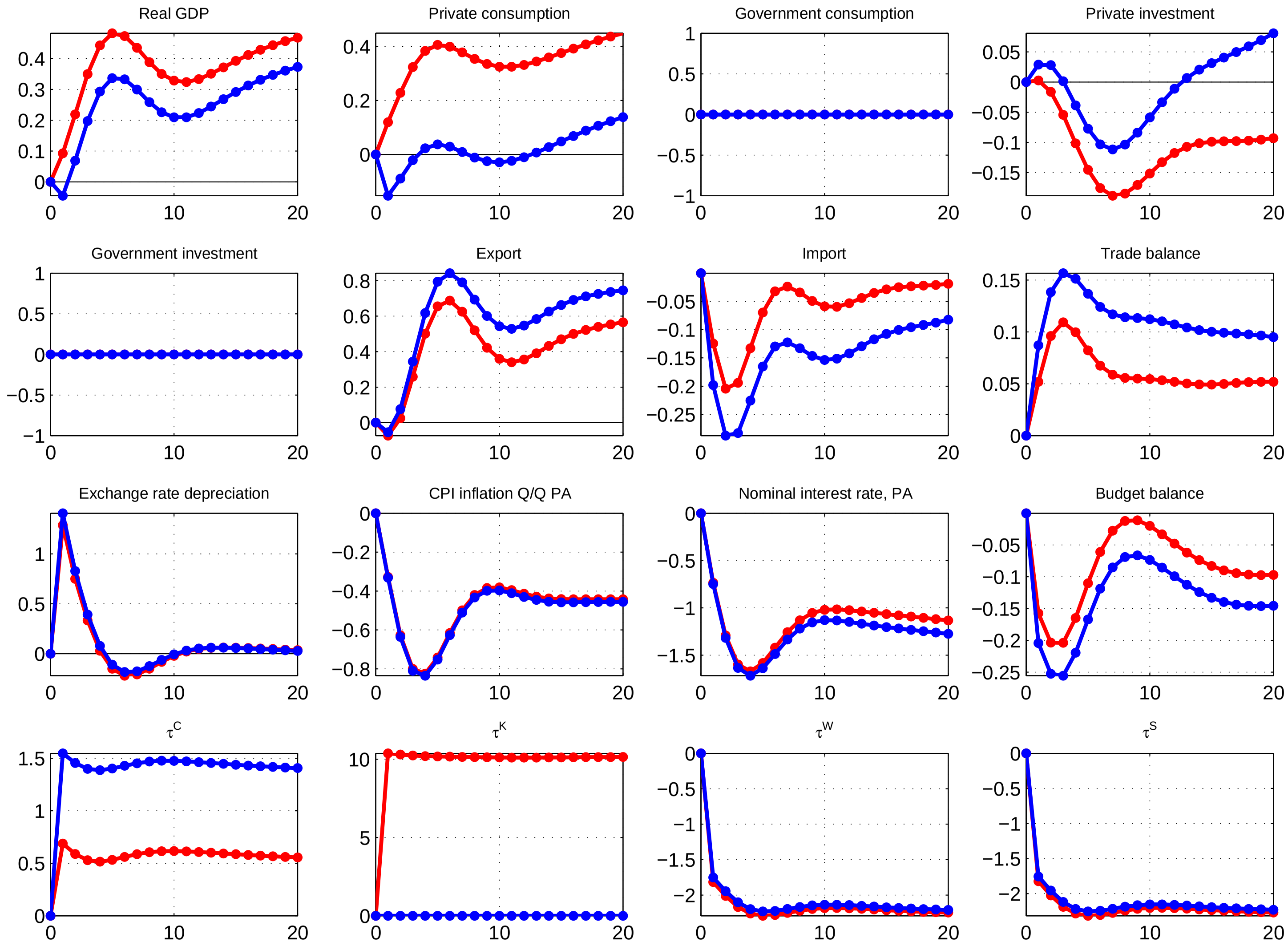
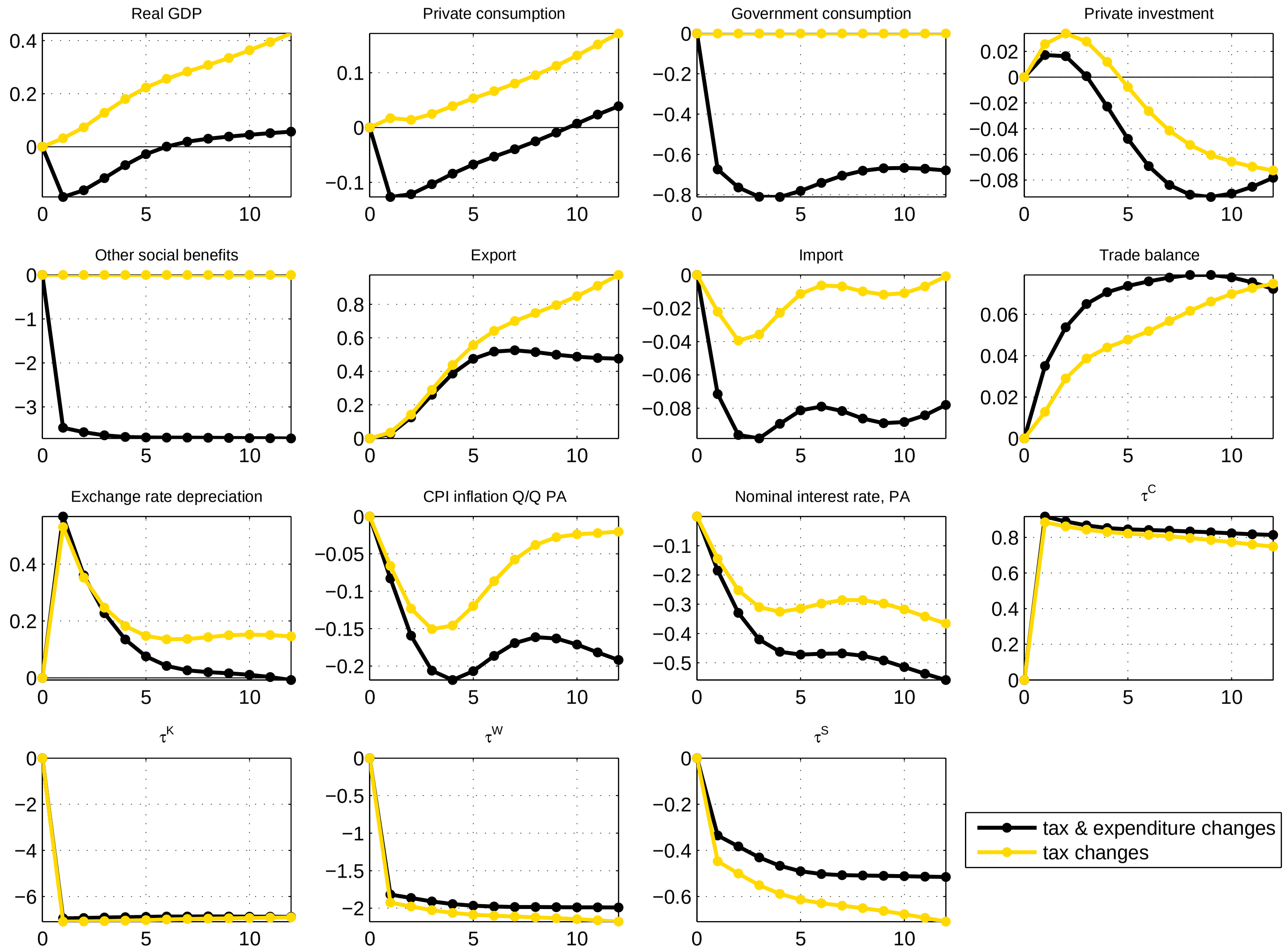


Figure 8: Fiscal Devaluation in the 2008 Stabilisation Reform



Abstrakt

Konstruuji strukturální fiskální DSGE model, abych se věnoval třem důležitým záležitostem české fiskální politiky. Za prvé, fiskální multiplikátory jsou vypočteny pro několik příjmových a výdajových položek vládního rozpočtu. Největší fiskální multiplikátory po prvním roce jsou nalezeny u vládní spotřeby (0,6), vládních investic (0,5) a sociálních příspěvků placených zaměstnavatelem (0,4). Za druhé, fiskální multiplikátory jsou využity k odvození vhodné kompozice fiskálních strategií. Například, kompozice dočasné fiskální konsolidace je víc zaměřená na vládní příjmy, když se zvyšují spotřební (30%-tní podíl v kompozici) a mzdové daně (17%-tní podíl), a na výdajové straně se snižují ostatní sociální dávky (35%-tní podíl). Za třetí, je ukázáno, že fiskální devalvace může podpořit růst reálného HDP o 0,4 procentního bodu v prvním roce po rozpočtově neutrálním přesunu od přímých daní k zdanění spotřeby a kapitálu v rozsahu 1 % HDP. Tyto výsledky potvrzují, že vláda může jednoduše podpořit ekonomiku vhodným nastavením fiskálních instrumentů.

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